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Subscriber's copy VOLUME 17 | ISSUE 12 | March 2025

WORLD SUSTAINABLE DEVELOPMENT SUMMIT 2025

PARTNERSHIPS FOR ACCELERATING SUSTAINABLE DEVELOPMENT AND CLIMATE SOLUTIONS

WSDS SPECIAL ISSUE

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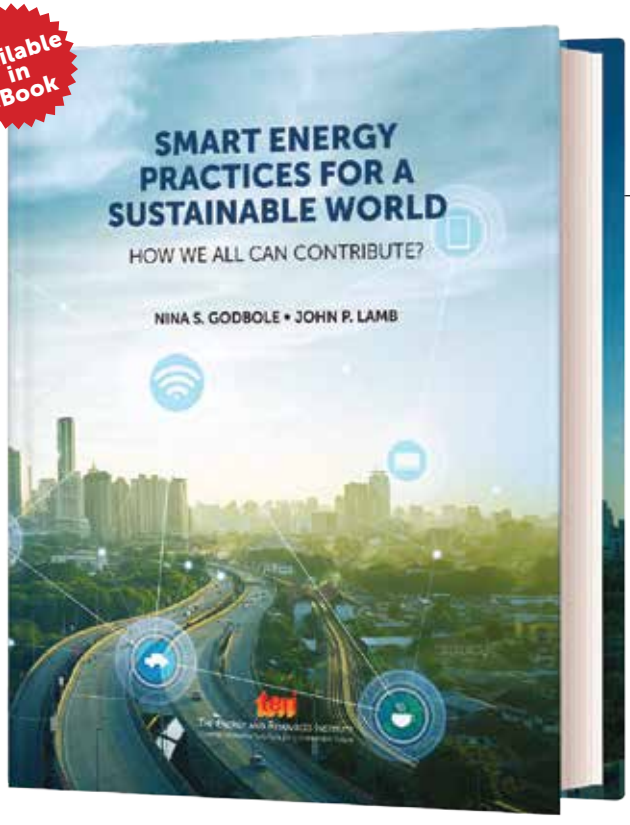

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This book stresses the need for us to judiciously, sustainably, and smartly harness and use energy techniques in order to effectively combat climate change. The book also gives an in-depth discussion on utilization of artificial intelligence and information technology to realize energy efficiency in various sectors of economy including such as transportation, buildings, infrastructure, health care, and other services.

Text is supplemented by case studies that depict ground-level reality to facilitate comprehension of the subject matter. The appendices serve as an extended learning of the concepts discussed in the chapters. The publication would serve as a valuable reference for both scholars and researchers engaged in the domain, in addition to, being a guide to industry and the academic world.

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EDITORIAL

> The 24th edition of the World Sustainable Development Summit (WSDS) will focus on the pivotal role of partnerships in catalysing transformative action and advancing global sustainability objectives.

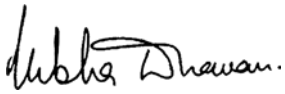
Multifarious challenges confronting the world are complex and interconnected, necessitating collective action. The most recent report on Sustainable Development Goals (SDGs) reveals that only 14 per cent of the 169 targets are progressing as planned, while 20 per cent aren't even being tracked. To advance sustainable development and climate solutions, all actors need to step up relentless efforts and building alliances is the key.

The 24th edition of the World Sustainable Development Summit (WSDS) will focus on the pivotal role of partnerships in catalysing transformative action and advancing global sustainability objectives. Under the theme 'Partnerships for Accelerating Sustainable Development and Climate Solutions', WSDS 2025 will be held from March 5–7, 2025, aiming to provide a platform for global leaders, thinkers and research fraternity to engage in a collective discourse and knowledge exchange. The Summit will aim to outline a clear pathway to strengthen partnerships among governments, businesses, civil society, and other key stakeholders around the shared purpose of designing sustainable solutions—driving meaningful change and lasting impact.

The cover story in this Special Issue of *TerraGreen* and other articles place emphasis on partnerships for accelerating sustainable development and climate solutions. Partnerships are vital for speeding up progress, promoting shared responsibility, and innovative solutions. By combining resources and expertise, partnerships can turn adversities into opportunities and generate tangible outcomes to tackle global challenges.

This special edition of *TerraGreen* covers a wide range of themes including but not limited to Just Energy transition, green job opportunities, SDGs, climate action in India, agroecology, energy efficiency, climate finance and carbon market, gender-responsive climate budgeting, sustainable agriculture, sustainable development, and COP29. The articles showcase results from in-depth research and provide insights to drive action and design futuristic strategies. Some of the opinion pieces are portrayed in the form of 'innovation showcase' that include any innovative initiative, or technology that organizations in the sustainability sphere are testifying/implementing/promoting. Such narratives and practices may trigger further collaborative research, informed decision-making and timely action. A wide range of contributions from various authors that make robust, informative, and well-analysed propositions will go a long way in fostering climate adaptation strategy and building resilience while safeguarding our biodiversity and the ecosystems.

Happy reading!



Vibha Dhawan
Director-General, TERI

I liked reading the February 2025 issue of *TerraGreen*. The cover story on Mahakumbh 2025 was a revelation. It highlighted that Mahakumbh 2025 was not only a spiritual event but a pioneering environmental movement, demonstrating that large-scale gatherings can be sustainable while preserving tradition. By blending technology, community engagement, and eco-friendly practices, it set a new standard for water preservation and sustainability, offering a model for other global events. The success of these initiatives reflects a growing commitment to environmental responsibility.

Raghav Gupta
Bengaluru, Karnataka

The February 2025 issue of *TerraGreen* carries apt environmental stories. The article on India's mitigation plans vis-a-vis Budget 2025 is a good read. Encouragingly, the budgetary allocation focuses on PM Surya Ghar Muft Bijli Yojana—a scheme that intends to promote subsidized installation of rooftop solar panels for 10 million households along with free electricity of 300 units per month. Moreover, extensions have been given to Green Energy Corridors, RE Parks, PM-KUSUM, and the National Green Hydrogen Mission.

Mridula Sharma
Kota, Rajasthan

The article on aquifer thermal energy storage published in the February 2025 issue of *TerraGreen* highlights that aquifer thermal energy storage (ATES) is an energy system that stores thermal energy in subsurface aquifers and uses this energy for heating and cooling spaces in terms of seasonal needs. Aquifers are underground reservoirs that store water. They are made up of layers of sand, rocks and even gravel. Water from different sources including rain seeps into aquifers. These aquifers essentially function as storage for thermal energy in the form of hot or cold water. So, when it is summer, cold water is pumped into the aquifer for storage and during winter, hot water is pumped into the aquifer. During summer when cooling is needed, cold water from aquifer is pumped into the building to cool it. Similarly, during winter, hot water from aquifer is pumped into the building to heat it. However, aquifers need not be only natural, these days human-made aquifers in the form of tanks are used to store thermal energy in water and use it for heating and cooling spaces. The author tries to find if ATES is the right solution to heating and cooling needs of households and commercial enterprises.

Abhishek Ganguly
Dhanbad, Jharkhand

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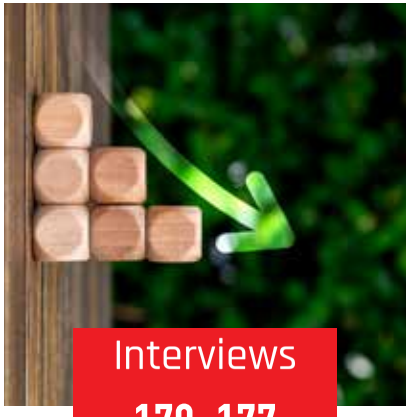

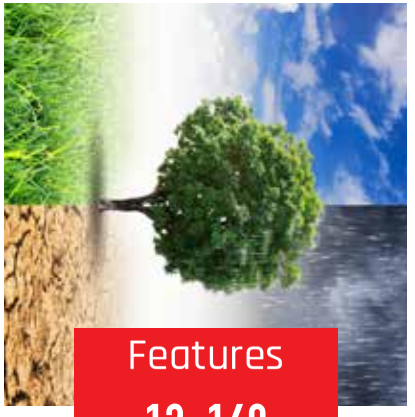

CONTENTS

Enabling Partnerships

The World Sustainable Development Summit and the Role of Track 1.5 Dialogue

This article penned by **Dr Vibha Dhawan**, **Dr Abhilash Kolekar, and Taruna Idnani**, enlightens us on the relevance of global partnerships in suitably addressing climate change and achieving mandates of the Sustainable Development Goals (SDGs). The trio has explained and established that environmental issues are global, hence, they require global-scale solutions. These solutions lie in participation and involvement of the global citizenry via constructive dialogues and deciphering effective implementation of the relevant policies.

Goal 17 of the 2030 Agenda emphasizes the importance of enhancing global partnerships to achieve the Sustainable Development Goals (SDGs). Yet, with only half a decade remaining, the global community needs to accelerate its collective efforts to achieve the set targets. While Track 1 Dialogue, or government-to-government interaction, remains the primary mechanism for adopting international laws and agreements, the widening disparities between the Global North and South, exacerbated by post-pandemic challenges and geopolitical tensions, have emerged as major obstacles to the process.

Against this backdrop, Track 1.5 Dialogue led by civil society organizations (CSOs), which engages both governmental and non-governmental actors, can play a critical role in bridging these divides. By fostering multi-stakeholder engagement, enabling inclusive partnerships, and complementing governmental efforts, this approach holds significant promise for accelerating progress towards the SDGs.

Urgency of the Situation

In 2015, United Nations General Assembly (UNGA) unanimously adopted the Resolution on 'Transforming our world: the 2030 Agenda for Sustainable Development' (United Nations, 2015). Consisting of 17 broad goals and 169 detailed targets, the ambitious agenda was formulated to steer global initiatives towards sustainable development until 2030. It acknowledged that eradicating poverty and other forms of deprivation must be accompanied by strategies that enhance health and education, reduce inequality, and promote economic growth, while simultaneously addressing climate change and preserving oceans and forests.

However, according to the 2024 Sustainable Development Goals Report (United Nations, 2024) only 17% of the targets are on track, with nearly half showing minimal or moderate advancement, while progress on more than one-third has either stalled or regressed. The UN Secretary General Antonia Guterres brings to attention the interconnected nature of global crises that have compounded these challenges. The lingering impacts of the COVID-19 pandemic, rising geopolitical tensions, intensifying conflicts, and worsening climate disruptions have collectively disrupted efforts to meet the 2030 targets.

Adding to these hurdles are deep-rooted systemic inequities in the global economic and financial structures, which disproportionately burden developing

countries. For example, Africa has received only 3% of the global climate finance despite contributing the least to global emissions (Detelinova, 2024). Similarly, Small Island Developing States (SIDS) face heightened vulnerability to climate-induced disasters but lack adequate international support (Canagarajah, 2024).

Understanding the Various Forms of Dialogues

In the realm of diplomacy, interactions between nations occur at multiple levels, ranging from highly formal governmental engagements to informal discussions led by academics and CSOs. These interactions can be categorized into Track 1, Track 2, and Track 1.5 Dialogue, each playing a unique role in fostering communication and resolving global concerns (Longhini and Zimmerman 2021).

Track 1 Dialogue is the traditional and official form of diplomacy, organized by or with direct involvement of the state. These meetings are attended by Diplomats, Heads of States and other government authorities. The high-level summits organized by the United Nations (UN) and bilaterally negotiations between nations fall under this category.

In contrast, Track 2 dialogue is an unofficial channel of diplomacy between non-state actors, without direct government involvement, and aims to achieve a specific goals, such as enhancing partnerships between nations. Academic institutions and CSOs usually sponsor such dialogues, often involving senior non-serving officials with rich past experience and access to official policy making circles. For example, the India–US Track 2 Dialogue on Climate Change and Energy, organized by the Ananta Aspen Centre, India, and the Aspen Institute, United States (US), has been held annually since 2010 (Ananta Aspen Centre, 2024). Acting as a bridge between Track 1 and 2, Track 1.5 represents a hybrid form of dialogue, organized by CSOs but with state-level backing and participation. It aims to address a wider agenda and is not restricted to a specific issue. Participants include multiple stakeholders, involving non-state actors and government representatives. The Raisina Dialogue series hosted by the Observer Research Foundation in partnership with the Ministry of External Affairs, Government of India since 2016, is an example of Track 1.5 Dialogue (Ministry of External Affairs, 2024).

There are not many differences between Track 1.5 and Track 2, other than latter not involving serving officials. However, both aim to facilitate Track 1 dialogue by providing a platform for all stakeholders to freely address sticky issues in a conducive environment. With the rise and engagement of CSOs or Non-Governmental Organizations (NGOs) - voluntary groups led by civil society actors with a common purpose and a non-profit motive, particularly in the post-Cold War era, the world has seen an increase in Track 1.5 events (Burlinova, 2022).

Significance of Track 1.5 Dialogue

Highly politicized issues, such as climate finance, technology transfer, and the socio-economic impacts of transitioning to green economies, remain contentious in official forums. The recent impasse at COP29 in Baku exemplifies these challenges (Chandrasekhar, 2024). When formal diplomatic channels become gridlocked, Track 1.5 Dialogues can offer alternative avenues for meaningful discussions, fresh perspectives, and innovative solutions.

A Multi-stakeholder platform for discourse building

Track 1.5 Dialogues provide a common platform for a diverse range of stakeholders from government, multilateral organizations, civil society, and private sector to share their perspectives and engage in discussions. It allows for the maintenance and strengthening of communication on critical issues and developing a deeper understanding of cultural context. This can, in turn, lead to exploring new ideas that potentially can be fed to Track 1 dialogues (Sokol, 2022).

For instance, since its inception in 2001, the World Sustainable Development Summit (WSDS), organized by The Energy and Resources Institute (TERI), has convened 58 Heads of State, 137 Ministers, 13 Nobel Laureates, and 2,045 Business Leaders to address critical issues related to climate change and environmental protection. The Summit's activities are guided by the theory of

constructivism, that is, providing a platform for stakeholders to socialize, engage in dialogue, and actively shape knowledge rather than merely remain passive recipients of information (TERI, 2024).

TERI's success in advancing this mission stems from its multifaceted approach as a research institution. For over five decades, it is dedicated to fostering change through interdisciplinary research, policy advocacy, and the development of innovative technologies across diverse areas, including energy, energy efficiency transitions, sustainable agriculture, eco-friendly transportation, sustainable development, efficient building practices, and climate action.

Open and free environment

Since Track 1.5 Dialogue does not carry the burden of official talks, it offers the participants, a free and open space to build trust and hold conversations with their official counterparts which is not possible in Track 1 dialogue. Track 1.5 Dialogue also keeps a channel of communication open in situations, where due to political reasons, the official counterparts are not talking to each other (Staats, 2019).

However, the value of such dialogues evolves over time through continuous engagement. A study found that a series of Track 1.5 Dialogues on nuclear issues in the early 2000s helped dispel misperceptions and contributed to sensitizing the next generation of officials and experts. Simultaneously, these dialogues enabled the current generation to assess the complexities of ongoing debates (Wheeler, 2014).

Policy enhancement and testing new ideas

These platforms also allow officials to test new ideas through 'trial balloon' approaches, that is, receiving feedback before introducing them into formal negotiations. The discussions also enable them to gain a clearer picture of how their policy initiatives will be perceived by their foreign counterparts (Staats, 2019). For example, at the 2009 Shangri-La Dialogue, prompted by the Sichuan earthquake and Cyclone Nargis, attending ministers discussed the need to establish guiding principles for responding to humanitarian disasters (Longhini and Zimmerman, 2021).

For these dialogues to be effective, they must be linked to the formal policy process. To enhance the relevance of Track 1.5 Dialogues, government representatives should relay their

learnings to their respective agencies, while non-government participants should be encouraged to convey their insights to government officials.

Enabling Partnerships

Track 1.5 Dialogue can act as a driving force for action by nurturing collaborations among a wide range of stakeholders, encouraging shared responsibility, pooling of resources, and the creation of innovative solutions to address global challenges.

WSDS has consistently served as a platform for fostering such partnerships. Some of the recent notable examples with the Government of India, UN and the Corporate Sector include:

Partnerships to drive India's energy transition

At WSDS 2024, the Ministry of Power, in partnership with TERI, initiated the concept of the Institute of Energy Transition. This endeavour highlights the importance of collaborative efforts between the Government of India and TERI in exploring sustainable energy solutions and promoting innovation in the field of renewable energy (TERI, 2024).

TERI's partnership with United Nations Framework Convention on Climate Change (UNFCCC)

During WSDS 2023, a letter of intent was signed between the UNFCCC Secretariat and TERI to collaborate on energy transition, mitigation, adaptation, and sustainable development. The partnership aims to leverage their combined expertise to facilitate the exchange of knowledge, data, and research in climate science, technology, and innovation. It also seeks to promote expert exchanges to strengthen dialogue and enhance global cooperation in addressing climate change (TERI, 2023).

Collaborations with Indian industry

At WSDS 2023, TERI and Capgemini formalized their partnership by signing a memorandum of understanding to enhance collaboration in advancing sustainability and environmental, social, and governance (ESG) objectives. This alliance combines Capgemini's proficiency in sustainable advisory services and digital solutions with TERI's extensive expertise in clean energy, water management, carbon sequestration, climate change, and sustainability. By leveraging their complementary strengths, the two organizations aim to develop innovative solutions for both new and existing clients, promote industry-wide sustainability transformation, and foster knowledge sharing, technology integration, and strategic partnerships (TERI, 2023).

The Act4Earth initiative

The Act4Earth initiative, launched in WSDS 2021, embodies this approach by engaging governments, businesses, academia, and civil society through research and dialogue. Its primary objective is to accelerate progress on sustainable development and climate solutions by encouraging evidence-

based policymaking, capacity-building, and knowledge exchange. Since its inception in 2021, the initiative has organized numerous side events, mini-dialogues, and produced various knowledge documents to facilitate informed discussions and drive collective action (TERI, 2022).

Conclusion

Track 1.5 Dialogues serve as a crucial bridge between formal and informal diplomacy, fostering trust and enabling multi-stakeholder engagement on critical global challenges including climate action and sustainable development. Their flexible and inclusive structure encourages open discussions and policy experimentation, often complementing official negotiations.

By incorporating diverse perspectives into policy dialogues, Track 1.5 Dialogues enhance long-term diplomatic understanding and promote enduring partnerships.Looking ahead, as global crises become increasingly interconnected, these dialogues will be vital in addressing challenges beyond 2030. Emerging issues such as climate-induced migration, digital governance, and shifting geopolitical alliances highlight the growing need for adaptable, inclusive, and action-oriented dialogue platforms.

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India's Roadmap to COP33

Rethinking Climate Finance Post-COP29

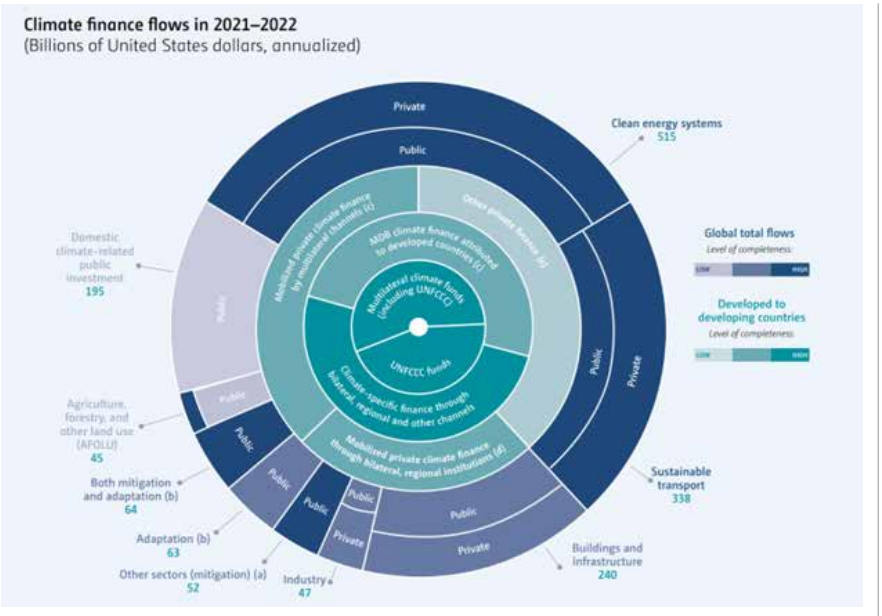
The global economy is preparing for the upcoming COP30 and for that to happen, there is a lot to learn from COP29. This conference helped put into numbers the need to fill the gaps in climate finance alongside the deep-rooted issues that exist. Closing the gaps requires a movement away from minor upgrades to major and intentional changes that are embedded with elements of equity, accessibility, and accountability, says **Abhinish Boora** in this article.

Climate change consequences are deepening around the world, and climate finance gap needs to be filled in with urgency and importance in equal measure. Meeting in Baku, Azerbaijan, COP29 called for a change in the global perspective on how climate-related activities are financed by tackling the issue of inequality and inefficiency in the financial obligations. Real steps have been taken in addressing the deficit in climate financing, but there is a pile of challenges to surmount, especially for the Least Developed Countries (LDCs) and Small Island Developing States (SIDS).

Gaps in the Current Commitments of COP29 Global Climate Change Conference

The COP29 was hosted in Baku, Azerbaijan, with the aim to make COP29 a 'Finance COP' with a focus on restructuring inequalities in climate funding. In the review sessions, the New Collective Quantified Goal (NCQG) was hot in the debates instead of the old $100 billion target set for 2009. It was agreed that the developing countries would be funded on a triples basis but critics consider the bush $300 billion annual goal unjustifiable as $1.3 trillion would be required to achieve the world's climate goals.

Costing preferences in terms of loans as opposed to grants also triggered a lot of dispute. The majority of developing countries were already in debt and loans presented them with opportunities cost that further restrict their possibilities to funding adaption and mitigation programmes. In addition, the stagnant procedural arguments such as contributors and recipient countries and



other executive policies demonstrated the persistent market imperfections in the global finance governance. Such ingredients, along with the postponed debates concerning the modalities of the Loss and Damage Fund clearly alienated the developing countries.

Adaptation Finance: Gaps and Challenges Still Persist

Adaptation finance continues to be the weak point of late climate finance. As COP29 has reaffirmed the target of doubling adaptation finance by 2025, the United Nations Environment Programme (UNEP) cautions that even this increase would be of little help to narrowing the already wide gap. More effort and funding will be needed for these regions, especially vulnerable ones, which need investments in adaptation.

It is also difficult to secure them. Application and reporting processes are lengthy and rigorous, and the costs involved are great, which disadvantages LDCs and SIDS. Redundancies in multilateral climate funds that result in underfunded projects add to the problem, delaying the disbursement of funds needed for essential Sea-level Rise Adaptation efforts. This sets back measures to make these regions more resilient to the more extreme consequences of climate change in the future.

Creative Strategies to Narrow the Gap

Amid other challenges, COP29 also demonstrated the ability of some innovative financing mechanisms to complement the familiar ones. Blended finance which incorporates both public and private inputs turned out to be a useful instrument to reduce the risks of investment and lure the private sector. The green, social, and sustainability-linked bonds are also capable of attracting substantial resources for funding activities undertaken about the climate.

Public–private partnerships (PPPs) provide another outlet for increasing the resources devoted for climate finance. Combining the skills and dollars of the private sector with the projects tends to make them more efficient and improves the prospect for continued funding. Furthermore, resilience bonds which are aimed at supporting investments into climate-resilient infrastructure can help in directing resources towards the areas most hit by climate change.

Studying Structural Injustices

The COP29 mentioned the unequitable distribution of climate finance as a constant issue. There was never a lack of political controversy over the designation of countries as 'Annexes' and 'non-Annexes' to the UNFCCC. In the context of increasing multilateral engagement, India, China and other developing economies come under greater expectation to increase their contributions while the developed countries continue to ignore expectations for extra focus onto neglected areas.

One of them is the Loss and Damage Fund operationalization, which is one of the most essential resolutions made during COP29. The Fund aims to promote justice for nations that were more negatively impacted by climate change, so it seeks to provide better attention to some of the effective concerns. Nonetheless, success will hinge on the existence of good systems of governance, effective infrastructure for payments, and appropriate systems for allocation of resources. Planned and hence more likely to be trustworthy and sustainable over the long term in the at-risk countries.

Bridging the Divide: Key Recommendations

To foster growth, one must go beyond mere promises and actually deliver on their climate finance needs and goals, which in return will aid in closing the gap between needing funding and the funds already pledged.

- **Mending resilience**: It is necessary to note that adjustment funds should not be regarded as supplementary to the climate finance policy and practice, they should be integrated into the centre approach of climate finance strategies. This also calls for additional funds to be raised as well as a new paradigm to be developed for private sector investment in building resilience programmes.
- **Improved accountability**: The implementation of the framework without template reporting such as The Climate Transparency Platform, which was recently developed is a crucial aspect. Verified public reports of financial information will allow stakeholders to follow up on the transfers, track the targets and ensure that promises made are met by described performance.
- **Make access mechanisms easier**: There are strict processes meant to curb money laundering from developing countries which they often find significantly burdensome. Making application and reporting processes less rigid, alongside providing support to local communities, can empower these countries to develop and adopt better approaches to fight climate change.
- **Increase involvement of the private sector**: Providing risk-sharing instruments, guarantees, and/or concessional loans can increase the involvement of the private sector in adaptation finance. Together with the efforts to increase the capacity of the multilateral development banks to source private money, it will help in narrowing the funding gaps.
- **Encourage stakeholder collaboration**: Use of joint climate finance efforts that target local or regional stakeholders including local governments, non-governmental organizations (NGOs) and the private sector can increase the effectiveness and benefits of climate finance. These partnerships must ensure that the needs of marginalized communities are foremost in the desired outputs.

The Road Ahead

The global economy is preparing for the upcoming COP30 and for that to happen, there is a lot to learn from COP29. This conference helped put into numbers the need to fill the gaps in climate finance alongside the deep-rooted issues that exist. Closing the gaps requires a movement away from minor upgrades to major and intentional changes that are embedded with elements of equity, accessibility, and accountability.

There is an urgent need for action, especially when considering the results of the 6th BA and the findings from the COP29. The goal of rethinking climate finance should not just be focused on reaching an outcome but rather achieving goals that pave the way for a sustainable and resilient future. However, in this crucial decade, the goal remains the same, action is what is required. ■

Mr Abhinish Boora is Project Associate, TERI.

Restoring Forests, Strengthening Communities

TERI's Climate Action in North–East India

North–East (NE) India is a treasure trove—providing habitat to breathtaking biodiversity, with diverse natural landscapes, and ecological wealth. The indigenous communities of NE India have cultures, practices, traditions, festivals, and food that are deeply entwined with the region's natural resources, creating a rich tapestry of life that reflects their profound connection to the environment. This vast yet fragile ecosystem, which is home to several endemic flora and fauna, is currently facing mounting pressure of climate change, rapid urbanization, and deforestation. Via this article, **Pranjul Chauhan** and **Aniruddh Soni** share how TERI has been leading impactful conservation and restoration efforts in this ecologically rich and culturally diverse region.

Nestled within the Eastern Himalayan Region, one of the world's 18 major biodiversity hotspots, NE India stands out as a unique and extraordinary region, rich in natural heritage. It is a treasure trove providing habitat to breath-taking biodiversity, with diverse natural landscapes, and ecological wealth. The indigenous communities of NE India have cultures, practices, traditions, festivals, and food that are deeply entwined with the region's natural resources, creating a rich tapestry of life that reflects their profound connection to the environment. These communities have extensively identified and utilized various plant species for their diverse needs, showcasing their deep ecological knowledge and understanding of the specific roles each species plays in the ecosystem.

Indigenous communities have inhabited these areas for centuries, sustainably utilizing and conserving the forest resources. But the increasing temperature of the planet has resulted in erratic and devastating effect of climate, which has particularly impacted the indigenous communities in the region. Furthermore, the growing population and the corresponding rise in resource demands are putting significant pressure on the ecosystem. This vast yet fragile ecosystem, which is home to several endemic flora and fauna, is currently facing mounting pressure of climate change, rapid urbanization, and deforestation.

The Energy and Resources Institute (TERI) has been leading impactful conservation and restoration efforts in this ecologically rich and culturally diverse region. Committed to sustainable development, the Centre for Biodiversity and Ecosystem Services (CBES), alongside TERI Guwahati Centre, has been tirelessly collaborating with the Forest Department, universities, and multilateral organizations to restore land and enhance the lives and livelihoods of farmers and forest-dependent communities in the state. Some of our notable interventions in the NE region have been explained here.

Climate Change Mitigation and Adaptation Strategies

In an effort to drive innovative evidence-based approach to combat climate change the CBES has undertaken a project by Assam Project on Forest and Biodiversity Conservation (APFBC) funded by Agence Francaise de Development (AFD). For driving sustainable forestry and biodiversity management vulnerable zones were identified for Assam leveraging RS-GIS based modelling. A state level socio-economic assessment was conducted to analyse different drivers of degradation contributing towards the vulnerability of the regions. To arrest the drivers of degradation three strategies were suggested:

1. Maintain and enhance green cover and vitality of forest ecosystem
2. Maintain, conserve, and enhance biodiversity in forest ecosystems; and
3. Drive socio-economic development of forest-dependent communities

Furthermore, a measurement, reporting, and verification (MRV) system was developed to track the impact of the climate change mitigation and adaptation strategies developed for Assam. The MRV developed under the project was used to conduct an extensive filed-based forest inventory with the help of TERI Guwahati Regional Centre. This was used to prepare Forest Reference Emission Level (FREL)/ Forest Reference Level (FRL). This is a key component of National Forest Monitoring System

(NFMS) which provides baseline against which the emission reduction and subsequently can be used for result-based payment system.

Benefiting Communities Through Carbon Financing Mechanism

Despite clear progress in its effort to enhance the forest cover, India, continues to witness significant gaps in the on-ground implementation. The intrinsic link between forest conservation and protection, employment, and livelihood underscores the importance of integrating decentralized conservation models/frameworks for employment and sustainability. Biodiversity, intertwined with communities in an astounding multi-faced way requires complex conservation efforts which need to be treated as a collective problem. One of the major initiatives in NE India is the work on more inclusive, and community-centric forest management models. Through the collaborative approach, local communities are actively engaged in sustainable forest resource management, restoration of degraded lands, and biodiversity conservation. The indigenous groups and local communities are engaged for implementing tree plantation (including agroforestry, reforestation, and afforestation), and providing them with alternative livelihood options ensuring their resilience towards climate change. The integration of local communities in conservation governance has increased the effectiveness of conservation outcomes and ensured social justice for marginalized communities.

Carbon finance projects have become an important tool in the fight against climate change by connecting community-based conservation with livelihoods, and investments in forest protection and conservation which can translate to higher income and opportunities. The CBES has stepped in with innovative carbon finance projects in agriculture, forestry, and other land use (AFOLU) sector aimed at not only increasing the carbon sequestration potential of the forests but also providing newer avenues for income generation for the local indigenous communities; thereby preserving the natural ecosystem. The different carbon finance projects being undertaken in NE includes:

a. **Empowering Communities for Sustainable Forest Management and Biodiversity Conservation in Zunheboto District, Nagaland**

A key success story lies in the forest conservation and protection project implemented in Nagaland wherein community-conserved areas (CCAs) in Zunheboto district are being established and formalized by TERI with the help of funding from Value Network Ventures (VNV) and Conservation International (CI). The local communities (Sumi tribes) are encouraged to designate more areas as CCA's, biodiversity conservation and partake in community-based forest protection and management. In Nagaland, communities have a rich cultural heritage, and traditional indigenous knowledge (TIK). TERI has capitalized on this potential by working with the Sumi tribe to make *jhum* practice more sustainable. TERI has also formulated a youth-based monitoring system, wherein, local youths are engaged and employed for project monitoring. Necessary training, guidance, resources, and raising their awareness towards forest protection and conservation is also being done. These initiatives of the communities will be developed into a regulating emissions from deforestation and forest degradation (REDD) carbon finance project which will serve as a tool to generate supplementary financial resources that can be

utilized for community development and the conservation of forests and biodiversity. This initiative aims to achieve multiple outcomes, including adaptation measures, enhanced carbon sequestration, and the reduction of pressure on forests. The project is currently being developed in 21 villages covering an area of 18,577 hectares, with an expected carbon sequestration potential of 5,33,520 tonnes of carbon dioxide equivalent over 40 years.

b. Enhancing Climate Resilience Through Agroforestry in Assam

In Assam, Baree is traditional land-use practice, mostly around the dwelling house and sometimes in isolated distant locations, where numerous diverse species are planted by the local communities, farmers, and homestead owners. These areas formed a rich biodiverse structure providing multiple social, economic, and environmental benefits. Owing to challenges such as rapid population growth, modernization, and market pressures the landowners are forgoing traditional practices of home gardens and have converted their lands to either agriculture areas, or settlements. With the attractive short-term profits from cultivating cash crops these traditional baree systems are diminishing, leading to decreased forest cover. TERI, with the help of Assam Agriculture University (AAU), Krishi Vigyan Kendriya (KVK), and funding from ReNew is working in close collaboration with these landowners. They are encouraged to carry out eco-friendly agroforestry plantations with organic fertilizers, proper rotation cycles, and integrated pest management. These agroforestry plantations are being developed as a part of the carbon finance project. The aim of this carbon project is to provide financial incentives to the farmers, sequester more carbon and promote sustainability through the integration of trees or woody plants into agricultural landscapes of the individual farmers in the selected ten districts of the state of Assam, namely, Baksa, Barpeta, Bongaigaon, Darrang, Golaghat, Jorhat, Nalbari, Sivasagar, Sonitpur and Udalguri. The project is expected to sequester 1,10,75,592 tonnes of carbon dioxide from 1 crore plantation over a period of 40 years.

Biodiversity Hotspot Preservation: The Goal of the Mountains to Mangroves Initiative

The Mountains to Mangroves (earlier Great People's Forest) initiative of the Eastern Himalayas, a globally recognized biodiversity hotspot, is one of the largest reforestation and conservation efforts in South Asia. The initiative will seek to plant 1 billion trees and restore and protect 1 million hectares of land across the Eastern Himalayas. TERI as a consortium partner has set a target to plant approximately 2 million native tree species over the course of the next 5 years in degraded forests and private lands of small farmers. The project also aims to implement forest conservation and preservation activities in a network of 25 Sacred Groves and CCAs covering a total area of about 10,000 hectares. In the first year the CBES will undertake plantations in Assam, and Nagaland. The local farmers and indigenous communities will be trained to actively participate in the conservation and management of forest land and provided best practices for tree plantation, resulting in improved socio-economic conditions and cultural preservation. With such activities TERI intends to integrate climate change mitigation strategies, enhancing resilience of the local ecosystem, sequester carbon, enhance biodiversity, and conserve this vital landscape for the generations to come. ■

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Study on Implementation of Compensatory Afforestation in India

This piece of writing by **Ritika Singh** and **Aniruddh Soni** sheds light on both limitation and potential of compensatory afforestation. The authors have included a study conducted by the Land Resources Division of TERI to evaluate the implementation of compensatory afforestation in India. The study received support from The Infravision Foundation (TIF). This study identified challenges, address gaps, and propose actionable solutions. The authors concluded, if managed properly, this mechanism could ensure that not only are forests regenerated but foster long-term environmental and societal well-being. With a more effective implementation strategy, compensatory afforestation can serve as a powerful tool for channelling funds into forest conservation efforts. It can also play a pivotal role in uplifting communities, both directly and indirectly.

Forests are indispensable for sustaining life on Earth, providing essential ecosystem services and supporting the livelihoods of millions of people. However, increasing human demands over the years have led to the deterioration of forests to meet those needs. As development is an inevitable aspect for a developing nation like India, it has become crucial to establish a system that balances development and conservation by assessing whether the loss of forests is justified and, if so, determine ways to mitigate or compensate for the loss.

A notable initiative by the Government of India in this context is the 'compensatory afforestation' that frequently makes headlines due to its large-scale figures and the concerns it raises about its success in achieving its intended goals.

The Land Resources Division of TERI conducted a study supported by The Infravision Foundation (TIF) to evaluate the implementation of compensatory afforestation in India. This study aimed to identify challenges, address gaps, and propose actionable solutions. The study included an extensive desk review of the existing acts, rules, guidelines and handbooks, alongside research papers, news articles and data available on various dedicated platforms. The findings were validated using remote sensing and discussions with subject-matter experts.

In October 1980, the Government of India enacted the Forest (Conservation) Act (FCA). It aimed at keeping a check on the alarming rate of forest land diversion in India. The basic objective of the Act is to regulate the indiscriminate diversion of forest lands for non-forestry uses and to maintain a logical balance between the developmental needs of the country and the conservation of natural heritage. Prior to 1980, the rate of diversion of forest lands for non-forestry purposes was about 1430 sq. km per annum but, with the advent of the FCA, 1980, the rate of diversion of forest lands has come down to around 150 sq. km per annum (MoEFCC).

Compensatory afforestation is a key aspect of regulating the diversions

which implies, 'afforestation done in lieu of the diversion of forest land for non-forestry use under the Forest (Conservation) Act, 1980'. It encompasses more than just afforestation; including the compensation for ecosystem services lost as well. Though the process of compensation was put in place with rules for land identification and fund collection for plantation and forest conservation activities, the problem arose when the funds collected against land diversion was not wisely spent for forest conservation activities. As a result, the Supreme Court of India notified the creation of the Compensatory Afforestation Fund Management and Planning Authority (CAMPA) for better management and utilization of funds. However, until CAMPA came in place, a proxy body known as Ad-hoc CAMPA was operationalized. State CAMPA guidelines were also issued in 2009 which established a three-tier structure for fund management, involving a governing body, Steering Committee, and Executive Committee.

Despite these measures, a 2013 audit by the Comptroller and Auditor General (CAG) highlighted significant issues in the implementation of compensatory afforestation, including the underutilization and unauthorized use of funds, as well as improper processing of proposals. These problems were largely attributed to the absence of an efficient system for fund utilization. Hence, the Compensatory Afforestation Fund Act (CAF) was enacted in 2016, with its rules introduced in 2018, establishing dedicated funds and authorities such as National CAMPA and State CAMPA to strengthen the system. In accordance with the Act, an amount of INR 72,112.84 crore, collected towards compensatory levies was disbursed to 33 states/UTs who have established their State Funds (National CAMPA). To improve transparency and accountability, initiatives such as e-Green Watch were developed for monitoring and evaluating afforestation efforts, while the Parivesh portal was launched to digitalize and streamline the approval process for forest land diversion proposals.

Various articles and newspaper headlines often equate this concept to 'offsetting' or 'green washing', however, a thorough examination of the rules and guidelines reveals that the programme's primary intent is genuinely aimed at conservation. The CAMPA has played a vital role in ecosystem conservation and sustainability, addressing critical areas that would otherwise face challenges in securing financial resources. The National Authority has approved Annual Plan of Operations (APOs) of states/UTs with amount of INR 27,093.92 crore from 2018–19 to 2021–22, out of which an amount of INR 16,753.48 crore have been utilized by the state/

UT authorities for implementation of CAMPA activities. Additionally, till 2022, the total of 9,58,360.85 hectares (88.39%) of Compensatory Afforestation (CA) has been completed against the target of 10,84,220.90 hectares (National CAMPA).

In this study, the states and UTs of India were ranked based on indicators like year of notification of State CAMPA, public transparency of documents, targets achieved from 2016 to 2023, forest area, area of land diverted, compensatory afforestation land identified, and plantation works done in the state. This was followed by identifying challenges in implementation and doing detailed analysis for Haryana, Odisha, and Uttarakhand.

Despite the timely advancements, the implementation has been subject to criticism from various media outlets and publications, often overlooking the complexities and pressures involved in managing such a large-scale and intricate system. The challenges exist not in the well-thought policy and law but in its execution, in an efficient manner.

One of the significant challenges in compensatory afforestation in India is finding appropriate land parcels for plantation. For example, in Jharkhand, the land identified for afforestation exceeds the diverted forest land by over 500 sq. km, whereas in Uttarakhand, the land identified is 200 sq. km less than the area diverted. While non-forest land is often scarce in states with significant forest cover, the strategy of inter-state compensation—where forest losses in one state are compensated through plantations in another—fails to fully replace the ecological and social value of the lost forests. For instance, in Rajasthan, the amount of plantation work exceeds the extent of forest land diverted, even though the state has seen relatively less forest diversion. While Rajasthan offers non-forest land for the plantation activities, its arid climate and unique ecology cannot replicate the ecosystems and biodiversity lost in states with higher-quality forests, such as Uttarakhand while also impacting the original ecology of Rajasthan's desert ecosystem.

Another challenge in identifying suitable land is the vastness of required area. Large patches of forest land are often cleared for development, but in return, afforestation efforts tend to be scattered across small, fragmented parcels of land. While these efforts compensate for the number of trees cut, they fail to replicate the ecological benefits of large, contiguous forest areas. Moreover, the term 'compensation' is not accurate in the context of compensatory afforestation, as challenges such as land scarcity and fragmentation render it almost impossible to recreate a forest equivalent to the one that has been deforested.

In addition to ongoing challenges in maintaining forest quality, the efficiency of the system is further compromised by a lack of transparency and data discrepancies. The National CAMPA website is often inaccessible, and at the state level, only six states—Uttarakhand, Uttar Pradesh, Telangana, Odisha, Jammu & Kashmir, Delhi, and Haryana—have dedicated websites for their records. Several states, including Bihar, Kerala, and Punjab, as well as most UTs, lack an online presence for CAMPA activities. Moreover, data inconsistencies across various platforms and documents, coupled with inaccuracies in data uploads, often create a misleading picture of the extent of CAMPA activities.

Since June 28, 2022, a total of 3,359 projects have received in-principle approval, out of which 1,832 projects have been granted final approval within a span of two and half years as on 15 January 2025 (Parivesh). Such rates of approvals of forest diversion under the Act reflects a prioritization of development over forest conservation. A large portion of these projects involve constructing roads, bridges, and access routes, which create linear structures that fragment forests, disrupt habitats, and contribute to biodiversity loss.

As relaxation is provided to central and state public undertakings, compensatory afforestation is frequently carried out in degraded forests rather than non-forest land, especially in states with extensive areas of open forest such as Haryana and Rajasthan. Furthermore, the modifications to the Forest (Conservation) Act in the name of simplification raises serious concerns about its long-term efficacy in safeguarding India's forests as more relaxations are introduced for certain projects along with exclusion of lands under the purview of the Act. While some projects are indeed essential, forest conservation cannot continually be compromised for development.

Despite the challenges, the compensatory afforestation programme holds immense potential for contributing to India's climate goals, forest conservation efforts, and biodiversity preservation. To unlock this potential, it is essential to address the gaps between policy and practice.

Evaluating the economic impact of land diversion by comparing the value of forest land and its services against the socio-economic costs of the proposed project could be crucial in determining and prioritizing only the most essential projects.

Establishing baseline and revising it periodically is essential to assess the balance between forest loss due to diversion and conservation efforts funded through CAMPA. Strengthening inter-state coordination can help address the land scarcity problem, while the creation of land banks for degraded lands can provide additional space for afforestation activities. Revising net present value (NPV) rates to accurately reflect ecosystem service losses will ensure that financial compensations align with environmental realities. Improving fund utilization through better planning, capacity-building initiatives, and timely fund disbursement will enhance the efficiency of forest departments.

Monitoring activities executed through CAMPA funds must be robust and include biodiversity assessments and impact evaluations to track changes and progress from the baseline. Additionally, the data management system must be upgraded to ensure accuracy while validating data on different portals, promoting transparency and reliability in the information presented.

With a more effective implementation strategy, compensatory afforestation can serve as a powerful tool for channelling funds into forest conservation efforts. It can also play a pivotal role in uplifting communities, both directly and indirectly, by promoting sustainable development that benefits the masses. If managed properly, this mechanism could ensure that not only are forests regenerated but foster long-term environmental and societal well-being. ■

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Energy Transitions - Quo Vadis?

With his article, **Ambassador Arne Walther**, gives us the major takeaways of the COP29. He stresses the significance of energy transitions and additions. The world needs more energy, not less, to fuel global economic and social development. But it must be cleaner energy, used in a more efficient way, accessible and affordable for all. Despite all that is being done to develop and scale up renewable energy options, and contrary to climate ambition, global demand for fossil fuels is increasing and that at higher price levels. Increasing global energy demand heightens the urgency of both energy transitions and energy additions.

The bad news for many stakeholders from COP29 in Baku in November last year was that governments failed to reach consensus on how to follow up their call from COP28 in Dubai 2023 for nations to transition away from fossil fuels. The good news in Dubai had been the parties agreeing for the first time in a consensus statement on the need for 'transitions away from fossil fuels in energy systems in a just, orderly and equitable manner'. Fossil fuels, long the elephant in the room, had, as it were, been given public notice to leave. And direction was given for phasing in green energy production, distribution and use.

While the ambition was clear and the celebratory mood high, some stakeholders nevertheless cautioned that the 'consensus' could mean that there still were some implementation devils hidden in the COP28 outcome call on 'Parties to contribute in a nationally determined manner, taking into account the Paris Agreement and their different national circumstances, pathways and approaches'. The Dubai pledge lacked the detail and global enforcement mechanism that would allay the temptation for governments to pursue business-as-usual energy policies at odds with climate objectives.

Evolving Polychange Halfway to COP 30

How to operationalize the Dubai consensus on energy transitions remains on the COP agenda as the climate delegates meet again in New Delhi on March 5-7 at the 24th World Sustainable Development Summit (WSDS). Convened by TERI, the WSDS takes place half-way in time between COP29 and COP30 in Belem, Brazil later this year.

Also, when we meet at the WSDS, the world's mightiest economic and military power will be a month and a half into a new Presidency. Global attention will be focused on the course the new administration is charting at home, in trade relations and geopolitically. Assessing not least the impact of new US energy and climate policies on global energy transitions, global efforts for sustainable development and to address the global challenge of climate change. Adding to uncertainties, the political landscape is changing also elsewhere in the Global North, where the 'my country first' mantra is increasingly being heard, overshadowing calls for multilateral approaches to meet common global challenges. While the Global South, with India as a leading voice, is asserting itself calling for a more just world order.

All this as the war continues in Europe and West Asia, while tension is rising in the South China Sea. Without any early end in sight and with potential to spin into wider conflict. The media headlines of our day must not let us lose sight of the many other conflicts that simmer, erupt, and are allowed to continue elsewhere with dire humanitarian consequence. The loss of lives and devastation may be local, but the disruptive economic, social, and political

impact is global in an evolving normal of 'polychange'. A web of geo-political change, economic change, demographic change, energy change, and climate change, all entangled into each other. The political polarization, disparities, and inequality in and among nations are increasing. While we continue to mismanage the environment to the peril of our planet. And while short-term priorities put longer-term sustainability goals on the backburner.

Headwinds and Tailwinds

A gloomy backdrop, indeed, with headwinds also for pledged and just energy transitions. Contrary to climate ambition and the COP28 call for transitions away from fossil fuels, demand for them is still increasing, still accounting for some 80% of the global energy mix. Fossil fuels will remain for some time crucial for the energy security of individual countries. There are no quick fixes or one-size-fits-all solutions for energy transitions as governments address the dual challenge of energy and climate security. Countries are different. They have differentiated capabilities and responsibilities determined by their national circumstances.

The gloom aside, we can also be impressed by the tailwinds, all that is being done in India and elsewhere to develop and scale up renewable energy options, speeding up energy transitions. The International Energy Agency (IEA) expects the world over the next five years to add more renewable capacity than has been installed in the past 100 years. Transitioning away from fossil fuels in the electricity system, we see promising trends for solar and wind. Nuclear is being revived. All pushed by both energy security concern and the need to cut carbon emissions.

But despite all the pledges by countries and all achievements so far, the COP global stocktake acknowledges that we are not on track to meeting the ambitious global emissions' and climate targets that would bring the world to carbon neutrality by 2050 and limit global warming to 1.5 degrees Celsius above pre-industrial levels by the end of the century. Setting ambitious goals is good. Achieving them through workable solutions in multilateral effort is much better.

Energy Transitions and Additions

To be sure, we need more energy, not less, to fuel global economic and social development. But it must be cleaner energy, used in a more efficient way, accessible and affordable for all. Despite all that is being done to develop and scale up renewable energy options, and contrary to climate ambition, global demand for fossil fuels is increasing and that at higher price levels. Increasing global energy demand heightens the urgency of both energy transitions and energy additions.

Also to be sure, policy adjustments and resets may in some cases be what is needed to move forward for the common global good in a just and realistic way. Global transition to renewable and cleaner energy is the call of the day for reducing carbon emissions and mitigating global warming.

We need more, not less, international dialogue and cooperation in energy among countries and across political and economic dividing lines. Innovative policies are called for at global, national, sub-national, and city levels. Business has an important role to play. But energy transitions cannot be left to market forces alone. Governments must play their part by providing incentives and framework conditions that 'nudge' industry in the sustainable direction. A new public–private energy partnership with global reach is required to accelerate just transitions to a greener and renewable energy future. An imperative to be pushed on by technological innovation and an impatient civil society. ■

Ambassador Arne Walther is a member of the International Steering Committee for TERI's World Sustainable Development Summit. A former Norwegian diplomat, he has served as Ambassador to India, Japan, Austria and the UN Organizations in Vienna. He has been Chairman of the Governing Board of the International Energy Agency (Paris) and was the founding Secretary General of the International Energy Forum (Riyadh).

Energy Critical Elements and India's Just Energy Transition

This article, contributed by **Arpita Victor**, examines the reliance of renewable energy technologies on the extraction and processing of energy critical elements (ECEs) and emphasizes the importance of ensuring that the energy transition is truly fair and equitable for all stakeholders impacted along the ECE value chain.

The energy transition in India is critical for meeting its climate goals, particularly its commitments under the Paris Agreement. A shift to renewable energy could decarbonize the power sector by 90%, underscoring its centrality to meaningful climate action. In line with its climate commitments, India has pledged to achieve 50% of its installed power capacity from non-fossil sources and reduce the emissions intensity of its gross domestic product (GDP) by 45% by 2030, compared to 2005 levels. In under a decade, India's installed renewable energy (RE) capacity has surged by over 400%, achieving targets ahead of schedule. This remarkable growth has been fueled by technological advancements, favourable government policies, and robust private sector competition, which have collectively driven down the costs of RE, making it more affordable than traditional coal power.

However, a shift away from coal does not coincide with a shift away from extractives—'clean' renewable technology requires a more complex blend of minerals to enable the exploitation of nature's forces to produce energy. These are referred to as energy critical elements (ECEs) and are essential for manufacturing technologies like wind turbines, solar panels, and electric vehicle batteries, making it imperative to adopt ethical and sustainable mining practices in regions rich in these resources. Given these minerals are more diffuse in nature and harder to extract and process, integrating circular economy principles, such as recycling ECEs and fostering research on viable alternatives, can further strengthen a resilient and sustainable green transition. This article examines the reliance of renewable energy technologies on the extraction and processing of ECEs and emphasizes the importance of ensuring that the energy transition is truly fair and equitable for all stakeholders impacted along the ECE value chain.

What Are Energy Critical Elements and How Are They Used in Clean Technologies?

ECEs are a group of metals and minerals that are vital for the development and functioning of clean energy technologies. These elements are typically characterized by their unique physical and chemical properties, such as high conductivity, magnetism, or catalytic activity, which make them indispensable for advanced energy applications. However, they are often limited in supply due to geological scarcity, geopolitical factors, or extraction challenges, making them 'critical' for energy transitions.

Among the most notable ECEs are rare earth elements (REEs) like neodymium, dysprosium, and praseodymium, which are essential for manufacturing powerful magnets used in wind turbines and electric vehicle (EV) motors. Lithium, another critical element, has become synonymous with the energy storage revolution. Found in lithium–ion batteries, it is a cornerstone of EVs, renewable energy storage, and portable

electronics. Similarly, cobalt and nickel are integral to enhancing the energy density and efficiency of these batteries, making them crucial for decarbonizing transport and stabilizing grids reliant on intermittent solar and wind power.

Other elements like indium, gallium, and tellurium have enabled advancements in thin-film solar panels, while platinum and palladium, known as platinum group metals (PGMs), play a central role in hydrogen fuel cells and electrolyzers. Copper, a less exotic but equally important element, serves as the backbone of renewable energy systems and EVs due to its exceptional conductivity, enabling efficient transmission of electricity.

Wind turbines rely on rare earth magnets for their lightweight and efficient generators, while thin-film photovoltaic cells depend on indium and tellurium for harnessing solar power. Lithium–ion batteries, powered by lithium, cobalt, nickel, and graphite, store energy from renewable sources and drive EVs forward. Meanwhile, hydrogen fuel cells, equipped with platinum catalysts, promise to power industries and transport with zero emissions. Advanced semiconductors made from gallium and silicon carbide are critical for the development of smart grids, ensuring seamless integration of renewable energy into the power system.

India's Energy Critical Elements' Supply Chain

India's journey in the extraction and production of ECEs has been guided by its growing ambitions in renewable energy and clean technologies. While the country has rich mineral resources, its role in the global ECE value chain remains limited, and there is significant untapped potential to become a key player in this critical sector.

India's exploration of minerals that are now classified as ECEs began in the mid-20th century, primarily with the extraction of REEs. These elements were initially mined as by-products of monazite sands found along the coastal regions of Kerala, Tamil Nadu, and Odisha. Monazite, rich in thorium and REEs, was primarily processed for thorium production during the era when India was pursuing nuclear energy as part of its energy security strategy.

The Indian Rare Earths Limited (IREL), a government-owned entity established in 1948, became the primary player in the extraction and processing of rare earths. For decades, India exported raw monazite and basic rare earth compounds, focusing on mining rather than value-added processing or manufacturing. By the 1990s, global competition, primarily from China, which offered lower costs and developed advanced processing capabilities, caused India's rare earth production to stagnate.

Today, India recognizes the strategic importance of ECEs for its clean energy and technological aspirations. ECEs such as lithium, cobalt, nickel, and REEs are essential for renewable energy technologies, including wind turbines, solar panels, and batteries for EVs. However, India remains a net importer of most of these critical elements, with limited domestic production and processing capacity.

India possesses significant reserves of rare earth-containing monazite sands, estimated at around 12 million

metric tonnes, primarily in coastal states like Odisha, Kerala, and Tamil Nadu. Despite this potential, India's rare earth production accounts for 1% of global output even though it has 6% of the global reserve. The country focuses mainly on basic rare earth compounds and lags in advanced processing and magnet production. IREL remains the primary producer, with limited private sector participation due to stringent regulations and lack of infrastructure.

Lithium, a critical component of clean energy technologies, is sourced mainly from two types of deposits: brine pools and hard rock mines. South America's Lithium Triangle, spanning Argentina, Bolivia, and Chile, is home to some of the world's largest brine reserves. Here, lithium is extracted by evaporating brine water from salt flats, a process that requires vast amounts of water, often in arid regions, raising concerns about water scarcity and its impact on local communities and ecosystems. In contrast, Australia, the largest producer of lithium, primarily extracts it from hard rock mines, which have a different set of environmental and logistical challenges.

Cobalt, critical for battery manufacturing, is heavily sourced from the Democratic Republic of Congo, which supplies over 70% of the world's cobalt. While the Democratic Republic of Congo's rich reserves are essential to global clean energy ambitions, cobalt mining is fraught with issues such as unsafe working conditions, child labour, and corruption. These challenges have led to calls for greater transparency and the adoption of ethical sourcing practices in the supply chain.

India currently has negligible domestic production of lithium and cobalt, and to reduce reliance on imports, the country has recently taken steps to explore lithium reserves in Jammu and Kashmir, where a deposit of 5.9 million metric tonnes was identified in 2023. However, these resources are still in the early stages of exploration and development. For cobalt, India remains dependent on imports, primarily from the Democratic Republic of Congo.

Nickel, another key element in battery production, is extracted in countries like Indonesia, the Philippines, and Russia. While nickel mining plays a crucial role in the energy transition, it poses significant environmental risks, including deforestation and contamination of water bodies due to tailings disposal. Efforts are underway to adopt more sustainable mining practices, but the industry faces an uphill battle in balancing demand with environmental and social responsibilities. India has limited domestic production of nickel, with most of its requirements met through imports. Nickel reserves in Odisha and Jharkhand remain underexplored, representing an opportunity for India to enhance its self-reliance.

Platinum group metals (PGMs), including platinum and palladium, are sourced primarily from South Africa and Russia. These metals are essential for hydrogen fuel cells and catalytic converters, making them crucial for decarbonizing transportation and industry. However, the extraction of

PGMs often involves deep mining operations with high-energy consumption and associated greenhouse gas (GHG) emissions.

Other ECEs, like indium, gallium, and tellurium, are typically by-products of mining for more common metals such as zinc, aluminium, and copper. For instance, indium is extracted as a by-product of zinc refining, with major production hubs in China, South Korea, and Canada. This dependency on the extraction of base metals adds another layer of complexity to securing a stable supply of these critical elements.

Conclusion

The sourcing of ECEs is a complex and often controversial process, deeply intertwined with geology, geopolitics, and environmental challenges. ECEs are not evenly distributed, and their extraction is concentrated in a handful of countries, making supply chains vulnerable to market fluctuations and geopolitical tensions. The sourcing of these elements underscores a paradox at the heart of the clean energy transition. While they are essential for building a sustainable future, their extraction and processing often come with significant environmental and social costs. As demand for ECEs grows, driven by the global push toward renewable energy, electric vehicles, and energy storage, it becomes increasingly important to develop sustainable mining practices, invest in recycling technologies, and foster international collaboration to address the ethical and environmental challenges associated with their production.

To address its dependence on imports, India has launched initiatives such as the National Mineral Policy (2019) and the Critical Minerals Strategy. These policies aim to promote the exploration, sustainable mining, and processing of ECEs while encouraging private sector participation. Challenges such as lack of advanced processing technologies,

environmental concerns, and regulatory hurdles persist.

India has also begun focusing on recycling and the circular economy for ECEs. Efforts to recover materials like lithium and cobalt from spent batteries are gaining momentum, with companies like Tata Chemicals and government initiatives leading pilot projects. However, the recycling sector is still in its infancy, with limited infrastructure and technical expertise.

What Are the Impacts of ECEs Extraction and Processing?

The extraction and processing of ECEs, while crucial for advancing clean energy technologies, often come at a significant environmental and social cost. The methods used to mine and refine these elements frequently result in ecological destruction, pollution, and harm to local communities, creating a paradox in the quest for a sustainable future.

The mining of REEs, for instance, often involves open-pit mining and extensive chemical processing. These operations generate enormous quantities of toxic waste, including radioactive by-products such as thorium and uranium, which can contaminate soil, water, and air. In regions like Inner Mongolia in China, where a significant portion of global REE extraction takes place, waste tailings have created hazardous 'toxic lakes', rendering nearby land infertile and water sources unsafe. For communities living near these mining sites, the environmental degradation is compounded by health issues such as respiratory problems, cancer risks, and reduced agricultural productivity.

Similarly, lithium extraction, especially from brine deposits in South America's 'Lithium Triangle', has raised alarms over water scarcity. Extracting lithium from salt flats requires vast amounts of water for brine evaporation, in some cases depleting local aquifers. In arid regions like Salar de Atacama in Chile, this process has disrupted the delicate balance of ecosystems and reduced water availability for Indigenous communities and farmers. Livelihoods dependent on traditional farming and herding practices have been particularly affected, exacerbating social inequalities.

Cobalt mining, predominantly concentrated in the Democratic Republic of Congo, highlights another

layer of challenges. Much of the cobalt extracted in the Democratic Republic of Congo comes from artisanal and small-scale mining, often conducted under hazardous conditions. Informal miners, including children, face dangerous work environments with little to no safety measures, risking exposure to toxic substances and life-threatening accidents. Moreover, the environmental impacts include deforestation, soil erosion, and water pollution caused by tailings and chemical runoffs, which affect both biodiversity and local water supplies.

Nickel extraction, particularly in countries like Indonesia and the Philippines, poses similar threats. The disposal of tailings from nickel mines into rivers or coastal waters, a practice known as 'deep-sea tailings placement', leads to the destruction of marine ecosystems and contamination of fish stocks, which many coastal communities depend on for food and income. On land, deforestation caused by mining activities disrupts habitats and accelerates climate change, affecting both wildlife and indigenous populations.

The extraction of platinum group metals, largely sourced from deep mines in South Africa and Russia, involves energy-intensive processes that produce high levels of GHG emissions. In South Africa, mining operations also consume vast amounts of water, exacerbating water stress in already arid regions. Communities near mining sites often face displacement, poor living conditions, and limited access to clean water and sanitation.

Across the board, the social impacts of ECE extraction are deeply intertwined with environmental harm. Many mining operations are located in economically vulnerable regions where local communities have limited political or legal means to advocate for their rights. Land disputes, forced evictions, and inadequate compensation for resource exploitation are common, leaving communities disenfranchized. Moreover, the influx of mining activities can disrupt traditional ways of life, introduce social tensions, and lead to long-term economic dependencies that are difficult to break.

The processing of ECEs adds another layer of environmental damage. Refining rare earth elements, for example, requires the use of acids and solvents, resulting in chemical waste that can leach into groundwater and rivers. In countries like China, which dominates global REE processing, lax environmental regulations have compounded these problems, creating toxic legacies that will take decades to address.

As the global demand for ECEs grows, driven by the clean energy transition, addressing these environmental and social harms is imperative. Solutions such as adopting stricter environmental regulations, ensuring ethical supply chain practices, investing in sustainable mining technologies, and scaling up recycling and reuse efforts are essential to mitigate these impacts. Only by balancing the need for ECEs with responsible practices can the promise of a green future truly benefit both people and the planet.

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PFAS Management

Exploring the Scope, Impacts, Evolving Challenges, and Mitigation Strategies

The PFAS represent one of the most pressing environmental and public health challenges of the 21st century. Their persistence, mobility, and bioaccumulative characteristics have resulted in widespread contamination and significant health risks. The article in hand by **Avanti Roy-Basu** and **Dr Kriti Akansha** explains how addressing PFAS necessitates immediate and coordinated action, integrating stringent regulations, innovative remediation technologies, and international collaboration. As scientific knowledge advances, adaptive strategies must be formulated to mitigate PFAS risks and protect ecosystems and human health. By prioritizing sustainable solutions and fostering collective action, we can pave the way for a healthier, more sustainable future while effectively addressing the challenges presented by these 'forever Chemicals'.

Per- and polyfluoroalkyl substances (PFAS) are a vast and diverse group of synthetic-fluorinated chemicals that have become indispensable in modern life. Comprising over 12,000 known compounds, PFAS have unique chemical and physical properties that make them valuable in industrial and consumer applications. These substances are widely used in consumer products, such as food packaging, firefighting foams, nonstick cookware, stain-resistant fabrics, and electronics. However, their resistance to degradation, often earning them the name 'forever chemicals', presents significant challenges to human health and environmental safety.

The PFAS can be classified into two main categories: non-polymer and polymer PFAS. Non-polymer PFAS, including perfluoroalkyl acids (PFAAs) and their precursors, are persistent, mobile, and bioaccumulative, making them a primary focus of environmental studies. Polymer PFAS, such as high-molecular-weight fluoropolymers, are less bioavailable and generally pose lower risks. Despite their utility, PFAS contamination has only recently gained attention, with advancements in detection methods during the early 2010s revealing their presence at trace levels in air, water, soil, and even in remote ecosystems. These findings have spurred toxicological research, uncovering the bioaccumulative nature of some PFAS and their potential health risks.

Sources of PFAS and its Global Spread

The widespread use of PFAS over several decades has led to their persistence in various environmental media (air, water, soil, living organisms).

- Industrial emissions are among the primary sources of PFAS contamination. Factories producing or utilizing PFAS, such as those involved in fluoropolymer manufacturing, release these chemicals into the environment through untreated wastewater and atmospheric emissions. Airborne particles and vapours containing PFAS eventually settle on land or water, leading to widespread contamination. Studies have shown that industrial discharges contribute significantly to high PFAS concentrations in nearby rivers, lakes, and groundwater systems. Another significant source is firefighting foams, particularly aqueous film-forming foams (AFFF), used to suppress high-intensity fires. The AFFF has been extensively employed at airports, oil refineries, and military installations, where its repeated use has caused long-lasting contamination of soil and groundwater. Once released, PFAS from AFFF migrate into groundwater systems, contaminating drinking water sources.
- To enhance durability and resistance to heat, water, and grease, PFAS have been commonly used in everyday consumer products like non-stick cookware, waterproof and stain-resistant textiles, food packaging, and certain cosmetics. Over the products' lifecycle, PFAS leach into the environment through wear, washing, and disposal. For example, non-stick cookware can release PFAS when exposed to high temperatures, while treated textiles shed PFAS during laundering, contaminating wastewater systems. Cosmetics (foundations, mascaras, sunscreens) can contain PFAS that wash off into water systems.
- Landfills and solid and liquid waste

management practices can be major sources of PFAS contamination. Disposed products containing PFAS could release them into landfill leachate, which can seep into surrounding soils and groundwater, if not adequately treated. The application of biosolids—sewage treatment byproducts identified as a PFAS source—as fertilizers in agriculture further disperses PFAS into soil and crops, potentially introducing them into the food chain. Additionally, irrigation with PFAS-contaminated water impacts the agricultural systems.

- Another pathway for PFAS dispersion is atmospheric deposition. Here, volatile forms of PFAS released from industrial processes or consumer products can travel significant distances in the air before settling, thereby contributing to contamination in faraway areas. With detectable levels being found even in remote regions like the Arctic, these mechanisms underscore the global reach of PFAS pollution.
- PFAS are highly mobile, travelling long distances through air and water. The grasshopper effect of PFAS migration from warmer areas to cooler regions has been documented. PFAS has been detected in remote areas such as polar ice caps and deep oceans. Their presence, persistence and ability to bioaccumulate in wildlife, including polar bears and fish, highlights the ecological risks posed by PFAS as they enter the food chain and spread their impact globally.

Public Health Impacts of PFAS Exposure

Due to their persistent nature and bioaccumulative properties, PFAS exposure has been linked to a wide range of adverse health effects, impacting various physiological systems. These chemicals, particularly perfluorooctanoic acid (PFOA) and perfluorooctane sulphonate (PFOS), interfere with cellular and biochemical processes, leading to chronic diseases and long-term health consequences.

One of the most severe health effects of PFAS exposure is the increased risk

of liver, testicular, and kidney cancers. The carcinogenic potential of these chemicals arises from their ability to interfere with cellular functions, including DNA repair mechanisms, promoting tumour formation over time. The PFAS also disrupt endocrine and reproductive health by interfering with hormonal systems, affecting fertility and foetal development, as well as results in low birth weight, preterm births, and developmental delays (in children).

PFAS also impair immune responses, reducing the body's ability to produce effective antibodies, which diminishes vaccine efficacy and increases vulnerability to infections, especially in children and vulnerable adults. PFAS are linked to elevated cholesterol levels, obesity, and insulin resistance that contributes to increased risks of cardiovascular diseases and type-2 diabetes. Neurodevelopmental impacts (cognitive deficits, behavioural disorders, long-term neurological impairments) also occur. Further, chronic PFAS exposure is linked to kidney diseases, including reduced renal function and non-alcoholic fatty liver disease.

Evolving Challenges of Managing PFAS

- The persistence, mobility, and widespread use of PFAS make them a challenging environmental issue, necessitating robust monitoring, mitigation strategies, and regulatory frameworks to protect human health and the environment. The PFAS are chemically stable, resistant to degradation, and cause long-term water, air, and land contamination. The PFAS remediation methods are intricate and expensive. The current remediation choices (like granular activated carbon) are often costly, energy-intensive, and not widely used. Cutting-edge technologies (e.g., electrochemical oxidation) are being designed, and they are in the scaling stage now, which means they will soon be available for real-world application.
- There is a link between the exposure to PFAS and several health problems, including cancer. The bioaccumulative feature of PFAS in human and animal tissues leads to additional negative health effects, necessitating extensive research to find viable and cost-effective solutions.
- Contrary to the fact that there is growing evidence showing the impact of PFAS, the regulation of PFAS varies widely among the regions and

countries. There is no uniformity in the global PFAS standards for drinking water and emission control or on the safety of consumer products, making global risk management more complex.

- The shift from PFAS with long chains (like PFOA) to those with short chains has presented newer problems as the latter are still persistent and can move around in the environment, thus bringing about the same health and environmental risks.
- Consumers often lack knowledge and awareness of the presence (and hazards) of PFAS in several everyday products like clothing, furniture, food boxes, etc. This leads to a reduction in demand for safer alternatives.
- Industrial restrictions imposed for PFAS management can alter global supply chains and international trade, which needs to be addressed effectively through the sustainable development lens.
- Information about the toxicity, behaviour, and alternatives of PFAS is currently limited. Further research is necessary to find out new scalable, low-cost alternatives, and improved remediation techniques.
- Rising global temperatures, altered water cycles, and severe weather events possibly can result in a shift of PFAS distribution as well as the mobilization pattern, increasing the environmental and health risks, especially in vulnerable ecosystems and for underprivileged communities.

Regulatory and Scientific Responses

Initiatives to address the widespread problem of PFAS contamination have been diverse, involving regulatory actions, scientific progress, and heightened industry responsibility.

- **Global regulatory frameworks** aim to limit PFAS contamination and protect public health. The European Union plans to phase most PFAS by 2030, while the United States Environmental Protection Agency (USEPA) has set legally enforceable levels (maximum contaminant levels or MCLs) for six PFAS in drinking water. Australia's National PFAS Management Plan (2018) adopts a risk-based approach to manage exposure and remediation. These regulations reflect growing recognition of the urgency to control PFAS pollution through stringent guidelines and proactive policies.
- **Advancements in PFAS detection and remediation**: Since the 2010s, advancements in analytical methods have enabled the identification of PFAS at environmentally relevant concentrations, leading to:
  - Identification of new PFAS compounds
  - Correlating health risks with PFAS levels
  - Establishment of regulatory limits for potable water and environmental media

  However, as currently available analytical methods detect only a fraction of PFAS, there will be significant detection gaps. With regards to remediation, technologies such as granular activated carbon (GAC) and ion exchange resins have been widely used to remove PFAS from contaminated water, but they only concentrate PFAS on another medium. Emerging destruction techniques such as plasma-based technologies and electrochemical oxidation have been developed to break down the robust PFAS compounds into harmless byproducts. These scientific solutions are crucial for addressing PFAS contamination at its source and minimizing its long-term impacts.
- **Industry accountability:** Through various regulatory frameworks and legal actions, industries are being held accountable for PFAS pollution. Increased public awareness and subsequent demands for safer alternatives are compelling businesses to transition to less hazardous substances, thereby reducing reliance on PFAS compounds. This shift reflects a growing trend towards sustainable practices and corporate responsibility, driven by both societal expectations and regulatory compliance.

The combined regulatory, scientific, and industrial responses constitute a comprehensive strategy for alleviating PFAS contamination. Ongoing collaboration and innovation across sectors are essential for effectively managing and ultimately eradicating the risks associated with these persistent chemicals.

Conclusion

The PFAS represent one of the most pressing environmental and public health challenges of the 21st century. Their persistence, mobility, and bioaccumulative characteristics have resulted in widespread contamination and significant health risks. Addressing PFAS necessitates immediate and coordinated action, integrating stringent regulations, innovative remediation technologies, and international collaboration. As scientific knowledge advances, adaptive strategies must be formulated to mitigate PFAS risks and protect ecosystems and human health. By prioritizing sustainable solutions and fostering collective action, we can pave the way for a healthier, more sustainable future while effectively addressing the challenges presented by these 'forever Chemicals'.

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The Indo-Norwegian project INOPOL is gratefully acknowledged.

Synergistic Localization of SDGs and Climate Actions in India

Circulating and Ecological Sphere Approach

In this article, **Bijon Kumer Mitra**, **Vibhas Sukhwani**, and **Kazuhiko Takeuchi**, experts from the Institute for Global Environmental Strategies (IGES), Japan, talk about the potential application of circulating and ecological sphere concept as a multi-scale and multi-dimensional approach for synergistic localization of climate and sustainable development actions in India.

Why Localization of Global Goals Matters?

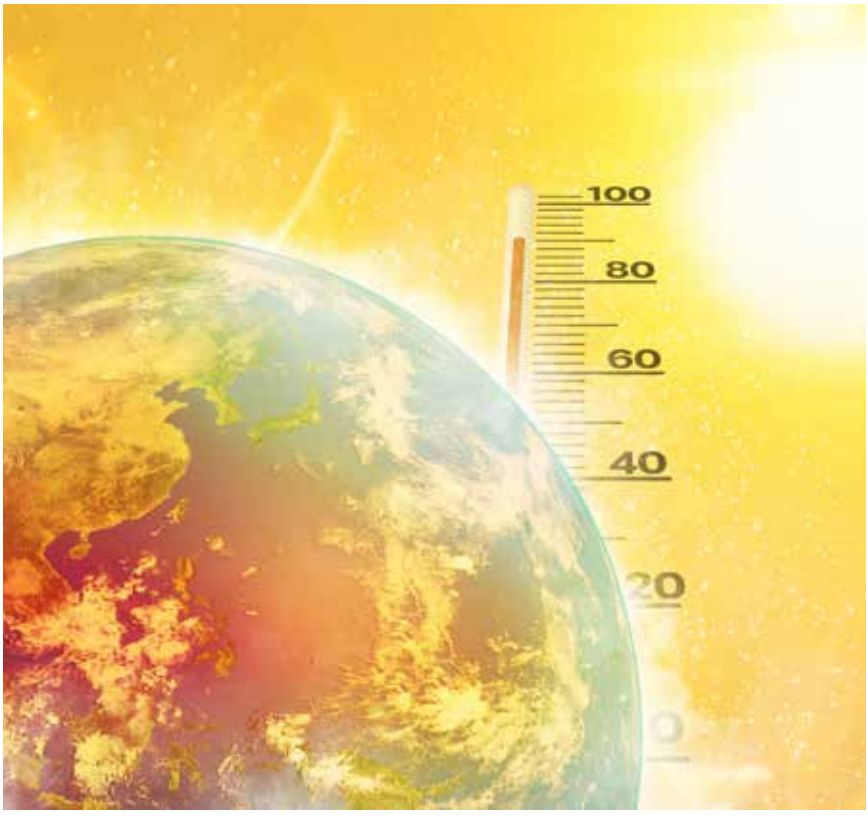
A number of international agreements, such as the Sustainable Development Goals (SDGs) and the Paris Agreement, are designed to foster a sustainable and equitable future for all. However, achieving these goals remains a significant challenge. According to *the United Nation's 2024 SDG Progress Report,* only 17% of the SDG targets are currently on track, and over 700 million people still live in extreme poverty. Similarly, despite commitments under the Paris Agreement, global temperatures are projected to rise by 2.7°C by the end of the century without drastic action. A key obstacle in realizing these global targets is the inadequate alignment of international frameworks with local development policies and investment plans. While national governments are increasingly adopting and committing to global agreements, there is a disconnect between global ambitions and the specific needs of local communities. The local governments often lack the resources, technical capacity, or political will to prioritize the global frameworks over local development priorities. To stimulate local-level transformative actions, there is a critical need to promote integrated approaches that can synergize the local–national–global development policy loops to uphold safe and just earth system boundaries.

Contemporary Development Paradigms in India

As a party to many global agreements, India has shown proactive commitment to sustainable development and climate actions. The country today stands at the crossroads of developmental transformation, steering along the path of ambitious urbanization and resilient rural empowerment. Driven by visionary initiatives like the Smart Cities Mission and Atal Mission for Rejuvenation and Urban Transformation, urban centres in India are transforming into hubs of innovation with modern infrastructure and public services. On the other hand,

the developmental initiatives in rural India (home to over two-thirds of the population) are aligned more with a welfare-centric approach. Programmes like the Pradhan Mantri Awas Yojana and the National Rural Livelihood Mission are focussing on rural livelihoods, improving infrastructure, and sustainable agricultural practices. Initiatives like the Shyama Prasad Mukherji Rurban Mission also offer integrated models for blending urban amenities with rural clusters.

While the urban development initiatives in India often follow a centralized governance model, with collaboration between state governments and municipal bodies, the governance structures in context of rural India are largely decentralized, involving Panchayati Raj Institutions. Owing to such divergence in urban–rural governance structures and socio-economic dynamics, complex challenges like rural–urban migration, rural depopulation, and uneven development continue to persist. To address these issues, harmonized policies and integrated governance frameworks are essential. By fostering synergy between policy processes and nurturing regional economies, India can stride towards a future where cities and rural areas thrive together—balancing growth with sustainability, climate resilience,, and well-being.



Circulating and Ecological Sphere Approach and Its relevance for India

As an integrated approach for climate and sustainable development actions, circulating and ecological sphere (CES) provides a new development paradigm that aims to maximize the vitality of all regions through equitable and efficient utilization of local resources (mountains, agricultural lands, water bodies, huge renewable energy potential, etc.) in an integrated manner. The CES approach emphasizes on stronger urban–rural connectivity to rediscover the untapped potential of localities to simultaneously achieve decarbonization, optimal resource circulation, harmony with nature, economic revitalization, and community well-being. The concept is also introduced in the Japanese policies, like the Fifth and Sixth Basic Environment Plan, as a tool for localizing global goals.

Centred on strengthening urban–rural linkages, the CES concept aligns well with India's development needs and policy priorities. For instance, the Government of India has been emphasizing on self-reliance and decentralization through the Atmanirbhar Bharat initiative. Through promoting localized production and consumption across the urban–rural continuum, India's efforts

towards self-reliance can be bolstered through CES-based transformations. Likewise, the notion of CES can also complement India's goal of achieving net-zero emissions through regional decarbonization and emphasis on decentralized energy systems. CES also resonates with India's National Action Plan on Climate Change (NAPCC) missions, such as National Solar Mission and Green India Mission, which are mobilizing urban and rural communities towards sustainable practices of promoting cleaner air, water, and energy.

Potential Areas of Circulating and Ecological Sphere Application in India

Depending on the local context across the vast geographical expanse of India, diverse avenues can be explored for application of CES approach. Based on the ongoing research projects of IGES in India, three key areas are described in the following sub-sections.

Synergistic Decarbonization and Revitalization

Agriculture serves as the primary source of livelihood for rural communities in India. However, the sustainability of agricultural practices is faced with changing climate, decreasing land productivity, volatile market, and rural depopulation. To address these issues, the country's progressive net-zero policies and initiatives on clean energy can be leveraged to enable CES-based transformations, like through agrivoltaics practice, which enables symbiotic use of agricultural lands to simultaneously yield food and solar energy. The Government of India's Pradhan Mantri Kisan Urja Suraksha evam Utthan Mahabhiyan (PM-KUSUM) scheme is also promoting renewable energy transformations for farmers. Through conducting local-level feasibility assessments in Ajmer (Rajasthan) and Nagpur (Maharashtra) based on geospatial parameters, researchers from IGES and regional counterparts (Central University of Rajasthan and Visvesvaraya National Institute of Technology 'VNIT') have uncovered immense potential of agrivoltaics implementation in India, which can not only boost clean energy production but also enhance energy access, create green jobs, strengthen local economy and enhance climate resilient livelihood .

Transboundary Cooperation for Water Resource Management

As India becomes increasingly urbanized, rising water demand in cities, coupled with changing climate, is exacerbating the supply–demand gaps locally, and sparking rural conflicts. To sustainably manage the shared water resources, transboundary cooperation is imperative. To achieve the same, incentive and market-based benefit-sharing mechanisms can be leveraged, a promising example of which is 'The Basic Policy for Kanagawa Water Source Environment Conservation and Restoration (2007-2026)'. Experts from IGES, Keio University and VNIT have conducted in-depth investigations to explore the feasibility of a similar CES-based intervention in Nagpur. Through contingent valuation scenario-based economic valuation, clear willingness to pay (average 278 to 525 INR/year/household) is also uncovered for improved water management in Nagpur city and surrounding regions through urban–rural partnership.

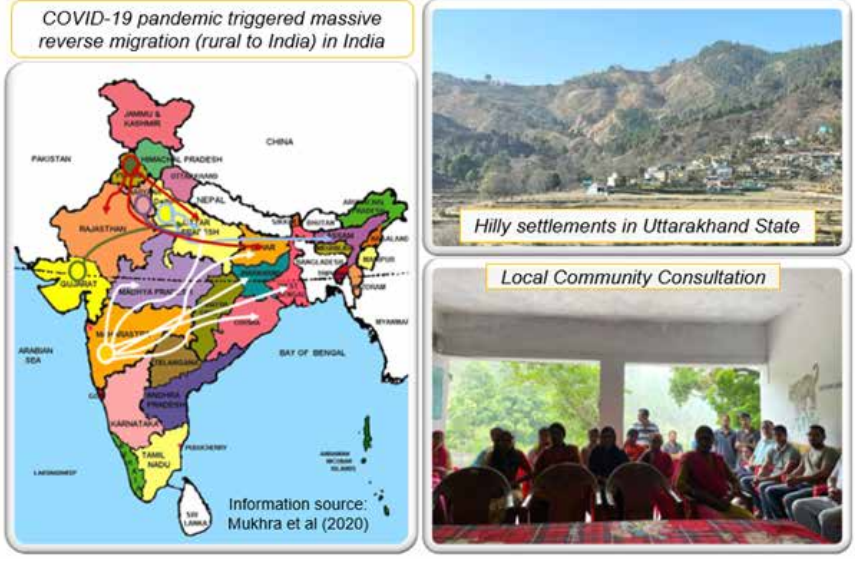
Revitalization of Rural Livelihoods and Resilient Transformations

Rural depopulation is a major concern across the world. The lop-sided

development in rural areas, coupled with a lack of social amenities and limited livelihood options, has over the years triggered out-migration and depopulation. In pursuit of sustainable livelihoods and improved quality of life, rural population is increasingly abandoning their ancestral lands, which gradually turns into fallow, forestland, or barren terrain. Markedly, during the outbreak of COVID-19 in India, many migrant people lost their jobs in cities and returned to their rural homelands. At this juncture, it was recognized that in the post-COVID era, rural revitalization is the key to drive resilient transformation through optimum use of available capital assets. The ecosystem-centric CES-based revitalization policies can contribute to enhance rural livelihoods based on locally available resource and enhance community resilience. Through conducting evidence-based research in hilly areas of Uttarakhand state of India (mainly Haridwar and Pauri Garhwal districts), experts from IGES and IIT Roorkee have also revealed increasing migration trends and their consequent implications on land use dynamics.

Enabling Environment for CES-based Development Transformations in India

- The alignment of CES principles with India's development policies requires overarching reforms. For enhancing integrated resource management, the national- and state-level policies must foster inter-local government collaboration to strengthen local capacities.
- To advance urban–rural integrated development planning, targeted incentive mechanisms need to be introduced to drive local-led transformations, which can not only empower local communities but also foster stakeholder partnerships.
- Establishment of local and regional platforms will be crucial for connecting financial resources, skills, and people, facilitating the co-development of local need-based policies, plans, and actions.
- Piloting and development of a few CES-based model cases will be crucial to demonstrate the tangible benefits and success of CES transformations in context of India, fostering broader adoption and scaling across the country.
- To inspire CES-based development models in India, emphasis needs to be laid on capacity development of local governments for transboundary collaborative works, as well as promoting education, knowledge exchange and skill-building.
- Facilitating regional cross-mutual learning with other countries can unlock new avenues of partnerships on advancing CES implementation. In October 2021, IGES together with their regional partners established the CES-Asia Consortium, which can be leveraged for advancing CES research and capacity building.



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Harnessing Decentralized Renewable Energy for Sustainable Aquaculture in Assam

Authored by **Rashmi Bahuguna** and **Jyotish Talukdar**, the present article dedicates itself to discussion on the decentralized renewable energy (DRE) technologies. At present, the DRE is in its early phase, but holds immense potential from the perspective of sustainable development. How Kalong Kapili, an NGO, with the use of DRE technologies, has been producing constructive results, in contributing towards environmental, economic, and social development in a sustainable manner, specifically in aquaculture sector of the North–East India has been well arrested by the authors.

With the support of a well-developed ecosystem for DRE technologies, many replicable business models can be created to drive sustainable economic development across India.

Assam is situated in the eastern Himalayas and is blessed with rich and fertile soil. The state has a humid tropical climate with heavy rainfall enabling it to be a biodiversity hotspot. The two major rivers flowing through the state are Brahmaputra and Barak. The freshwater wetlands (around 3500) constitute 1.29% of the total geographical area of the state (Assam SAPCC 2015-20). These wetlands are home to a variety of fish. Fish is an essential component of Assam's diet. Since more than 90% of the state's population consumes fish, there is a huge demand for it throughout the year. North–East is one of the major markets for Indian Major Carp (IMC) consists of Catla, Rohu and Mrigal, usually cultivated to meet domestic demand (World Bank, 2022).

Fishery is a promising sector in Assam, with a growth rate in fish production of around 6.2%. The state achieved a fish production level of 4.43 lakh million tonnes (MT) in 2022–23, with an increase in per capita consumption to 13.06 kg, up from 12.18 kg in the previous year, 2021–22 (Economic Survey Assam 2023-24). This state supports a substantial portion of both human and ecological populations. Despite these significant achievements, this sector still faces major challenges from rapid climate change, weather extremes, rising water temperature, biodiversity loss and increasing demand for energy (FAO, 2023). These factors are adversely impacting the state's economic growth. The World Bank data on greenhouse gas (GHG) audit of fisheries sector reported that, 89.8% of energy consumption in fish value chain is associated with the harvest phase (World Bank, 2022). As temperature continues to rise due to GHG emissions, the demand for energy is likely to go up (World Bank, 2017). Table 1 provides some statistics on energy and GHG emissions in fishery sector.

The current energy capacity is not enough to meet the demand, especially in remote areas of Assam, negatively impacting the rural livelihood including fishery sector (CLEAN 24). Hence, there is a need for reducing energy consumption in aquaculture sector.

Table 1 Energy and GHG emissions: key elements of value chain

Fish varieties	Value chain elements contributing to highest		
	Mass losses	Energy consumption	GHG emission
Aquaculture shrimp	Processing (33%) Retailer (6%)	Aquaculture (93.6%) Processing unit (5.6%)	Aquaculture (91.2%) Processing unit (6.5%)
Marine shrimp	Processing (33%) Retailer (6%)	Capture (94.5%) Processing unit (4.6 %)	Capture (87.5%) Processing unit (11.7 %)
IMC	Retailer (6%)	Aquaculture (89.8%) Transport (10.2 %)	Aquaculture (92.8%) Transport (30.7 %)
Finfish	Processing (30%) Retailer (6%)	Capture (99.5%) Processing unit (0.4 %)	Capture (98.4%) Processing unit (1.2 %)

Source: World Bank paper on GHG audit of fisheries sector (March 2022)

Decentralized Renewable Energy

Decentralized renewable energy (DRE) systems are small-scale energy units that use renewable sources of energy such as solar, wind, biomass waste, etc, to generate and distribute energy near to the point of use. This ensures limited or no transmission and distribution loss. The DRE contributes to climate change mitigation and protecting natural capital. It is less vulnerable to the volatility of the fossil fuel markets and brings added benefits of stimulating local employment, technological development, and economic growth (CEEW, 2023).

The DRE offers an opportunity and encourages use of renewable energy (solar) specifically in small fishing units. It can be utilized at various stages of fish production and supply chain, including postharvest management and value addition. Not only DRE appliances are cost effective, they provide more viability when used over the lifetime of around 10 years (CLEAN 2024). The integration of DRE in aquaculture will not only help in addressing the rising energy demands of fishery sector, but also contributes to the climate change mitigation in a sustainable manner and will improve the livelihood of small fish farmers.

Kalong Kapili and its Initiative on Decentralized Renewable Energy Technologies

Kalong Kapili is a non-governmental organization (NGO) based at Assam. Since its inception in 2007, Kalong Kapili has dedicated itself to the environmental, economic, and social development in a sustainable manner specifically in aquaculture sector of the North–East India. Kalong Kapili has helped more than one lakh families to generate sustainable income and empowered the youth and women and economically disadvantaged communities of the region. Recently Kalong Kapili has carried out a pilot project named 'Empowering the Fishery Value Chain in Assam through Decentralized Renewable Energy Technologies' in collaboration with farmer producer organizations (FPOs) in four districts: Nagaon, Karbi Anglong, Sonitpur, and Biswanath Chariali. The project was primarily supported by GIZ and co-financed by IKEA. The project commenced from May 2023 to September 2024, spanning 16 months.

The primary objective of this project was to pilot the DRE technologies and develop scalable, replicable business models tailored for fish farmers, FPOs, financial institutions, and NGOs. These models aimed to enhance affordable access to finance while supporting government efforts in policy convergence for sustainable aquaculture within the fishery value chain.

The initial phase of the project involved several activities like awareness programme, baseline survey, selection of project sites and fish farmers, district-level workshop, followed by procurement and installation of DRE technologies on selected sites. After successful installation, training-cum demonstration programme was organized for fish farmers. A total of 91 farmers from all four selected districts took part in the training-cum demonstration programme. The farmers were provided with the support of knowledge and training about DRE technologies in the fisheries value chain (FVC). In addition, a state-level workshop was conducted to discuss the impact and scope of the project and analyse the potential of DRE technologies in FVC of Assam. The pilot project received an overwhelming response. Number of requests received from farmers and other stakeholders, to replicate the same model in other areas of Assam.

Under this project, 10 solar-powered technologies were distributed to 10 farmers across four selected districts, including 3 solar water pumps, 3 solar aerators, 2 solar dryers, and 2 solar DC refrigerator-cum freezers. The solar water pumps facilitated water supply, solar aerators increased oxygen concentration in ponds, and solar dryers and refrigerators reduced post-harvest losses by preventing fish spoilage.

Solar water pump


Solar aerator


Solar DC freezer


Solar dryer


Declining water level in a pond


Increased availability of water in a pond through the utilization of solar pumps


Lower fish stocking density due to lack of aeration


Increased fish stocking density due to the solar aerator


Increased shelf life of fish with the solar refrigerator


Spoilage of fish due to the lack of proper drying facilities


Improvement in fish quality with solar drying technology

Impact of Decentralized Renewable Energy Project

Through this project, farmers directly benefited from the installation of the DRE technologies. By adopting these technologies, their reliance on electricity was significantly reduced, leading to increased annual revenue. The use of solar aerators improved pond water quality and oxygen levels, enabling higher stocking density. Additionally, solar dryers allowed farmers to produce hygienic dried fish without spoilage. The given images illustrate a comparative analysis of outcomes with and without DRE technologies.

The DRE technologies helped fish farmers overcome major constraints including mass mortality, water scarcity, and post-harvest loss. Therefore, this initiative paved the way for DRE technologies to expand their potential in strengthening the fish value chain across the state. Furthermore, it has contributed to improving the livelihoods of fish farmers. By replicating such DRE models across various sectors, Assam can increase its access to clean energy, thereby moving towards zero-carbon emission and a sustainable economic growth.

Conclusion and Future Direction

The National Action Plan on Climate Change (NAPCC) emphasized on harnessing new and renewable energy as sustainable source of energy. The DRE is a promising solution for reducing energy consumption. By scaling up the penetration of DRE across different sectors will help in providing more stable and sustainable energy solutions for the current and future energy demands.

As DRE is a nascent sector, it faces several challenges, such as acceptability,

financing, technology customization, and after-sales services. Hence, to integrate DRE in a coordinated and coherent manner, a robust ecosystem needs to be developed. This ecosystem should include:

Financial institutions: Financial institutions such as commercial banks, non-banking financial companies, and micro-finance institutions should develop financial products tailored to the needs of smallholder farmers to finance DRE technologies. Bilateral and multilateral agencies, corporate social responsibility initiatives of private companies, National Bank for Agriculture and Rural Development (NABARD) and the government sector should provide grants for pilot projects and viability gap funding to scale these technologies.

Technology players: Technology players should understand the needs of smallholder farmers and customize DRE technologies to meet their requirements and affordability. They should also collaborate with farmer collectives for testing and refining the technology.

Civil society organizations: Civil society organizations, being close to the community, should serve as a connecting link among technology players, farmer collectives, and farmers. These organizations should facilitate the testing and implementation of technologies within their operational areas. They should also build the capacities of farmers and farmer collectives to effectively use these technologies. Additionally, they should collect bottom-up feedback from farmers and develop case studies and knowledge products to document and share learnings.

With the support of a well-developed ecosystem for DRE technologies, many replicable business models can be created to drive sustainable economic development across India.

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Decoding India's Leadership in South Asia for Accelerating Sustainable Development and Climate Solutions

Perspectives from GEF-SGP

This article composed by **Prof. Susmita Mitra** and **Dr Nitya Nanda** explores India's possible role in advancing SSC in South Asia, focusing on the GEF-SGP as a model for promoting community-driven environmental action and fostering regional collaboration. The authors opine—the SGP offers a viable platform for successful uptake and replication and improvement of the impact and durability of exchanges bringing communities and government officials together to discuss common challenges and to share solutions that have worked, creating networks and establishing a community of practitioners; and using peer-to-peer exchanges to enable participants to learn about a previously applied solution and avoid repeating mistakes.

South-South Cooperation (SSC) has emerged as a vital mechanism for fostering sustainable development among countries in the Global South. By emphasizing mutual benefits, resource sharing, and knowledge exchange, SSC addresses the distinct challenges faced by developing nations. In their recent article *Environment and Sustainable Development in South Asia* in the Routledge Handbook of South Asia, Nanda and Mitra (2024) argue that SSC is indispensable in this region, where countries confront intertwined issues of climate vulnerability, environmental degradation, and poverty. As the largest country in the region, India holds the potential to play a pivotal role as a regional leader. In the current geo-political scenario, effective regional cooperation in South Asia seems difficult. But in a fast-changing world, it is quite possible that situation will improve soon.

South Asia's progress in SSC in this area is hindered by two significant challenges: limited financial resources and high exposure to climate risks, which exacerbate poverty and vulnerability. Without external financial support to mitigate climate risks while simultaneously creating co-benefits for development, the pace of cooperation will likely remain constrained. One effective platform addressing these challenges is the Global Environment Facility-Small Grants Programme (GEF-SGP) coordinated by the United Nations Development Programme (UNDP), designed to tackle both climate and development issues.

Established in 1992, coinciding with the Rio Earth Summit, the GEF-SGP embodies the principle of sustainable development by 'thinking globally, acting locally'. By providing financial and technical support, the Programme enables community-driven projects that conserve and restore the environment while improving livelihoods. It demonstrates how grassroots initiatives can balance human needs with environmental priorities.

This article explores India's possible role in advancing SSC in South Asia, focusing on the GEF-SGP as a model for promoting community-driven environmental action and fostering regional collaboration.

India's Leadership in South-South Cooperation in South Asia

India's leadership in SSC stems from its historical commitment to equitable development and climate justice. Independent India viewed its membership at the UN as an important guarantee for maintaining international peace and security. As a founding member of the Non-aligned Movement and a Global South advocate, India has championed solidarity among

developing nations. In its 2017 Voluntary National Review at the UN, India emphasized integrating SDGs into national policies while fostering regional and global partnerships, reinforcing its role as a leader in sustainable development and international cooperation.

Spatially, India holds a unique advantage in South Asia, sharing borders with Nepal, Bhutan, Bangladesh, and Sri Lanka, while facing geographical challenges with Afghanistan. Pakistan remains a distinct case. Unlike India, other South Asian nations face significant difficulties in deepening regional integration as they do not share borders, with the possible exceptions of Afghanistan and Pakistan.

India has actively promoted regional cooperation in South Asia through initiatives focused on capacity building, technology transfer, and knowledge exchange. Its support to neighbouring countries during the COVID-19 pandemic and natural disasters has further strengthened regional ties and garnered global recognition. India's 'Neighbourhood First' policy prioritizes strong ties with neighbours through enhanced cooperation and development. India's leadership of the G20, culminating in the grand Summit in New Delhi in 2023, was a declaration of the country's emergence as a force to be reckoned with on the global stage.

The GEF-SGP in South Asia: Possibilities of India's leadership

In South Asia, GEF-SGP has enabled a number of grassroots organizations to implement innovative solutions for biodiversity conservation, climate resilience, sustainable land management, along with improving livelihoods of vulnerable communities since 1994.

Table 1 reveals that Pakistan and Sri Lanka has been the first countries to receive GEF-SGP assistance. The Programme did not start in Afghanistan and discontinued in Pakistan in 2022 due to various reasons. As the first implementing country, Sri Lanka has the maximum numbers of projects, followed by India. Table 1 shows that apart from providing large amount of grant, GEF-SGP has been able to generate significant amount of co-financing in cash and kind. If we compare the co-financing generated in India and Sri Lanka, there are significant differences. India being a large country with diverse challenges has not only managed the programmes well but also been successful in generating more than double co-financing than the actual GEF financing. India's knowledge

Table 1: GEF-FGP in South Asia

Country	Start Year	Projects			GEF Grant Amount (US$)	Co-financing in cash (US$)	Co-financing in kind (US$)
		GEF	Non-GEF	Total			
Afghanistan	-	-	-	-	-	-	-
Bangladesh	2021	6	-	6	224,108	302,543	-
Bhutan	1999	207	18	225	5,973,880	1,864,701	3,373,494
India	1996	412	61	473	11,894,224	14,770,977	9,030,033
Maldives	2010	104	25	129	2,993,546	1,588,912	1,076,648
Nepal	1998	275	7	282	9,692,821	8,299,048	3,308,744
Pakistan	1994-2022[#]	302	10	312	9,373,503	9,194,163	4,790,708
Sri Lanka	1994	448	42	490	10,824,320	2,614,702	3,819,428

Source: Compiled from https://sgp.undp.org/

Note: [#]GEF-SGP discontinued since 2022

sharing regarding successful co-financing generation will be extremely useful for other South Asian countries for long-term sustainability of these programmes. Thus, India can play a role by documenting what works (vis-à-vis what doesn't and why) in co-financing, and how and in which context.

Some countries in South Asia face challenges quite similar to some of the states in India due to spatial reasons. Therefore, there are high possibilities of learning from similar interventions in order to avoid 'what doesn't work' and follow 'what works'. This is particularly true for the newcomers like Bangladesh. On the other hand, India can also learn from particular context-specific challenges and also successful case studies overcoming those challenges, in order to replicate that in similar contexts and help those countries to overcome the continuing challenges with economies of scale. The Himalayas play a crucial role in South Asia's geopolitics by influencing territorial disputes and strategic alliances, while also being a vital biodiversity hotspot that supports unique ecosystems and regulates climate patterns for the region. The Eastern Himalayas, spanning India, Bhutan, and Nepal, are facing threats from deforestation, climate change, and unsustainable practices. Through the GEF-SGP, India has implemented a project—Securing Livelihoods, Conservation, Sustainable Use, and Restoration of High Range Himalayan Ecosystems (SECURE-Himalayas)—across different regions in Ladakh, Himachal Pradesh, Uttarakhand, Sikkim, and Arunachal Pradesh. It supported community-led initiatives to protect endangered species like snow leopards and medicinal plants. The challenges being similar to different regions in Nepal and Bhutan, fostering cross-border collaboration for ecosystem restoration can be a possibility.

Similarly, the Sundarbans region, shared by India and Bangladesh, serve as a critical geopolitical zone for border management between India and Bangladesh, while also being a key biodiversity hub, home to diverse species such as the Bengal Tiger, and playing a significant role in coastal protection and climate regulation. Presently it faces challenges from rising sea levels, frequent cyclones, and energy poverty. Through the GEF-SGP, India has implemented a project in West Bengal—Conservation of Agro-biodiversity by Providing Alternate Livelihood Options to the Forest Dependent Community in Islands of Sundarbans. The project covered vulnerable and backward villages on the fringe of forest, with no alternate livelihoods and dependency

upon mangroves and non-timber forest product (NTFP) and emphasizes on natural farming activities and fuelwood efficient cookstoves for environment protection while reducing carbon emissions. By facilitating knowledge exchange and technical support, India can enable similar interventions in the Sundarbans of Bangladesh.

Tamil Nadu state in India and Sri Lanka face similar coastal challenges like erosion, pollution, sea-level rise, biodiversity loss, overfishing, and extreme weather. The SGP-India project in Ramanathapuram district of Tamil Nadu—Blue is the New Pink: Women Driving Sustainable Seaweed Cultivation and Climate Solutions—addresses environmental degradation, human-marine ecosystem disconnects, women's limited participation by promoting seaweed aquaculture, seagrass restoration (for carbon sequestration and enhanced fishery yields), vocational training, business development among other community-led sustainability initiatives. Knowledge and technology exchange will be useful for addressing similar challenges in Tamil Nadu.

Challenges to Overcome and Strengthening the Possibilities

South Asia, characterized by a blend of cooperation and contention, presents both opportunities and challenges that require innovative and imaginative strategies. Security remains a pressing concern in South Asia, with issues ranging from terrorism to maritime disputes. Creative solutions are required to deal with long-standing issues. A shift from South Asian Association for Regional Cooperation (SAARC) (including members from all South Asian countries to Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC), consisting five South Asian Counties (India, Bangladesh, Bhutan, Nepal, Sri Lanka) and two Southeast Asian countries (Myanmar and Thailand) indicate the reasons for the shift.

South Asia is highly vulnerable to climate change, particularly in agriculture, which sustains livelihoods and food security of huge masses in the region. Shared agro-climatic conditions, rivers, and oceanic waters underscore the need for regional cooperation in climate adaptation, water management, and marine pollution. India's scalable, affordable technologies can drive clean energy solutions and address regional challenges.

India's engagement with the GEF-SGP has generated a wealth of experience and best practices that are relevant to other South Asian countries. Indian projects have demonstrated how traditional practices can complement modern technologies for sustainable development. The SGP offers a wonderful platform for successful uptake and replication and for improvement of the impact and durability of exchanges bringing communities and government officials together to discuss common challenges and to share solutions that have worked, creating networks and establishing a community of practitioners; and using peer-to-peer exchanges to enable participants to learn about a previously applied solution and avoid repeating mistakes. ■

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Partnerships for Sustainable and Inclusive Business Ecosystems

Bridging the Gender Gap in Global Supply Chains

This article by **Elizabeth A Vazquez** and **Eroshan Alagaretnam** sheds light on the relevance of women entrepreneurship. Through purposeful purchasing, bold policymaking, and strategic partnerships, we have the power to create a world where everyone has an equal opportunity to contribute and thrive. The time to act is now. By championing the vast potential of women entrepreneurs, we can drive innovation, strengthen communities, and build a future defined by shared prosperity and sustainable growth for all. The path to a sustainable and inclusive global economy lies in recognizing and harnessing the power of women-owned businesses. In this endeavour, WEConnect International is leading the way by connecting buyers with women-owned sellers and fostering a fairer marketplace.

Women-owned businesses hold immense potential to transform global economies, yet they remain largely invisible in supply chains. Despite representing half the world's population, women are far from achieving equitable access to opportunities as suppliers in the global marketplace. To bridge this gap, governments, corporations, and civil society organizations must unite in a concerted effort to create a level playing field for women entrepreneurs.

Women's Untapped Potential in Business

Women around the world are educated, entrepreneurial, and determined to succeed. They create jobs, drive inclusive economic growth, and contribute significantly to poverty reduction. Yet, systemic barriers continue to restrict their participation as business owners. For instance, in India, women own just 20.5% of all the micro, small and medium enterprises (MSMEs) registered since 2020, and the country ranks 127th out of 146 nations in the 2023 Global Gender Gap Index, which measures gender parity across various factors, including economic participation.

The numbers speak for themselves. A Boston Consulting Group study estimates that closing the gender gap in entrepreneurship could increase global gross domestic product (GDP) by $2.5 trillion to $5 trillion. In India alone, equal opportunities for women-owned businesses could contribute $700 billion—or approximately $2,200 per person—to the GDP by 2025. Meanwhile, increasing women's labour force participation to 50% could raise annual GDP growth by 1.5 percentage points, according to the World Bank.

The Role of Policy and Global Leadership

India has taken significant steps

to promote women's economic empowerment, notably making Women-led Development a priority during its G20 Presidency. The Government of India has implemented reforms and initiatives such as Stand-Up India and Pradhan Mantri Mudra Yojana (PMMY) to support women entrepreneurs at all stages of their journeys. These programmes have delivered results: 69% of PMMY loans have gone to women, and 84% of beneficiaries under Stand-Up India are women.

India's target for 3% of government procurement from women-led MSMEs resulted in government-owned enterprises procuring goods worth INR 1,660.43 crore by 2021–22. This demonstrates how policy can drive measurable change, inspiring other nations and organizations to follow suit.

Gender-inclusive Supply Chains: a win-win strategy

Building gender-diverse supply chains isn't just a moral imperative—it's a smart business decision. Women-owned MSMEs hire more women, excel in cost management, and deliver strong financial performance. According to *Kinara Capital's 2024 MSME Insights Report*, women-led businesses employ 11% more women compared to businesses led by men, amplifying their impact on communities.

Organizations like WEConnect International play a crucial role in driving change. By connecting women-owned businesses with large buyers and providing resources to meet the procurement standards of very large buyers, WEConnect International has helped direct billions of dollars to women-owned businesses globally. In South Asia, many member buyers have increased their spending with women-owned businesses by 4.5%, proving that sustained investment can yield significant financial results.

Tackling Systemic Barriers

Despite progress, challenges like gender bias and fronting where companies falsely claim to be women-owned persist. Tackling these issues requires bold action from policymakers and corporate leaders alike. Governments and private sector buyers must ask hard questions: Are procurement systems free from gender bias? Are specific internal targets for sourcing from women-owned businesses being set and met?

Verification and certification processes, such as those implemented by WEConnect International, are critical to ensuring accountability and impact in supply chains. Such measures safeguard against fraud and ensure that women entrepreneurs truly benefit from inclusive procurement policies.

Unlocking a Shared Vision for Growth

The vision of Women-led Development offers a powerful road map for inclusive growth. Achieving this vision requires collective action from all stakeholders—governments, businesses, and civil society organizations. Together, we can unlock the economic and social benefits of supporting women entrepreneurs,

transforming communities and global economies alike.

How You Can Make a Difference

- **Corporations and governments**: Commit to gender-inclusive sourcing and set measurable goals for sourcing from women-owned businesses.
- **Civil Society organizations**: Provide relevant training and advocate for policies that support women entrepreneurs and hold stakeholders accountable for progress.
- **Consumers and investors**: Buy from women-owned businesses and support brands and that prioritize gender diversity in their supply chains.

Conclusion: A Call to Action

The path to a sustainable and inclusive global economy lies in recognizing and harnessing the power of women-owned businesses. WEConnect International is leading the way by connecting buyers with women-owned sellers and fostering a fairer marketplace.

Through purposeful purchasing, bold policymaking, and strategic partnerships, we have the power to create a world where everyone has an equal opportunity to contribute and thrive. The time to act is now. By championing the vast potential of women entrepreneurs, we can drive innovation, strengthen communities, and build a future defined by shared prosperity and sustainable growth for all. ■

Elizabeth A Vazquez is the CEO and Co-Founder of WEConnect International, and Eroshan Alagaretnam is the Regional Director for South Asia, WEConnect International.

Indo–German Cooperation

How Indian Cities Are Shaping Sustainable Mobility

The article talks about Indo–German cooperation on sustainable mobility. **Kashmira Dubash** shares with us the success story of 'India Cycles4Change and Streets4People Challenges'—how the initiative traversed its path—from an ideation to a reality. The author opines and demonstrates how no best practice can truly take shape without active citizen and public engagement in this Indo–German alliance.

India and Germany share a longstanding and close cooperation on climate, the environment and sustainable development. Since 2008, India is one of the priority countries with which the International Climate Initiative (IKI) maintains a particularly close cooperation. The IKI projects in India are implemented in cooperation with the Indian Government and address a wide range of climate actions, aim to restore and conserve natural carbon sinks and to conserve biodiversity.

Zooming-in on Implementation on the Ground

An apt example of Indo–German cooperation is in the area of sustainable mobility. In 2020, a bold vision to transform urban mobility took shape through the collaborative efforts of India's Smart Cities Mission, the Ministry of Housing and Urban Affairs (MoHUA), and the Institute for Transportation and Development Policy (ITDP), which was supported by the International Climate Initiative (IKI) of the German Government. The India Cycles4Change and Streets4People Challenges were launched with the goal of reshaping India's streets into safer, more accessible spaces for walking and cycling. What began as a shared ambition quickly evolved into a dynamic journey of change that has reshaped the landscape of urban mobility across the nation. Over four years, the Challenges enabled participating cities to build strong partnerships, engage communities, and strengthen their capacities by collaborating with national and local experts to create safer and more accessible streets for everyone.

About the Project: from challenge to change

As the project reports, this level of commitment was urgently needed and remains essential. Many of India's streets have become increasingly unsafe, with pedestrians accounting for 20% of road fatalities in 2022, resulting in a tragic loss of 32,800 lives, as reported by the Ministry of Road Transport and Highways (MoRTH). Additionally, India's air pollution and environmental quality rank among the worst globally. To address these challenges, it is crucial to encourage more people to choose walking and cycling over private vehicles whenever possible. In response, ITDP, with ongoing support from the IKI, has been working with Indian cities to foster safer and more supportive environments for both new and existing pedestrians and cyclists, driving this much-needed shift.

When the national Challenges began in 2020, the team quickly realized that expecting rapid on-the-ground transformations was overly ambitious. While 117 cities had signed up, each was at a different stage in its journey in terms of resources, infrastructure,

geography, and institutional set-up. Despite the friendly, competitive spirit of the initiative, fairness would be compromised if cities began from such varied starting points. As a result, the team reassessed and revised the approach. The focus shifted from solely measuring the scale of physical transformations to also emphasizing the importance of mainstreaming dialogue around walking and cycling, enhancing community engagement, and building a solid foundation for capacity building and institutional reform.

The National Government and ITDP focused on three key strategies to ensure the sustainability of their efforts over the four years. First, they built an ecosystem of champions, including city leaders and local communities, for guidance. Second, they encouraged cities to engage citizens from the outset to secure their buy-in. Third, they consistently enhanced cities' technical capacities through innovative methods.

Building Local and National Ecosystems of Champions for Sustainable Mobility

At the start of the Challenges, cities were tasked with piloting walking and cycling interventions locally and gathering community feedback before making permanent changes. Many cities successfully used tactical urbanism to test designs that could evolve based on public consultation. For example, Kohima transformed an old parking lot into a vibrant community space for pedestrians and cyclists, featuring food vendors, pop-up seating, colourful artwork, and new landscaping. They also organized street festivals to activate the community. Cities without the expertise formed partnerships with civil society organizations, design experts, resident groups, and cycling advocates, demonstrating the value of building a local ecosystem of champions. These

stakeholders guided cities through the design and implementation process, ensuring sustainability and impact.

At the national level, a similar ecosystem was taking shape. The commitment to promoting active mobility was fully supported by the National Ministry, driven by strong leadership that believed in the cause. This inspired many city leaders to become champions themselves. The national ecosystem was further strengthened through collaboration with organizations like ITDP, which offered technical expertise and guided cities through the process.

Engaging Communities to Drive Behaviour Change and Embrace Walking and Cycling

No best practice can truly take shape without active citizen and public engagement. Initially, cities faced significant challenges in motivating their residents, changing perceptions, and overcoming stereotypes about cycling and walking. Many viewed these modes of transport as impractical alternatives to personal vehicles. However, as the Challenges evolved, involving communities in decision-making became essential for fostering a sense of ownership, which led to greater acceptance and shifts in behaviour. Take Davanagere, for example. The city launched a creative campaign that made cycling 'cool' again, featuring themed merchandise, bike rallies, and citywide promotions. Soon, local residents wholeheartedly embraced cycling, rallying around the vision for safer and more sustainable mobility. That is the power of bringing people along for the ride.

Empowering Cities through Expertise, Innovation, and Interactive Learning

Equipping cities with the right expertise and skillsets was also a critical part of the strategy. Throughout the process, ITDP facilitated 18 sessions, including national workshops on Healthy Streets and Public Spaces in Bengaluru, Chandigarh, and Pimpri Chinchwad, along with interactive design clinics where city leaders received expert guidance. Over 85 toolkits and technical resources on planning, budgeting, and infrastructure design were developed and shared during these

workshops.

To make capacity building more engaging, ITDP introduced an innovative gamified approach. This interactive experience allowed city leaders to learn how to create a 3-year Healthy Streets Action Plan with clear interventions to ensure action on-ground, foundation set-up through intuitional reform, and communication for citizen buy-in. By moving beyond traditional presentations, this 'gamification' strategy provided a hands-on, immersive learning experience, allowing leaders to better understand the complexities of sustainable mobility.

Paving the Way for Long-term Transformation in Indian Cities

By January 2024, 15 cities had emerged as leaders, with many others making significant progress in transforming their streets. Across 33 cities, more than 350 km of improved footpaths and over 220 km of cycle tracks were developed, while 48 cities initiated projects to revamp over 1,400 km of streets. Additionally, 15 cities adopted Healthy Streets Policies, 18 established dedicated Healthy Streets cells, and 17 cities created the three-year action plans. To sustain this momentum, 33 cities formed Apex Committees to foster ongoing collaboration.

As the Cycles4Change and Streets4People Challenges come to an end, these initiatives have set the stage for lasting change across India. Their success extends beyond immediate outcomes, focusing on building a sustainable framework that fosters ongoing dialogue, strengthens capacity, and cultivates a network of walking and cycling advocates. With the Ministry and ITDP's efforts, a strong foundation has been laid to scale up walking and cycling infrastructure nationwide. Now, it is vital for the national government to capitalize on this momentum by increasing funding and enhancing policies and reforms to create safe, inclusive streets for everyone. Let the next chapter of transformation begin!

About Institute for Transportation and Development Policy

The Institute for Transportation and Development Policy (ITDP) works with cities worldwide to create healthy and liveable communities through high-quality public transport including e-mobility, safe spaces for walking and cycling, traffic reduction mechanisms, and people-centred policies.

We believe that shifting from single-occupancy private cars to high-capacity public transport and zero-carbon modes such as walking and cycling, would drastically cut emissions, reduce traffic congestion, and better connect low-income communities to the opportunities and resources they need.

In India we work with governments, multilateral agencies, and civil society to make visible, on-the-ground improvements by providing technical expertise, policy solutions, research publications, and training programmes, at national, state and city levels.

About the International Climate Initiative

The International Climate Initiative (IKI) is part of the German Federal Government's international climate finance commitments.

The IKI is implemented by the Federal Ministry for Economic Affairs and Climate Action (BMWK) in close cooperation with the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) and the Federal Foreign Office (AA).

The IKI has been funding the India Sustainable Mobility Initiative since 2015. With this project, the German Government is supporting ITDP's commitment in the field of sustainable transport and mobility. Within the German Government, BMUV is in the lead for this project. ■

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Addressing Climate Change through Agroecology

Insights from the JIVA Programme

The article by **Dr Deepak Chamola**, **Pritam Majumdar** and **Dr R Ravi Babu** makes the readers aware of the JIVA—an innovative programme that has the potential to enhance sustainability and make agriculture climate resilient. The trio is of the opinion—the participatory method in the planning process and farmer-to-farmer learning approaches will ensure the outreach and sustainability of the initiatives.

The agricultural sector is a paradox—while it contributes to climate change, it also bears the brunt of its impacts. The increasing concentration of greenhouse gases (GHGs) is responsible for erratic rainfall patterns, rising temperatures, and heatwaves (Gupta and Pathak, 2016). Higher temperature leads to increased crop respiration rate and evapotranspiration, greater pest and weed infestation, reduced crop duration and diminished microbial activities in the soil (Malhi, Kaur, and Kaushik, 2021). Several studies have shown that climate change has a direct impact on the crop yields. Kumar, Singh, and Sharma (2020) found that variations in rainfall and rising temperature significantly affected the yield of rice and wheat in the Indian states of Haryana and Punjab. The Economic Survey (2023–24) highlighted the need to address climate change through adaptation measures. It cautioned "In the absence of the adoption of adaptation measures, rainfed rice yields in India are projected to drop by 20% in 2050 and 47% in 2080 scenarios, while irrigated rice yields are projected to reduce by 3.5% in 2050 and 5% in 2080 scenarios. Climate change is projected to reduce wheat yield by 19.3% in 2050 and 40% in 2080 scenarios" (GOIa, 2024). According to Malhi, Kaur, and Kaushik (2021), the negative impact of climate change on crop yield could result in a 0.3% gross domestic loss (GDP) loss globally by 2100.

In India, 55% of the net sown area is rainfed, contributing to 40% of the total grain production. Additionally, the rainfed area supports 40% of livestock and 80% of the total small and marginal farmers (NRAA, 2022). The poor socio-economic conditions of small and marginal farmers reduce their adaptive capacities, making them more susceptible to environmental stresses and shocks (Jayaraman and Murari, 2014). This makes Indian agriculture a vulnerable sector to climate change, which can cause severe economic impacts on smallholder farmers and threaten food and nutrition security.

Agroecology in Mitigating Climate Risks

In this context, agroecological approaches are gaining momentum as effective solutions to address climate change. The Food and Agriculture Organization of the United Nations (FAO) urged countries to scale up the

agroecological transition as it contributes to several Sustainable Development Goals (SDGs) of the United Nations and addresses the challenges of poverty, malnutrition, environmental degradation, and climate change (FAO, 2018). Agroecology offers a climate friendly and resilient approach to farming by integrating natural processes and resources into agricultural systems. It fosters the resilience of farmers and the agricultural sector by promoting polyculture, integrating livestock and forestation into the farming system, and managing soil health (Altieri, et al. 2015). Agroecological approaches help sustain traditional farming practices such as the use of local seeds, indigenous livestock, time-tested disease and pest management, along with soil and water conservation practices. They empower marginalized communities, including smallholders, women, and indigenous people, by fostering innovation, adaptation, and knowledge sharing. Farmers benefit from reduced dependency on external inputs, lower costs, and improved adaptation to climate shocks.

The Government of India has taken significant steps to promote agroecology and enhance agricultural resilience to climate risks. The National Mission for Sustainable Agriculture (NMSA), part of the National Action Plan on Climate Change (NAPCC), aims to develop strategies for climate-resilient farming. Similarly, the National Innovations in Climate Resilient Agriculture (NICRA) initiative, launched in 2011 by the Indian Council of Agricultural Research (ICAR), develops and promotes technologies to address climate challenges such as droughts, floods, and heatwaves. Since 2014, NICRA has introduced 1,888 climate-resilient crop varieties and 68 location-specific technologies, benefiting vulnerable districts across India. Recently, the Ministry of Agriculture and Farmers Welfare (MoAFW), Government of India, launched the National Mission on Natural Farming, a Centrally Sponsored Scheme, with an outlay of Rs 2481 crore (approximately $298.92 million) (GOIb, 2024).

In the backdrop of emerging international and national experiences in sustainable farming systems and considering the high-climate vulnerability of India's rainfed and drylands, the National Bank for Agriculture and Rural Development (NABARD) recognized the need for innovative solutions. As a strategic and transformational approach, NABARD launched an agroecology programme named JIVA within its watershed and tribal development projects. The JIVA includes soil health improvements, water resource management, and the adoption of diversified cropping systems, which align with global climate adaptation strategies. The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH supports the JIVA programme in areas of capacity building, knowledge management, and research in partnership with various expert agencies such as WASSAN and RySS, amongst others.

JIVA Programme

JIVA, derived from the Sanskrit meaning 'a living being imbued with life force', is a transformative programme advancing agroecological farming across 24 pilot projects in 11 states and 5 agroecological zones. Recently, JIVA expanded its reach, adding 19 new projects across 9 additional states, covering 8 agro-climatic zones. The programme emphasizes farmer-led extension systems, crop diversification, integration of livestock, nutrition garden, local marketing and value addition, along with empowering communities to share knowledge and drive local adaptation strategies. Its multi-dimensional approach is designed to enhance climate resilience, strengthen rural livelihoods, and promote ecological sustainability, creating scalable models for long-term agricultural transformation.

Climate-resilient Agriculture Practices under the JIVA Programme

Landscape planning

The JIVA programme focuses on landscape-based planning processes to identify activities that are relevant for developing the local agroecosystem. In this regard, application of the Geographic Information System (GIS) and remote-sensing tools along with participatory resource mapping exercises, involving farmers and villagers, is used to delineate the project area, and map natural, physical, and institutional resources. Landscape-based planning also helps to identify the climate-vulnerable regions and communities within the project area.

Crop diversification

The JIVA project has introduced the five-layer model, Surya Mandalam model, and the Any Time Money (ATM) model of crop diversification. The five-layer model is a sustainable farming approach that integrates multi-layered cropping, combining trees, shrubs, herbs, climbers, and ground crops. The Surya Mandalam model is natural farming model based on circular farming principles, focusing on symbiotic crop combinations and resource recycling. The ATM model is diversified farming model that ensures continuous income generation for farmers by integrating high-value crops, livestock, and allied activities, allowing farmers to access 'any

JIVA farmers growing multiple crops in their farm

time' income for their financial needs. The JIVA farmers grow crops like pulses, cereals, millets, oilseeds, vegetables, fruit trees, and medicinal plants in the same field, optimizing land use, improving soil health, and creating a more resilient farming system.

Pre-monsoon dry sowing

Farmers in rainfed areas under the JIVA programme are practising pre-monsoon dry sowing. This technique ensures better seed germination by utilizing residual moisture in the soil before the onset of the monsoon, thereby improving crop survival and yield during erratic rainfall patterns.

Integration of livestock and aquaculture in the cropping system

The JIVA project promotes livestock farming and aquaculture as an integrated approach to the cropping system. Livestock provides input for making bio-inputs and manures required for natural farming in the region. In several JIVA projects, farmers have undertaken poultry farming, goat rearing, and aquaculture alongside crop cultivation to enhance the local agroecosystem. These allied activities provide supplementary income and mitigate crop failure risks due to climate hazards.

JIVA farmers rearing livestock along with crop production

Bio-resource centres

Farmers under the JIVA programme established bio-resource centres in several regions as part of an entrepreneurial model, where they produce a wide range of bio-inputs and organic concoctions including Beejamrit, Jeevamrit, Neemastra, and others. These centres promote natural farming by providing bio-enhancers and microbial inoculants, reducing the need for agrochemicals and enhancing soil health.

JIVA farmers preparing bio-inputs

Local markets and circular economy

The JIVA programmes focus on nurturing the integration of local production and consumption systems (local markets) to enable a circular economy. In this regard, the programme develops local enterprises and entrepreneurs as a support system for farmers to reduce dependency on external resources and markets. In the long run, it can develop resilient downstream and upstream agri supply chains that are better equipped to withstand climate risks.

Impact of the JIVA Programme

The implementation of diverse climate-resilient agricultural practices under the JIVA programme has significantly transformed farming communities. A total of 1,066 beneficiaries have adopted natural farming techniques across 330.88

hectares in the first year. Intensive efforts have been directed towards empowering approximately 720 farmers, including 230 women, to become lead farmers. These individuals now serve as farmer resource persons, playing a pivotal role in supporting fellow farmers in adopting natural farming and transitioning towards an agroecology-based farming system. With crop diversity ranging from 8 to 20 varieties including millets, pulses, millets, oilseeds, vegetables, and fruits-farmers have increased their resilience and productivity. Incomes have raised by ₹10,000 to ₹15,000 (approximately $120 to $180) per season, and soil health has improved with enhanced moisture retention, better texture, and higher microbial activity due to bio-resources, natural mulching, and year-round crop cover. These initial results from the first year highlight the success of JIVA's integrated approach to sustainable and climate-resilient agriculture.

Conclusion

The JIVA is an innovative programme that has the potential to enhance sustainability and make agriculture climate resilient. The participatory method in the planning process and farmer-to-farmer learning approaches will ensure the outreach and sustainability of the initiatives. There is a need to constantly evaluate the programme in collaboration with the farming community and local implementing partners to understand what is working and what is not working. Scaling up climate-resilient programmes like JIVA requires policy alignment, enhanced financial support, and widespread adoption through public-private partnerships.

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Disclaimer: This article reflects the personal opinion of the authors and does not represent the organizations, they work with.

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India and Japan

Strategic Collaboration in Energy Transition

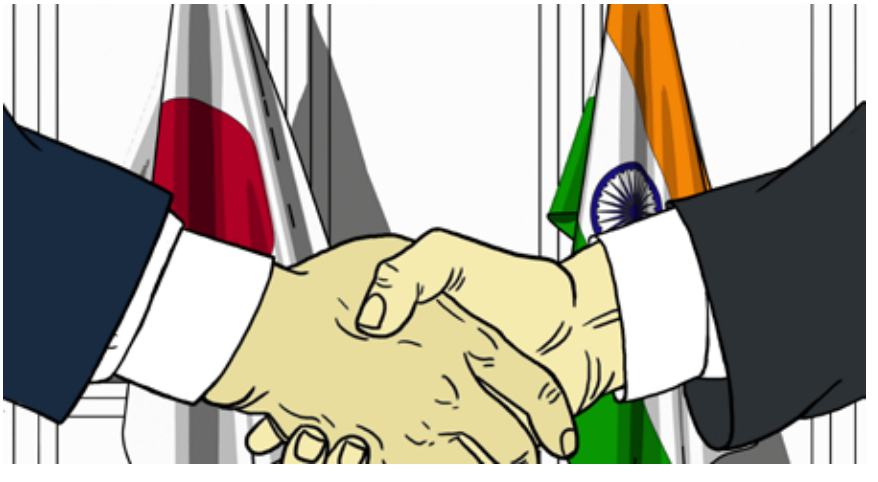
India and Japan have been associated with each other from the past many decades. This partnership has always played a crucial role in promoting stability and prosperity on both regional and global scales. This article composed by **Shinichiro Imahori** is dedicated towards discussions on strategic collaboration in the sphere of energy transition. The nations would take multiple initiatives to enable stable renewable energy supply and efficient power transmission from remote areas to urban centres, significantly improving India's energy mix.

On the India–Japan Strategic Partnership

India, with a population exceeding 1.4 billion and having recently surpassed China as the world's most populous country, is projected to overtake Japan in nominal GDP this year according to the estimation by International Monetary Fund (IMF). India's presence in Japanese industry is also growing rapidly. According to the latest survey titled *JBIC Survey (36th) Report on Overseas Business Operations by Japanese Manufacturing Companies* released in December 2024, India has ranked number one for three consecutive years as the most promising country for medium-term (approximately three years) prospects for approximately 500 Japanese manufacturing companies. Japanese companies have accelerated their shift of manufacturing bases from China to India, driven by the need to strengthen supply chains and ensure economic security, underscoring India's significance as a key partner of Japan.

India is a traditional friend of Japan, and the two nations share a Special Strategic and Global Partnership transcending conventional bilateral relations. Our partnership plays a crucial role in promoting stability and prosperity both regionally and globally. In recent years, the collaboration in the field of security has deepened significantly, highlighted by the Annual Malabar Joint Naval Exercises involving Japan, the United States, and India, as well as the signing of the India–Japan Acquisition and Cross-Servicing Agreement (ACSA).

On 20 March 2023, former Japanese Prime Minister Fumio Kishida delivered a policy speech in New Delhi, India, titled 'The Future of the Indo-Pacific: Japan's New Plan for a 'Free and Open Indo-Pacific—Together with India, as an Indispensable Partner'. In this speech, he unveiled a new plan for achieving a 'Free and Open Indo-Pacific' (FOIP). The plan emphasizes enhancing the connectivity of the Indo-Pacific region, foster the region into a place that values freedom, the rule of law, free from force or coercion, and make it prosperous. The FOIP initiative aims to be a shared goal among India, Japan, the United States, and Australia under the Quadrilateral Security Dialogue (QUAD), advancing regional security and economic cooperation. Through alignment between India's Act East Policy and Japan's focus on high-quality infrastructure partnerships, the development of India's north–eastern region and the enhancement of economic connectivity across South Asia are progressing steadily.



The strategic relationship between two nations has also led to collaboration in the renewable energy sector. The Indian government has set an ambitious goal of expanding non-fossil fuel-based power generation capacity to 500 gigawatt (GW) by 2030, with 50% of the total electricity generation coming from renewable sources. To achieve this, India is implementing a series of government-led initiatives, including large-scale renewable energy auctions,

grid enhancement projects, and the introduction of large battery energy storage systems (BESS) to stabilize the power system. Measures such as waivers for inter-state transmission system (ISTS) charges, regulatory relaxation for the corporate power purchase agreement (CPPA) market, and mandates for renewable energy procurement by distribution companies are further optimizing supply and demand.

In addition to these policy efforts, India's abundant solar potential, especially in the western regions, and its competitive construction costs have positioned solar power as a cost-effective energy source, now cheaper than coal-fired power. Leveraging this vast renewable resource, India is prioritizing the development of a green hydrogen industry. In January 2023, the Indian government approved the National Green Hydrogen Mission to promote the domestic production of electrolyzers and hydrogen, aiming to achieve an annual production capacity of 5 million tonnes of green hydrogen by 2030.

Green hydrogen, once produced, is expected to be utilized domestically for fertilizer plants, refineries, and hard-to-electrify sectors such as steel manufacturing and heavy transportation. At the same time, India sees the export of green hydrogen as a key strategy to address its trade deficit. Japan, targeting the supply of 3 million tonnes of hydrogen annually by 2030 domestically, presents a significant market for India, offering competitive export potential due to lower transport costs compared to other producers. Several projects involving Japanese firms in partnership with Indian companies aim to produce and export green ammonia in eastern India. With strong governmental support under the India–Japan Clean Energy Partnership, enhanced collaboration in the hydrogen value chain is highly anticipated.

In transmission, high-voltage direct current (HVDC) projects involving Japanese companies are drawing attention. These initiatives enable stable renewable energy supply and efficient power transmission from remote areas to urban centres, significantly improving India's energy mix. Additionally, innovative technologies such as perovskite solar cells, developed with Japanese expertise, hold great potential in India's decarbonization efforts. Lightweight, flexible, and semi-transparent, these cells can be used for novel applications, including vehicle-mounted systems and building-integrated photovoltaics, driving urban energy efficiency and renewable energy adoption in transportation.

Diversified Approaches for Sustainable Development

As Asia's economies grow, electricity demand is expected to rise, while fossil fuel dependence persists. Each country faces unique circumstances, and transition pathways vary. Achieving decarbonization, economic growth, and energy security requires a realistic approach that includes nuclear and natural gas options.

In the automotive sector, India's reliance on coal-fired power, which accounts for over 70% of its energy mix, limits the emission reduction benefits of electric vehicles (EVs). In addition, greenhouse gas (GHG) emissions from EV production, particularly from the energy-intensive battery-manufacturing processes, need to be considered. Life Cycle Assessment (LCA) studies reveal the carbon footprint at each stage of a vehicle's life cycle, including raw material extraction, manufacturing, operational emissions and end-of-life disposal. For example, while EVs may offer lower operational emissions, their production often involves certain amount of carbon footprints due to the mining of critical minerals and battery manufacturing. As a result, a diversified approach that includes compressed natural gas (CNG) vehicles and hybrids vehicles is emerging as a practical and sustainable solution, while hybrids and CNG vehicles may offer a more balanced trade-off in terms of overall emissions and resource use. By using LCA as a guiding framework, policymakers, and industry can identify solutions that optimize environmental benefits while taking into account India's energy realities and supply chain constraints. LCA-based financial incentives are also gaining attention in the financial sector.

India–Japan relations are poised for further development across economic, energy, and environmental domains. As Japan's policy-based financial institution, JBIC will remains committed to supporting climate change initiatives through financial measures, fostering business opportunities for Japanese companies, and contributing to the deepening and advancement of India–Japan economic ties.■

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Citizen's Engagement in a Decentralized Wet Waste Management Approach

Waste management is a global challenge. The present article authored by **Chandreyee Mitra, Mohammed Idris**, and **Jai Kumar Gaurav** makes us aware of a unique wet waste management approach. The trio presents Bengaluru as a case study that demonstrates how in order to reduce the burden of unscientific handling of large volumes of municipal solid waste the city has opted to shift from a centralized single stream collection and landfill disposal system to a decentralized multiple stream collection and scientific processing system.

Waste management is a critical challenge in India, driven by rapid urbanization, increasing waste generation, diverse waste types, limited space for processing facilities, constrained financial resources, and inadequate infrastructure. According to Swachh Bharat Mission-Urban, India generates 161,919 tonnes per day (TPD) of municipal solid waste and 80% is being processed. Inadequate waste collection, transport, treatment, and disposal have become major causes for environmental and public health concerns in the country.

Karnataka with its growing population and rapid urbanization has been facing drastic increase in per capita waste. About 11,044 TPD of municipal solid waste (MSW) is generated in the state, of which 50–55% is wet/organic waste, 30–35% is dry waste, and 10–20% is construction and demolition (C&D), and inert wastes. By 2031, the MSW generation in Bengaluru alone is projected to exceed 13,000 TPD.

Current Situation: solid waste management of Bengaluru

Spanning an area of 709 sq. km, divided into 243 wards and with a population of over 10 million, Bengaluru stands as the third most populous city in India. The waste generation rate in Bruhat Bengaluru Mahanagara Palike (BBMP) area is approximately 564 grams/capita/day. The waste generated is approximately 5760 TPD which includes 64% wet waste, 28% dry waste, 3% domestic hazardous waste, and 6% inert waste.

The city has adopted a 3-part strategy for its solid waste management system:

- **Strategy 1**: Decentralized processing of waste by stream
- **Strategy 2**: Bulk generators to manage their own waste
- **Strategy 3**: Creating a ward micro plan for management and execution of SWM services.

In order to reduce the burden of unscientific handling of large volumes of MSW, the city has opted to shift from a centralized single stream collection and landfill disposal system to a decentralized multiple stream collection and scientific processing system.

Defining the Problem

The wet waste generation of Bengaluru is 3687.19 TPD. Bengaluru has seven wet waste- processing plants established with a total capacity of 1,570 TPD.

According to the United Nations Environment Programme (UNEP), organic waste decay is responsible for 5% of the total greenhouse gas (GHG) emissions

globally. In an effort to combat this concern, there has been a lot of impetus on decentralized management of waste through composting. Hence, there has been an increase in a demand for urban home composting kits as well as community composters like lane and temple composters.

About the Project

Bengaluru is the one of the NAMA Supported Project (NSP) cities for the implementation of the Mitigation Action Facility, formerly NAMA (Nationally Appropriate Mitigation Action) Facility funded Waste Solutions for a Circular Economy in India project. The objective of the project is to focus on source segregation and adopt low-carbon waste management solution.

Installation of lane composters and temple composters is one of the approaches towards zero-waste initiative for the segregated wet waste (organic waste) taken up under this project. A zero-waste approach entails maximizing diversion from landfills and reducing waste at the source. By composting the wet waste at community level, we are able to close the loop at source itself.

Case Study

Community Composters: Bengaluru

With the support of BBMP, the project has installed lane composters in BBMP owned park, common spaces in residential areas and private apartment with support of Residents Welfare Associations and volunteers. The details of the lane composters are given in Table 1. At every location two-lane composters have been installed so that once a lane composter is filled to its maximum capacity, it is left closed for 45 days until the compost is ready to be harvested.

Overall, a total of 8900 kg of wet waste has been composted from these four localities and approximately 1500 kg of compost harvested through eight cycles, reflecting a small yet significant impact on waste management and sustainability.

The project has installed two temple composters in Bengaluru as mentioned in Table 2.

Table 1: Lane composters installed under Waste Solutions for a circular economy in India project

Location	Name of lane composter	No. of lane composter	No. of household catered	Daily wet waste*	Total capacity
Poornachandra Park, Yelachenahalli	Gaia Lane composter	2	30 HH	Approx. 13~15 kg/day	450 kg
Shyam Abhinandan Apartment Yelachenahalli	Eira lane composter	2	50 HH	Approx. 22~24 kg/day	750 kg
Nataraja Layout, Konankunte	Gaia lane composter	2	30 HH	Approx. 13~15 kg/day	450 kg
AGS Layout, Uttarahalli	Eira lane composter	2	40 HH	Approx. 22~24 kg/day	750 kg

* Actuals, as per site information

Table 2: Temple composters installed under Waste Solutions for a Circular Economy in India project

Location	Name of temple composter	No. of temple composter	Daily wet waste	Total capacity
Bhovi Colony, Byrasandra	Soil and health mesh composter	1	30 kg	1000 kg
Uttarahalli Pattalamma temple	Soil and health mesh composter	1	30 kg	1000 kg

Lane composter installations at different localities in Bengaluru

Inauguration of lane composter done by Zonal Commissioner, Bommanahalli, BBMP

Harvesting of manure from lane composters

Temple composter

Key Recommendations

In India, waste management is still considered as the sole responsibility of the government. Citizens' disinterest and reluctance to participate in waste management is a social problem, as much as a compliance issue. While decentralized waste management through initiatives such as community composting have multiple benefits, if systemic changes are introduced, and if there is more stringent application of waste management regulations.

- Promote source segregation through long-term behaviour change campaigns using success stories, peer-to-peer training, identifying local champions, involving public representatives and regular monitoring by sharing outcomes.
- Ensure compliance with SWM Rules, 2016 by engaging BWGs for on-site wet waste processing and designating public spaces for community composting in city plans.
- Train waste management staff and workers on segregation, decentralized waste rules, data monitoring, and conducting awareness campaigns and composting demonstrations.

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India's Energy Transition

What It Means for Government Budgets?

This article by **Laveesh Bhandari** is autobiographical in nature. It takes into account the tentative status of the government budgets (Central and states) as a consequence of India's energy transition. A little imagination would felicitate understanding. Over time as fossil fuel dependence falls, government will earn less and less revenue from the energy sector. Please read further to know more!

As the Indian economy transitions from a fossil fuel-driven economy to that driven by cleaner energy, there will be a range of changes in economic activities that would span across individuals, households, communities, companies, and the governments. Focusing on the last, namely governments, one element that is little understood is what would happen to governments' budgets. As is well known, state and central governments levy tax on fossil fuels differently. Coal has a low goods and services tax (GST) imposed on it as well as a compensatory cess, whereas petroleum products such as petrol and diesel are taxed with customs duties and excise by the Union Government, whereas state governments impose a value-added tax (VAT). In addition, many of the companies involved in fossil fuels are highly profitable and corporation tax also applies to them. On the other hand, as of now, the bulk of the renewable energy economy requires extensive support from the government through both monetary (subsidies) and non-monetary (regulatory) means. In other words, over time as fossil fuel dependence falls, governments will earn less and less revenues from the energy sector. How will they deal with this loss? Indeed how much of a revenue gap will they face? Would state governments be impacted more or less than the Union Government? What can they do about it? These are only some of the questions that come up.

My colleagues at CSEP and myself have been studying these issues for some time. In a sequence of studies, undertaken with Aasheerwad Dwivedi and Rajat Verma, I witnessed a range of issues associated with the fiscal transition that will need to accompany India's energy transition.

We found that as of 2019 tax and non-tax revenues, for both state and Union governments, from all fossil fuels including coal, petroleum products, and natural gas, were equivalent to 3.2% of India's GDP. Of this total, state governments' revenues were 1.2% of India's GDP and 2% for the Union or Central Government. To give perspective, revenues from fossil fuels are greater than all of India's defence expenditure, and also overwhelm all of the Indian government spending on health and education. Taking estimates of how fossil fuel use would change over the next 20 years we were also able to estimate how these revenues would change over time.

The numbers were quite unambiguous. Over time though revenues would increase as would consumption due to economic growth, as a share of government budgets and also as a share of India's economy they would fall. Why? Because of growth, fossil fuel consumption would steadily decrease over the next 20 years. But economic growth would be higher and consequently, over time in a relative sense, the dependence on fossil fuels would fall. We estimated that overall from 3.2% in 2019, the overall figure would be closer to 1.8% of the GDP by 2030 and down to 1% of the GDP by 2040.

Table 1: Relative fall of fossil revenues over time

	In Rs billion	As share of GDP	As Share of Government Expenditure
(1)	(2)	(3)	(4)
Central Government Fossil Revenue			
2019	4,047.5	2.0	15.0
2030	7,030.3	**1.1**	**10.8**
2040	9,953.7	**0.6**	**4.5**
State Government Fossil Revenue			
2019	2,427.1	1.2	6.2
2030	4,347.5	**0.7**	**5.4**
2040	6,253.8	**0.4**	**2.0**
Total Central and State Government Fossil Revenue			
2019	6,474.6	3.2	9.8
2030	11,377.8	**1.8**	**7.8**
2040	16,207.5	**1.0**	**3.0**

Source: Bhandari and Dwivedi (2023)

This led us to the question what would happen to the states, and we found that some states would be impacted far more, especially the states in the eastern parts of India. States such as Jharkhand, Odisha, Chhattisgarh, and even Madhya Pradesh would be greatly affected in many ways, but the key challenge is related to revenues from coal. As of now, these states obtain revenues from royalties and also the revenues that are associated with coal mining. Moreover, many thermal power plants are also located closer to the head of the mines. But as the use of coal stagnates, its share in their total tax and non-tax revenues would fall. In other words, these states would be challenged more than the states such as Maharashtra and Tamil Nadu which have a larger more diversified economy and also lesser dependence on coal. The question that arises then is, what kind of revenue options do we have? We looked at a range of tax options that could be imposed by both the Central and state governments. Options before India include increasing the tax rate, increasing the base of taxes, simplifying taxes, reducing government expenditures, and also imposing new types of taxes. We find that while many possibilities exist, increasing tax rates is less feasible than increasing coverage or introducing new forms of taxes.

A carbon tax is one such possibility. However, to institute carbon taxes the Union Government will need to figure out how it wants to share it with the states. The Constitution of India as per Article 248 empowers the Centre to institute a new tax, it does not allow the Centre to prevent states from taxing fuels. For that to occur a constitutional amendment will be required, which we believe will be difficult as state governments have limited autonomy over taxation post-GST. But imposing a carbon tax over and above the taxes already in place seems like a difficult proposition. Another possibility is to subsume carbon taxes into the GST, which also will be difficult and the states and Union Government will need to come to some mutual agreement. Another possibility is for the Union Government to impose a distance-based tax that would work something like a fast tag that operates currently. However, our subsequent work also shows that the distance-based tax will have a significant negative impact on economic growth.

To sum up the current understanding, many options exist, but each option has some strengths and weaknesses and Union and state governments will need to work together to come to a mutually acceptable solution. They will need to do so fairly early, for the transition is a given, and given that RE and EVs are currently taxed little and subsidized significantly, both state and Union governments' budgets are bound to be impacted negatively if early action is not taken. ■

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Cyanobacteria

Nature's Ally for Sustainable Development

This article penned by **Farheen Islam** and **Dr Mandira Kochar** makes the readers aware about the role cyanobacteria can play in mankind's efforts towards realization of sustainable development. Commonly known as blue-green algae, cyanobacteria are primitive microorganisms that have inhabited the earth for 3.5 billion years and possess a vast potential in addressing important global challenges that are related to climate change, agriculture, and health care. Cyanobacteria have now emerged as a potential source for sustainable agriculture, better reliable non-toxic medical supplies, food supplements, and nano-bioconjugates without harming the environment.

Nature itself offers powerful support in this pursuit of sustainability, as the earth comprises several beneficial microorganisms, including algae, bacteria, fungi, and viruses. Exploring the potential of these microbes can provide a healthier, economical, and eco-friendly path towards the aim of sustainable development. Cyanobacteria, commonly known as blue-green algae (BGA) are primitive microorganisms that have inhabited the earth for 3.5 billion years and possess a vast potential in addressing important global challenges that are related to climate change, agriculture, and health care. Cyanobacteria have now emerged as a potential source for sustainable agriculture, better reliable non-toxic medical supplies, food supplements, and nano-bioconjugates without harming the environment.

Cyanobacteria in Sustainable Development

Blue-green algae are renowned for their unique potential of fixing atmospheric nitrogen and performing oxygenic photosynthesis. Cyanobacteria can be used as biofertilizers and reduce dependency on chemical fertilizers,

thereby making them invaluable in sustainable agriculture. Unlike the other synthetic fertilizers which are not only costly but also pose a threat to the human health as well as the environment, cyanobacterial biofertilizers can naturally enhance soil fertility, increase crop yields, and decrease greenhouse gas (GHG) emissions. Rice, which is the staple food for millions in the world has shown an improvement in its yield after the application of cyanobacteria as a biofertilizer. Besides playing a crucial role in agriculture, cyanobacteria also play a potential role towards sustainable development through various other means. They can make barren land productive as they have the capability of growing on non-arable lands.

Blue-green algae are also a very important source of biofuel which helps in reducing dependence on fossil fuels and decreases carbon emission. Apart from this, cyanobacteria also release bioactive compounds with significant pharmaceutical potential including anti-carcinogenic, anti-microbial, and anti-viral properties.

Meeting the Growing Food Demand

Nowadays, food security is becoming a major concern in developing nations. For this, cyanobacteria offer a feasible solution for increasing agricultural productivity. Other than fixing atmospheric nitrogen, they also enhance soil health by promoting the availability of essential nutrients like sulphur, phosphorus, and carbon. Additionally, they also help in the reclamation of salt-affected soils and bioremediation, thereby enhancing their utility in sustainable farming. For assuring long-term sustainability, a healthier ecosystem and better food quality, incorporating cyanobacteria into agricultural systems and pharmaceuticals seems to be a promising choice towards sustainable development. Their ability to function as biocontrol agents and plant-growth promoters strengthens plant resistance against various biotic and abiotic stresses like drought and pest attack. Also, cyanobacteria can enhance soil quality and fertility by improving physio-chemical features like water-holding capacity and mineral nutrient conditions of the damaged lands by modulating pH, controlling salinity, and absorbing heavy metal contaminants.

Cyanobacteria in Health Care and Pharmaceuticals

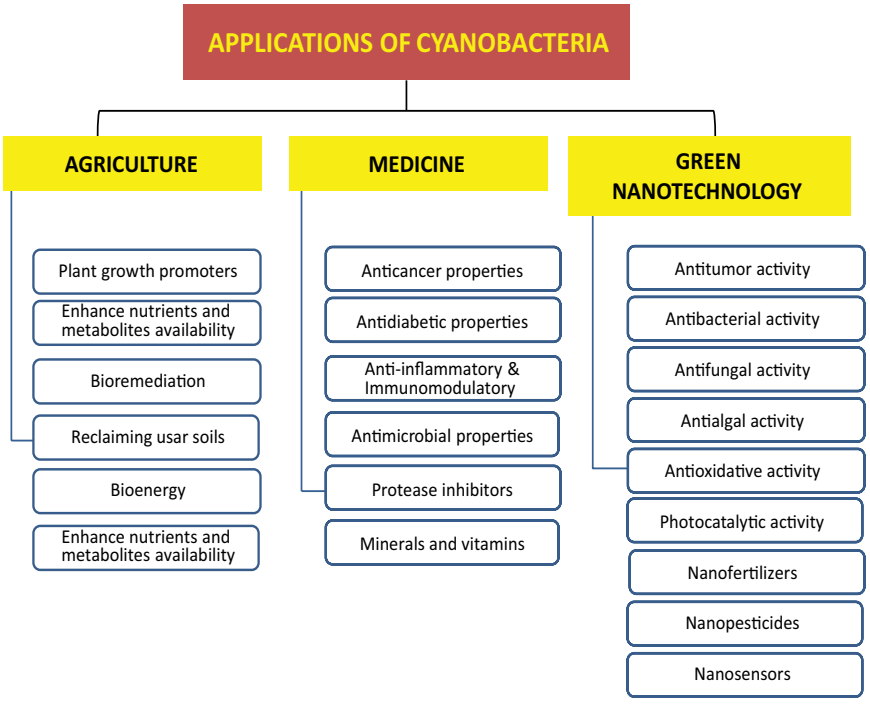
Advancement in microbiology has led to the understanding and exploring that cyanobacteria are an extremely rich source of secondary metabolites. Hence, the potential of cyanobacteria goes beyond agriculture into the realm of health care. During the last two decades, the potential of cyanobacteria as a very good source of novel therapeutic compounds including anticancer, antidiabetic, anti-inflammatory, immunomodulatory, antimicrobial (antibacterial, antiprotozoal), and antiviral (including against HIV and SARS COV-2) properties, has been realized. There is an increasing demand for natural, bioactive compounds in drug development as with the changing lifestyle there are rising rates of chronic diseases such as cardiovascular ailments, diabetes, and cancer. Blue-green algae consists of a diverse array of metabolites including peptides, alkaloids, and fatty acids which possess promising therapeutic properties.

Notably, these bacteria have already shown their effectiveness against several viral diseases including COVID-19, underscoring their potential in modern medicine. Despite the immense promise, only a fraction of these bioactive compounds has been fully explored. Also, cyanobacteria are a rich source of vitamins and minerals that can act as strong antioxidants and fight disease and therefore provide an eventual mixture of nutrition in the right quantities

of a single food. The solubility of the bioactive compounds is one of the major challenges for their utilization and this can be addressed through advanced technology like nanotechnology.

Nanotechnology: enhancing the potential of blue-green algae

Nanotechnology plays a crucial role in attaining sustainable development as it offers a revolutionary approach to address the capabilities of cyanobacteria to provide sustainable solutions in different fields. Researchers can develop innovative products by combining cyanobacteria with nanomaterials and making them available for agricultural as well as pharmaceutical purposes. For instance, the development of nanofungicides and pesticides, nanofertilizers and nanocarriers for drug delivery. The development of nanoparticles using cyanobacteria is a rapidly emerging field with the potential for application in pharmaceuticals, agriculture, and environmental remediation due to their ability to grow rapidly, along with their potential to absorb heavy metals. For example, the gold nanoparticles synthesized using cyanobacteria have shown potential in improving radiotherapy and also the magnetic iron oxide nanoparticles are used to enhance cancer diagnostics.



Partnerships for a Greener Future

Collaborative efforts across multiple sectors are required to explore cyanobacteria and its potential in sustainable agriculture, pharmaceutical, and green nanotechnology. Research institutions, industries, government, and international organizations must come forward and work together to promote innovative research and large-scale application of green and eco-friendly solutions to attain sustainability in agriculture. Partnerships towards incorporating cyanobacteria into the development of bioenergy, sustainable agriculture, and the production of medicines, can play a crucial function in accelerating growth towards the goal of global sustainability. By promoting and enhancing the partnership across farmers, researchers, and industries, we can explore the all the capabilities of cyanobacteria and other such microorganisms, which pave the way for a greener, healthier planet. ■

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Knowledge Co-production

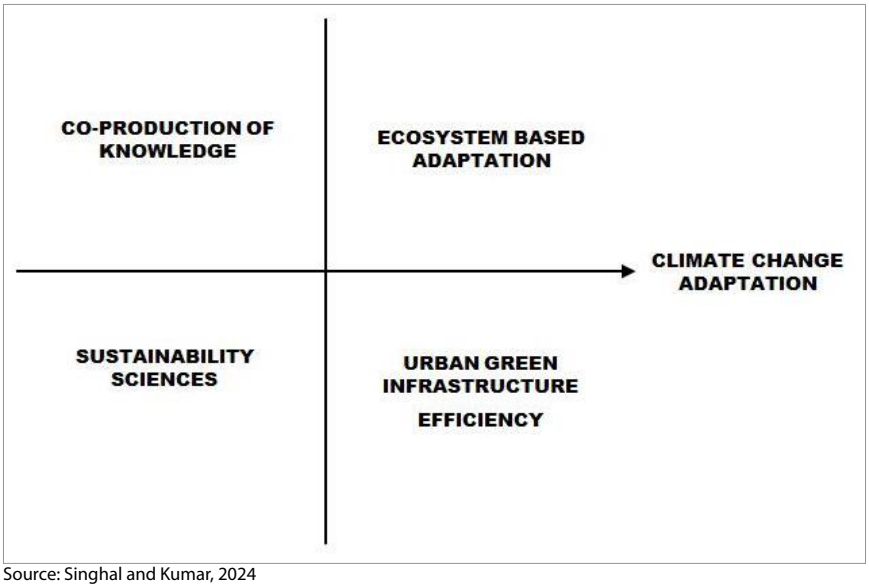
A collaborative research approach to addressing sustainability's wicked problems

Sustainability challenges are inherently complex, as they intersect in physical, biological, and social dimensions. Solutions proposed by scholars, researchers, and policymakers often face real-world constraints, making it difficult to implement risk-free resolutions. Via this article, **Sagarmoy Phukan, Dr Amit Kumar Jaglan,** and **Prof. Shaleen Singhal** offer how innovative approach can help us to overcome such constraints. This approach assists in overcoming the limitations of linear models, where researchers and policymakers operate within defined boundaries.

Around two decades ago, we examined how key environmental concerns were likely to unfold for India. Projections were made and strategies were recommended to address air pollution, water pollution, solid waste management, and land degradation-related challenges for articulating the alternative scenario (Pachauri, Singhal, and Kandra 2004) for 'India 2025'. This led to a call for improvement across dimensions such as improved environmental governance and effective corporate environmental responsibility. Though these dimensions drew attention back then, today they still pose complexity and urgency to deal with and might remain so beyond 2025!

Sustainability challenges are inherently complex, as they intersect in physical, biological, and social dimensions (UNESCO, 2023). Solutions proposed by scholars, researchers, and policymakers often face real-world constraints, making it difficult to implement risk-free resolutions (Lönngren and van Poeck, 2021). These can be termed as 'wicked problems' as they are impossible-to-solve problems and require multidimensional viewpoints and assessments to offer holistic, practical solutions (Rittel and Webber, 1973; Lönngren and van Poeck, 2021).

Photo credit: Nishchint Srivastava



Source: Singhal and Kumar, 2024

One innovative approach to addressing such problems is integrating multiple stakeholders through the co-production of knowledge (Maas, Pauwelussen, and Turnhout 2022). This approach assists in overcoming the limitations of linear models, where researchers and policymakers operate within defined boundaries.

Knowledge co-production is a collaborative and iterative process involving diverse stakeholders to tackle complex sustainability challenges. By treating science and politics as inseparable and co-constituted, this approach generates context-specific knowledge and facilitates social learning while strengthening capacity, fostering social capital, and driving actionable sustainability practices. At the Emerson Centre of Excellence for Sustainability Studies at TERI-SAS, we attempt to strengthen the interface between science, policy and practice, valuing the interplay of political, economic, cultural and institutional factors. Overarching and specific recommendations are being developed by adapting knowledge co-production approach for areas such as energy and climate change, ecosystem-based adaptation and green infrastructure (Singhal and Kumar, 2024), sustainable smart cities, water and waste management, and sustainable consumption and production. For instance, we are using the approach towards developing a holistic framework to strengthening capacities of higher educational institutions (HEIs) for transitioning towards net zero. This participatory approach engages institutional leaders, academics, administrative staff, and students to collaborate on reducing emissions and achieving sustainability goals. The framework integrates scientific evidence with stakeholder values, opinions, and perceptions to provide context-specific sustainability policies. By combining science, social behaviour, governance, and financial considerations, the model fosters actionable and inclusive sustainability strategies for campuses.

We are also adapting the knowledge

Photo credit: Somi Rishabh


Photo credit: Saptarshi Majumder

co-production approach in assessing and developing the water, sanitation, and hygiene (WaSH) management strategies for the Maha Kumbh Mela. WaSH challenges at this mega event arise due to the influx of millions of devotees. Our study involves 14 key stakeholders, including pilgrims, Mela authorities, government officials, civil society organisations, vendors, and fishermen, to map perceptions, attitudes, and behaviours that affect WaSH outcomes. Through surveys and stakeholder interviews, we emphasize cultural sensitivity, inclusivity, and equity, ensuring sustainability practices align with spiritual values while addressing hygiene needs.

Our studies raise the significance of knowledge co-production approach in generating actionable insights and diverse, value-driven decision-making options. For example, at the Kumbh Mela, religious beliefs often take precedence over hygiene with limited yet much needed behavioural change. Our preliminary findings suggest that interventions designed and led by engagement of multiple stakeholders including religious leaders, are essential to address such deeply ingrained cultural practices. In conclusion, addressing wicked problems in sustainability necessitates knowledge co-production that strengthens science–policy–practice interface. By fostering collaboration, inclusivity, and cultural sensitivity, knowledge co-production provides robust frameworks for tackling complex sustainability challenges. At its core, this approach acknowledges the diversity of problem dimensions and stakeholder priorities, enabling the development of actionable, context-specific solutions.

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Climate Emergency and the Need for Meaningful Climate Partnerships

Comprehension of the phenomenon of climate change as a crisis forms the subject matter of the present article by **Prof. Emmanuella Doussis**. The author makes us view this emergency from different perspectives and establishes mere knowing it is not enough. We are already late in commencing the 'doing' process.

Over the last years, the term 'climate crisis' has been increasingly used to emphatically describe the severe deterioration of certain phenomena affecting the climate, and to awaken society. Sudden and extreme weather events, which are now occurring more frequently and with greater intensity and duration, alongside droughts, heatwaves, floods, and wildfires, cause massive destruction and impact water resources, agriculture, infrastructure, health, and security, accelerating population displacement and testing the resilience of governments and national economies.

However, a crisis is typically a temporary phenomenon that peaks and then subsides or transitions into something else. Thus, the term 'climate crisis' is misleading as it does not include the parameter of duration. Moreover, it gives the impression that a return to normality is possible. But this is now unattainable. The earth's average temperature has already risen significantly, and harmful greenhouse gas (GHG) emissions are still increasing rapidly. We are therefore facing a phenomenon that is causing an

emergency, a situation that requires urgent action in two directions—to drastically reduce the causes and to manage the consequences. This is a phenomenon that we will be constantly confronted with and which we must learn how to manage. There are practices that can help in this direction, but the pace of our mobilization is exceedingly slow.

The annual global climate conference—COP 29—which concluded on November 24, 2024 in Baku, Azerbaijan, had the main objective of reaching an economic agreement on the transition to clean energy and addressing the climate-related disasters in poorer countries that are most affected and least equipped to respond. An agreement was reached, but it falls short of expectations. Annual funding of $300 billion a year will be provided until 2035, but trillions are needed. Global climate cooperation under the auspices of the United Nations, while important for maintaining a channel of communication, is neither a panacea nor a provider of substantial solutions for managing climate change. The persistent search for global consensus serves only to lower the bar to the lowest common denominator.

Meanwhile, the upcoming assumption of the US presidency by the most well-known climate change denier is not good news. Certainly, the circumstances are not the same as in 2016, when the same president withdrew USA, the world's second-largest emitter, from the Paris Agreement. At that time, the biggest challenge was to convince the largest polluter, China, to make commitments to reduce harmful emissions. While China still relies on coal as its primary energy source, it has invested heavily in expanding renewable energy, aspiring to become climate neutral by 2060 while maintaining high exports of materials essential for clean energy. Therefore, it also has an economic reason to support the green transition. India, which has risen to third place on the list of global polluters, is also heavily investing in renewables, has set ambitious targets for 2030 and leads important global initiatives, such as the International Solar Alliance, to accelerate the deployment of solar energy technologies that will improve energy access and ensure energy security in participating countries.

Despite the heightened politicization of the green transition ahead of the European elections, the European Union, which ranks fourth on the list of global polluters, remained committed to achieving the European Green Deal goal of achieving climate neutrality by 2050. Having adopted most of the necessary legislation, attention now turns to implementation, which requires cooperation of the member states to achieve the collective European goal. Implementation is far from easy given the great turmoil affecting Europe. It will only succeed if the net-zero carbon emissions target is combined with large-scale investments in green technology and strong climate partnerships.

The example of the India–EU partnership is of particular importance. Since the elevation of India–EU relations to a strategic partnership in 2004, both

parties have made significant progress in enhancing collaboration across various sectors, including climate change. Key milestones include the establishment in 2005 of the India–EU energy partnership with the goal to promote cooperation on energy security, energy efficiency, and renewable energy; the recognition in 2008 that climate change is a global challenge and that clean and sustainable development is a joint priority area; the adoption in 2016 of a joint declaration on clean energy and climate partnership aiming to promote access to and dissemination of clean energy and climate friendly technologies; the adoption in 2020 of a roadmap to 2025 and a declaration on resource efficiency and circular economy; the introduction of a work programme in 2021 and the commitments to deepen cooperation in renewable energy deployment, energy efficiency, smart grid, storage, and market modernization, and to achieve a fair transition to a low-carbon future. Another milestone is increased funding from the European Investment Bank from 2014 to 2023, reflecting the growing collaboration between the two entities.

Both India and the EU have recognized the importance of combatting climate change and their cooperation is a crucial alliance towards the implementation of the goals of the Paris Agreement. Moreover, there are mutual benefits for both parties collaborating in renewable energy, technology transfer, and research and development. For India, focusing on affordable renewable energy and clean technology can drive economic growth and expand energy access, particularly in rural areas where many still lack access to energy. The EU can facilitate technology transfer, clean energy solutions, and financing. For the EU, India is a promising market for European renewable energy investments, thus helping the EU to achieve its Green Deal targets. Therefore, the India–EU partnership is beneficial for both parties, paving the way for innovating sustainable solutions. Cooperation can also be extended to other related areas, such as sharing good practices in improving energy efficiency, developing smart grids and energy storage, as well as strengthening the involvement of civil society in the partnership.

But beyond addressing the causes, which is one aspect of climate action, particular attention must also be given to adaptation to climate change and preparing to manage the inevitable. This involves more than flood prevention projects or developing early-warning systems and coordinating emergency services. Emphasis on prevention (such as monitoring vulnerable areas, better water management), better understanding of climate impacts, supporting knowledge sharing and research, increasing financial support, along with citizen education, are also critical factors.

Identifying and understanding the challenges is a priority, and this requires a common language of communication between science, policymakers, and society. In regions warming faster than others on the planet, communicating both risks and best practices is becoming a major issue. Today, many communication efforts try to convince the sceptics that climate change is happening and is an undeniable fact. Yet most citizens already know this. What they do not know is how it specifically impacts the area they live in and what they can do to protect their homes, land, businesses, and infrastructure to make them more resilient to climate change. Time is already running out. ■

Prof. Emmanuella Doussis is Professor at National and Kapodistrian University of Athens, Greece. She is also UNESCO's Chairholder on climate diplomacy.

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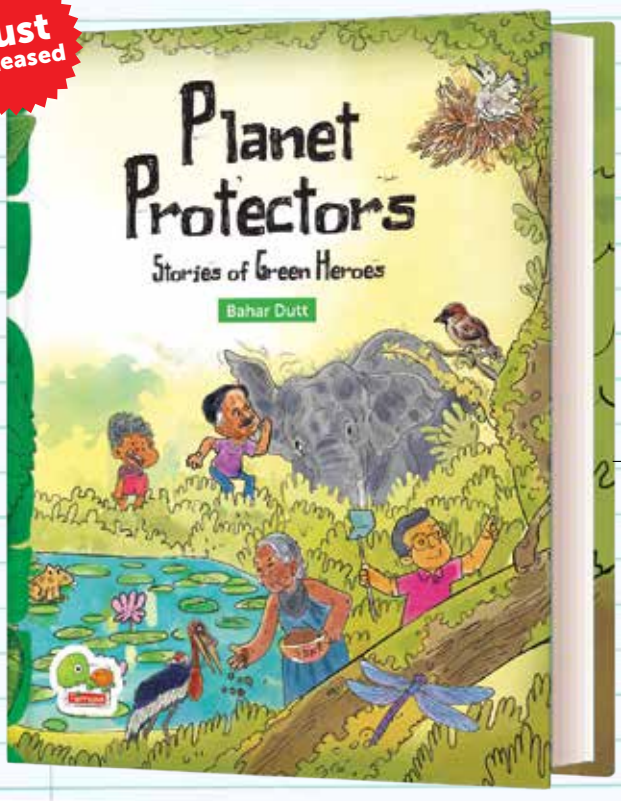

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Partnerships and Knowledge Sharing

Strategies to help MSMEs achieve clean energy transition

The path of sustainable development goes through decarbonization of the industrial sector. In this regard, MSME sector provides us with both challenges and opportunities. With its 63 million units, the sector provides employment to over 110 million people and stands for 45% contribution to the nation's GDP. The figures are self-explanatory for an energy-efficient transition. The author, **Girish Sethi**, has skillfully charted how partnerships and knowledge sharing are the key drivers in our quest for environmentally benign energy alternatives.

As the world strives to reduce CO_2 emissions from fossil fuel usage and mitigate the threats of climate change, the primary challenge is to decarbonize industry, which depends heavily on fossil fuels but also drives and sustains economic development. In India, industry accounts for nearly a quarter (24.1%) of India's total CO_2 emissions in 2022 (IEA).[1] At the same time, industry provides core inputs to every sector of the rapidly growing Indian economy and supports the livelihoods of millions of people.

The barriers to decarbonizing Indian industry straddle the domains

1 IEA, https://www.iea.org/countries/india/emissions

of awareness, technology, policy, finance, and capacity. These barriers are particularly formidable in India's vast micro, small, and medium enterprises (MSME) sector, with its 63 million units contributing 45% of the nation's manufacturing output and providing employment to over 110 million people. Most MSME units continue to use inefficient, fossil fuel-based technologies and practices that lead to high-emission levels as well as low-productivity and profitability. Other major barriers that MSMEs face include low-awareness levels, regarding energy efficiency; the lack of readily available (off-the-shelf) energy-efficient (EE) technological options; inability to secure dependable supplies of clean (low carbon) fuels at affordable prices; difficulties in accessing formal avenues of finance; and lack of capacities and opportunities in the domains of technical up-skilling, management, and marketing.

TERI's Industrial Energy Efficiency Division (IEED) initiated its efforts to decarbonize the Indian MSME sector in the early 1990s—a time when MSMEs were struggling to find ways to upgrade their low-efficiency technologies and practices swiftly in order to survive in the new, fiercely competitive markets that were emerging with the progressive liberalization of India's economy. The MSMEs also confronted the challenge of meeting increasingly stringent environmental regulations.

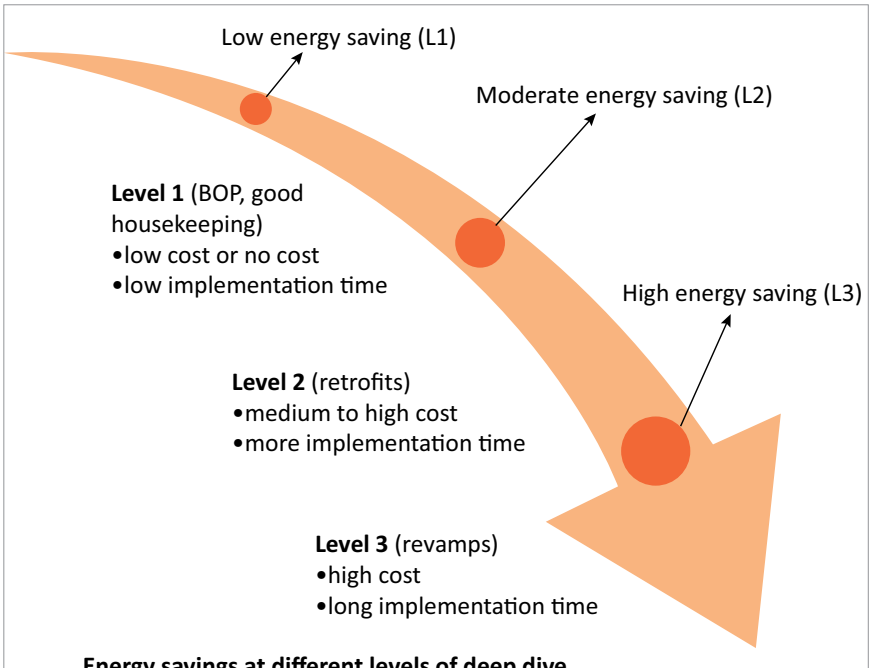
Intervention

TERI has successfully implemented two broad strategies to promote clean, EE technologies in the MSME sector. Partnerships, pooling of expertise and knowledge-sharing constitute core elements of each strategy, entailing activities from shop-floor to policy levels.

» The strategy known as research, development, demonstration and dissemination (RDD&D), first applied under a long-term project supported by Swiss Agency for Development and Cooperation (SDC), that has enabled the development, demonstration and widespread adoption of new/innovative low-carbon EE solutions such as EE furnaces in the small-scale foundry and glass sub-sectors, and EE biomass gasifiers for thermal applications in a range of industrial sub-sectors. In each case the intervention required intensive and iterative processes of R&D, field trials, technology demonstration and adaptation, training, and capacity building, with the close and sustained involvement of industry associations and other cluster-level stakeholders, and pooling of the multi-disciplinary competencies of Indian and international experts.

» The strategy known as 'deep dive' or 'saturation approach', which has enabled the large-scale adoption of commercially available EE technologies like IE3 motors, EE air compressors and pump sets, and LED lighting systems, etc., in a number of MSME clusters under different sub-sectors in close partnership with industry associations and other cluster-level stakeholders. The key elements of this approach are:

- Conducting detailed energy audits (EAs) on a large number of MSMEs in the cluster
- Identifying a set of energy conservation measures (ECMs) including best operating practices (BOP) for each MSME unit, that promise quick paybacks on relatively low or even zero investments
- Supporting interactions with technology vendors/suppliers, and providing technical assistance during implementations
- Quantifying the benefits of the ECMs in a few units at the early stages, so as to spur other units to follow suit
- Developing innovative business models to encourage the rapid and widespread uptake of the ECMs such as models based on deferred payment mechanism and demand aggregation, that are attractive for both equipment suppliers and end-users.



Energy savings at different levels of deep dive

Under both strategies, TERI has focused on establishing and strengthening cluster-level capacities on the EE technologies through awareness and training programmes for operators and other plant personnel. Local service providers (LSPs) have been identified and given suitable training so that technology replications take place without entrepreneurs having to seek support from external agencies.

For example: in the foundry sub-sector, the divided blast cupola, an EE melting technology that yields coke savings of 25% to 65%, first demonstrated in the Howrah foundry cluster under the SDC–TERI partnership project, has been successfully promoted in the Ahmedabad, Coimbatore, Nagpur and Rajkot foundry clusters. Also, ECMs in other process areas of foundry have been identified and promoted in Belgaum and Kolhapur foundry clusters under GEF–World Bank projects, and in the Ahmedabad, Howrah, and Rajkot foundry clusters in the last phase of the TERI–SDC partnership project. Under a UNIDO-supported project, TERI has strengthened the capacities of LSPs in the Belgaum, Coimbatore, and Indore foundry clusters.

In parallel with its cluster-level activities, TERI has conducted a sustained knowledge dissemination campaign through electronic and print media as well as through workshops, seminars, and conferences at regional and national levels supplemented by site visits, to spread awareness on the EE interventions more widely, in industry circles, as well as among other MSME stakeholders such as government officials at policy and regulatory levels, bankers, state development agencies (SDAs), donors, technical consultancies, academia, R&D institutes, and others. This campaign has helped place energy efficiency at the core of the policies and programmes formulated for the MSME sector by various government agencies at the Union and state levels. It has also spurred the development of financing schemes and innovative business models that make it easier and more attractive for MSMEs in India to adopt EE technologies.

Partnerships

Starting with the pioneering RDD&D project supported by SDC from 1993 onwards—a project that would extend for 25 years (till 2018)— TERI has been engaged in a large number of EE initiatives in the MSME space in collaboration with a host of other public and private organizations and institutions, Indian and international, for example, Agence Française de Développement (AFD), Bureau of Energy Efficiency (BEE), Energy Efficiency Services Limited (EESL), International Finance Corporation (IFC), Institute for Global Environmental Strategies (IGES), International Energy Agency (IEA), Japan International Cooperation Agency (JICA), MacArthur Foundation, Ministry of MSME (MoMSME), Ministry of Environment, Forest and Climate Change (MoEFCC), Ministry of New and Renewable Energy (MNRE), Petroleum Conservation Research Association (PCRA), SED Fund, Small Industries Development Bank of India (SIDBI), Shakti Sustainable Energy Foundation (SSEF), United Nations

Development Programme (UNDP), United Nations Industrial Development Organization (UNIDO), YES Bank, and the World Bank.

Platform

In the course of its work, TERI has established an informal and expanding network of MSME stakeholders and partner organizations—entrepreneurs, industry associations, LSPs, machinery and material suppliers, NGOs, R&D institutes, SDAs, consultants, and others. In order to provide a permanent forum with global outreach for these and other stakeholders in the MSME sector to share and synergize their knowledge, expertise, and experiences, SDC and TERI in collaboration with BEE and Ministry of MSME have established the web-based platform SAMEEEKSHA (www.sameeeksha.org) with its secretariat at TERI. SAMEEEKSHA hosts a range of knowledge resources on EE in the Indian MSME sector including case studies and videos on EE technologies and implementations, detailed cluster profiles/manuals, cluster summaries capturing key features of over 130 MSME clusters in different sub-sectors, and an interactive 'MSME Energy Map' that allows exploration of these and other resources. SAMEEEKSHA also publishes a quarterly newsletter, currently in its 57th issue (December 2024).

Snapshots

- Nearly 4000 energy audits (EAs) have been conducted in both large industries and MSMEs followed up in many cases with technical support services including training and capacity building, in a range of sub-sectors such as cement, ceramics, chemicals, engineering, fertilizer, foundry, forging, food processing, glass, iron & steel, power, pharmaceuticals, pulp and paper, etc. In addition, EA consultancy services have been extended to other countries such as Bhutan, Colombia, Ethiopia, Ghana, Guyana, Indonesia, Maldives, Nigeria, Tanzania, UAE, Uganda, Uzbekistan, and Zimbabwe.
- Under the aegis of SAMEEEKSHA, two National Conferences on Energy Efficiency were organized in 2012 and 2017. These events brought together MSME stakeholders at all levels from across the country, and helped in sharing success stories in adopting clean, EE technologies; capturing the key challenges in the overlapping domains of technology, finance, and capacity that continue to impede EE improvement among MSMEs; and outlining policies and measures that could help overcome these challenges.
- TERI supported BEE in preparing a manual titled 'Energy Conservation Guidelines for MSME Sector'. The guidelines cover the primary energy-consuming process equipment/systems used by MSMEs in 25 energy-intensive sub-sectors, as well as a range of auxiliary systems and utilities such as air compressors, boilers, fans and blowers, etc., that are used by MSMEs in all sub-sectors.
- As a part of the SAMEEEKSHA initiative, TERI has organized 24 platform meetings with various industry stakeholders across the country to gather insights and understand various issues facing the MSME sector in adopting clean energy technologies and practices.
- Energy and resource mapping studies have been done for 10 MSME clusters: five each in the chemical sub-sector and glass and refractory sub-sector.

Taking Stock

Through its successful promotion of low-carbon EE technologies in the MSME sector and sustained engagements with stakeholders at every level, TERI has progressively strengthened its own reputation as a dependable implementing agency, knowledge partner and strategic advisor with expertise in domains such as cluster/sectorial studies and energy mapping; diagnostic studies and energy audits; RDD&D initiatives; and technical assistance. Its initiatives have helped in the development of supportive policies, financing schemes and business models for EE technology delivery, and also catalysed a large number of EE initiatives by other agencies and organizations, thus helping the MSME sector achieve successful transition to clean energy. ■

Girish Sethi is the Senior Director of TERI's Energy Programme.

Zero-carbon Cooling in a Warming World

Expanding access while reducing carbon emissions

Cooling solutions have become a global necessity. On this matter, **Ita Kettleborough** makes us understand how collaboration and partnerships are vital to meet the rising cooling demand. As per the author, ensuring access to cooling and managing the resulting energy demand will be the two major challenges in the coming decades, but solutions exist and risks can be managed. A single solution will not work for the diversity of local conditions, building types, and people's needs so there is a lot to learn by sharing the diverse suite of existing solutions from across the world and encouraging adoption of solutions at the local level.

This past decade was the hottest in recorded history. As the world warms due to climate change, cooling indoor spaces becomes a greater necessity and challenge. Today, almost 4 billion people—half of the global population—live in hot climates, and the majority of the other half of the population experiences high temperatures at some point during the year. Yet, in 2022, only 37% of the global population had access to cooling technologies. Over the next 25 years, 700 million more people will live in hot climates due to climate change, and the challenges for those already in hot climates will intensify.

Prolonged exposure to high temperatures and humidity has severe health consequences, causing, on average, half a million deaths per year. SEforALL estimates that 1.2 billion people are at high health risk from heat without adequate access to cooling. Increasing global access to cooling technologies is critical. We need to broaden access to a comprehensive range of cooling solutions to effectively manage heat impacts, for example, increasing shade, constructing well-ventilated buildings, and installing efficient air conditioning (AC) and fans.

Simultaneously, we must reduce global greenhouse gas (GHG) emissions and reach net-zero emissions by mid-century to limit the most severe impacts of climate change, including global heating. Today, buildings account for a third of global emissions. This is primarily due to the energy required for heating, cooling, cooking and powering appliances, as well as the energy consumed during building construction. Globally, 2,200 terawatt hours (TWh) of electricity (around 6% of buildings' energy use) powers fans, AC, and dehumidifiers that cool buildings. Decarbonizing the building industry, including cooling, is essential to slow global warming and limit rising temperatures to below 2°C in line with global climate agreements.

The challenge is clear: we must simultaneously increase access to cooling while decarbonizing the energy used to provide it. Across the world, energy needed for cooling is likely to increase by 2.5 times by 2050, to over 5,000 TWh. In India alone, demand for cooling is expected to rise more than tenfold by 2050, requiring 15–20% of the forecasted electricity supply, up from 5–10% today.

In its latest major report, Achieving Zero-Carbon Buildings", the Energy

Transitions Commission (ETC) delves into the various aspects of building decarbonization, including cooling. We believe it is feasible to meet global cooling demands while reducing greenhouse gas (GHG) emissions. It will require a combination of solutions, such as significantly increasing the use of electric cooling technologies (e.g., AC, fans, dehumidifiers) supported by a transition from fossil fuel power systems to clean renewable electricity. Equally critical is implementing passive-

cooling techniques: building design methods that reduce indoor heat and humidity, such as external shading, white-painted roofs, and ventilating designs and materials. These non-energy-based solutions can, and must, make a substantial contribution.

Expanding Access to Air Conditioning Powered by Clean Electricity: a central pillar of global cooling

Air conditioning is set to become the world's leading cooling solution. ACs are electric, highly efficient, and compatible with a low-carbon future run on clean electricity. The International Energy Agency (IEA) expects the global stock of air conditioners to increase from around 2 billion today to 5–6 billion by 2050. Fans, which are a cheaper alternative cooling technology, currently outnumber ACs two to one. However, by 2050, these numbers are expected to equalize as household incomes rise and ACs become more accessible. The massive increase in AC use will bring new challenges, including managing the resulting surge in demand for clean power and preventing the release of refrigerants from ACs into the atmosphere, where they contribute to global warming.

Improving AC efficiency is the most effective way to reduce this surge in energy needed for cooling. ACs on the market today vary greatly in efficiency, within and across countries. The market

average model is much less efficient than best-in-class appliances. With the right policies, the global average AC efficiency could improve by 50%. For example, through the use of minimum energy performance standards (MEPS) and by introducing labelling regulations that indicate running cost implications to consumers. These types of policies could lower total annual global electricity requirements for cooling by 10–20% (500–1,000 TWh) in 2050.

Some countries are already experimenting with such policies. Since the US and EU introduced MEPS and efficiency labels, AC energy consumption has been cut in half. In China, tightening MEPS grew the market share of higher-efficiency ACs from 20% to 55% between 2019 and 2021. Better energy labelling and MEPS are keys to driving progress in other countries, like Thailand, where an AC over 600% efficient can cost the same as one less than 400% efficient.

Beyond efficiency, there are also regional variations in how ACs are used. Average annual energy consumption from AC use in households in Texas, USA is almost six times higher than use in Guangzhou, China, and Hyderabad. If households in India used their AC as much as those in Texas, electricity requirements for cooling would rise from ~400 TWh today to 2,700 TWh in 2050.

Alongside increasing global AC access, behaviours must adapt. For example, significant energy savings can be achieved with minimal impact on health and comfort by setting ACs no lower than 24°C and using them based on actual building temperatures rather than constant use. Some countries have implemented policies to encourage this type of AC use. For example, Belgium has cooling limits of 27°C in public buildings. Beijing deploys 'energy-saving inspectors' to ensure that ACs in commercial buildings (e.g., offices, hotels, malls) are not set below 26°C. The Indian government mandates default AC temperature should not be below 24°C, while Italy imposes fines of €500–3,000 for industrial buildings cooling below 25°C. The Japanese 'Cool Biz' (cool to 28°C) programme encourages dress codes that match varying office temperatures. Another consideration is that ACs contain refrigerants that contribute to global warming if leaked or vented. On average, 2–5% leaks annually and over 90% are vented at end-of-life. Global emissions from refrigerant leakage and venting (from cooling and heating technologies) are estimated at 0.5–1 gigatonnes of carbon dioxide ($GtCO_2$) today, which could rise to 3

($GtCO_2$) in 2050 if the use of high global warming potential refrigerants continues; this is equivalent to 15% of today's annual emissions from buildings. New types of refrigerants can significantly reduce this impact, but proper AC installation, maintenance, and disposal are crucial to avoid increased warming. Policymakers should enforce regulations, incentives, and skills accreditation for proper refrigerant disposal.

The Crucial, and Often Overlooked, Complementary Role of Passive Cooling

Expanding access to air conditioners is vital, but today's reality is that ACs are unaffordable and inaccessible for many households. Currently, 55% of Africa's population (just over 10% of the global population) live in hot climates, yet they account for less than 5% of global cooling energy demand. This becomes even more significant when considering that between now and 2050, nearly half of the world's population growth will be in Africa. It is estimated that by mid-century, more than 40% of the population living in hot climates could still be unable to afford or power AC. Passive cooling methods that are low-cost and low-effort can have a big impact on internal building temperatures and increase the energy efficiency of cooling globally.

Passive cooling techniques minimize heat retention and maximize natural ventilation which reduces the need for active cooling. Techniques include orientating buildings against the sun, using materials and colours that reduce heat absorption, and building designs that balance light (through windows) and shade. Our research shows that global improvements in average AC efficiency combined with passive cooling techniques in new and existing buildings could shrink total energy used to cool buildings by mid-century by almost 50%, from 2,200 TWh to 1,200 TWh.

Reflecting sunlight with white paint on roofs is a cost-effective way to lower indoor temperatures by around 2–4.5°C. In one instance, painting a factory roof white in Indonesia reduced indoor temperatures by 10°C. Cities including New York, Los Angeles, Toronto, and now Hyderabad have launched roof-painting cooling programmes. Hyderabad's cool roof programme targets 300 million m^2 of roof area by 2028 and involves mandatory painting of all public, commercial, and residential building roofs over 500 m^2; government support to paint roofs of social housing; and an outreach and awareness campaign including demonstrations, city-wide advertisement boards, and volunteering programmes to coat rooftops. Jodhpur, Bhopal, Surat, and Ahmedabad have similar cool roof community programmes targeting low-income communities where roofs are commonly made of heat-trapping tin sheets, cement sheets, plastic and tarpaulin. These programmes helped to lower inside temperatures by up to 5°C. Passive cooling techniques, such as external shading (from trees or awnings), reflecting heat, ventilation, and using heat-dissipating materials can theoretically reduce cooling energy needs by 25–40%. If optimal building design is combined with optimal urban design, energy demand reductions could reach as high as 75%.

However, passive cooling solutions vary in cost, ease of installation, and effectiveness. For example, techniques such as designing in natural ventilation and using building materials that are heat reflective are difficult to retrofit. This variability makes it challenging to estimate total possible energy demand reductions. Nevertheless, it is clear that passive cooling solutions can significantly contribute to addressing the global cooling challenge. Unfortunately, these techniques are often ignored today. In many cases, lack of know-how and awareness among developers and weak regulation stand in the way of adoption. Higher-standard building codes and training and awareness programmes for developers could help to realize some of the low-hanging fruit opportunities.

Global Collaboration and Learning: key to decarbonizing and expanding access to cooling

Collaboration and partnerships are vital to meet the rising cooling demand. For example, the UNEP and Rocky Mountain

Institute, are working in partnership with India's Ministry of Housing and Urban Affairs under the Cool Coalition framework, to develop an urban cooling programme for India's cities. They draw from stories and best practices from around the world to deliver local assistance for meeting cooling demand and improving energy efficiency and emissions from cooling. Ensuring access to cooling and managing the resulting energy demand will be two major challenges in the coming decades, but solutions exist and risks can be managed. A single solution will not work for the diversity of local conditions, building types, and people's needs so there is a lot to learn by sharing the diverse suite of existing solutions from across the world and encouraging adoption of solutions at the local level. Successful policies such as the cool roofs programmes, and air-conditioning efficiency standards and labelling demonstrate what is possible. Sharing transition stories and working collaboratively can help achieve healthier lives and a cooler planet.

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Energy Efficiency in India

An Overview and Course to Follow

Kriti Sharma expresses her thoughts on how India needs to remove barriers to scale-up new and additional cleaner sources of energy along with energy-efficiency measures. While lower tariffs have favoured the scaling up of large grid-scale projects, renewables do have hidden costs and other technical issues such as storage, efficiency of infrastructure, amongst others. There is a need for reforms to power market design to better integrate renewables alongside conventional sources of energy used by the country.

Optimizing energy intensity through energy efficiency is an effective way of achieving low-carbon, inclusive and sustainable growth objectives, without impacting the sustained growth trajectory of a resource-constrained country. The decoupling of economic growth from enhanced energy demand is yet to be achieved. It is often attributed to the underlying challenges of energy overuse on the economy and natural environment, on one hand, and the establishment of a regulatory framework for institutionalizing energy efficiency on the other.

India has gained significant ground as far as improving the effectiveness of energy use is concerned and this is clear from the observed decreases in energy intensity of GDP. As per World Energy and Climate Statistics, from 0.126 koe/$15p in 2010 to 0.109 koe/$15p in 2020 and currently standing at 0.105 koe/$15p (2023), India has significant energy efficiency achievements. In India, several energy efficiency policies and measures have been created in recent years including the Energy Conservation Act (2022). These measures incorporate schemes like Standards and Labelling by the Bureau of Energy Efficiency (BEE); Energy Conservation Building Codes (ECBC) by the Ministry of Power; and the UJALA Scheme, among others. However, the demand for the energy sector in the country has been growing at a rapid rate and is expected to grow further in the years to come. As per 20th Electric Power Survey (EPS) Demand projections, India's electricity demand will be doubled by 2030 and is expected to surpass 400 GW mark. The Indian energy sector is one of the most diversified in the world, compared to many developing countries where crude oil and natural gas and renewables play a major role. Sources for energy generation in India range from

conventional sources like coal, lignite, natural gas, oil, hydro, and nuclear power to other viable non-conventional sources like wind, solar, agricultural, and domestic waste. Because of insufficient fuel supply and low-generation capacity, the country has problems of energy shortfalls. As the growth of the economy in general and in the manufacturing sector is largely dependent on the creation of suitable energy infrastructure, the policy focus in India has been on infrastructure and energy investment. Such investment has increased manifold over time with increased private-sector participation in the country.

Challenges

The interaction between domestic energy policy and India's stance on global energy futures is by far underexplored. A more robust approach to domestic energy governance that addresses the persistent domestic problems that revolve around energy security and uncertainties in regulatory framework of the country, might ease the pressure of energy supply constraints and provide new directions for Indian foreign policy on energy and climate change. To follow this approach will require institutional depth, both within government and out of it, besides a more

robust debate on the links between domestic and foreign energy policy, and the complex connections between energy governance, supply security, and climate change. India will need to remove barriers to scale-up new and additional cleaner sources of energy along with energy-efficiency measures. While lower tariffs have favoured the scaling up of large grid-scale projects, renewables do have hidden costs and other technical issues such as storage, efficiency of infrastructure, etc., that need to be addressed. There is a need for reforms to power market design to better integrate renewables alongside conventional sources of energy used by the country. Scaling-up and bringing down storage costs of energy generated by renewable sources can be addressed by the government with a special focus on need-based demands. With the development of a broader range of renewable energy options (e.g., offshore wind, geothermal) to raise load factors and overcome land-use constraints, India can further boost the efficiency of both renewable sources and non-renewable resources. Just by raising the technical efficiency of installations and contract enforcement, the sector could receive a push.

Another drawback of the Indian economy is the lack of a domestic manufacturing sector which will again not only help the renewable sources to attain feasible targets but will have the infrastructure built out for the next three decades. Decisions of the people and governments are influenced by the world's energy economy.

Way Ahead

With rising demand, an increase in energy prices is inevitable. Coupled with depleting natural sources, the sustainability of life is under constant threat. A careful selection of generation methods by demands and regions is a must. Well-co-ordinated policymaking is essential to ensure that different institutions with responsibilities for various aspects of energy policy avoid operating at cross-purposes and synchronize the delivery of different parts of the system (e.g., new power plants with appropriate grid connections, coal supply with rail and port infrastructure, urban planning with provision for public transport). India has an untapped potential of energy savings which will not compromise its economic growth trajectory. By building capacities in technical and financial sectors of energy along with enhanced consumer awareness, India can scale-up its energy efficiency technologies. ■

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A Double Whammy

Conundrum of Energy Transition for Social Transition or for Climate Action or Both?

The article explores the critical role of people-centric, decentralized energy transitions in driving both social change and climate action, particularly in India's aspirational districts. **Anandajit Goswami** argues that while localized energy solutions like solar microgrids can improve livelihoods and reduce local emissions, their global impact on climate change remains limited, requiring a careful balance between development goals and climate commitments.

Is energy transition a necessary condition for social transition and climate action? Energy transition can only be a necessary condition for social transition when it is people-centric and just. Moreover, it will only result in scaling up for climate action if it leads to a marginal change first and then proceed towards radical change thereafter cascading to a transformational change.

For large-scale implementation, initial subsidy support through various business models such as blended finance, public-private partnerships, grant-based models may be required to subsidize 75 per cent of the electricity provision cost for the households and villages. These areas rely on decentralized solar microgrids to meet their lighting needs along with their demand for electricity for dehulling, irrigation, and education. Often the investment subsidy needed to scale up for decentralized microgrid-connected households in off-grid aspirational districts of India can be to the tune of 45 per cent.

Thus, subsidies for decentralized electricity provision can act as a social multiplier, particularly in the aspirational districts of Bihar, Jharkhand, and Uttar Pradesh. The following experience and learning emanate from one of the projects conducted by the Ashoka Centre for People Centric Energy Transition on

clean rural energy transition financing.[1,2]

However, it is undeniable that subsidized decentralized electricity can act as a catalyst for development, lifting villages out of poverty by supporting education, agricultural and horticultural livelihood creation, income generation, safe habitat, improvised primary healthcare services and sanitation conditions. Thereby, a transition to cleaner sources of energy generation through decentralized solar-based microgrids and enabled by various initial subsidy-based financing models

1 Ashoka Website

2 Clean Energy Transition Financing – Is it for Energy or Social Transition? - Pioneer Edge | Uttarakhand News in English | Dehradun News Today| News Uttarakhand | Uttarakhand latest news

comprising blended finance, public and private, philanthropic financing can provide a boost towards social transition.

However, while a subsidy-supported solar microgrid can serve as a necessary causal factor of social transition and change in these locations, it may not be a sufficient enabler driving large-scale climate action. Can such localized shift in the villages of aspirational districts of India significantly reduce global carbon emissions, even though it can affect the local pollution by reducing the carbon emissions from diesel-based pump sets?

Global Impact and Development Priorities

Even at a local level this can be considered as a form of climate action through people-centric energy transition. However, its scaling effects on global emissions may not be significant in terms of overall impact. These small changes can act as nudges towards a larger policy change to create a higher-scale impact of climate action. Local success stories of climate action through people-centric, decentralized clean energy transition can inspire a government to move towards large-scale renewable energy generation targets. Such policy signals can thereby act as levers in international climate negotiations, influencing global climate action. However, changes of this magnitude take time and no such action by developing and least developed countries can be taken at the cost of the development and equity priorities.

In this context, the Economic Survey of India of 2024 raised a critical concern regarding the prioritization process and the order of attainment of India's climate and developmental goals. This year's Economic Survey cited the work of Mike Hulme, stating — "It is quite easy to imagine future worlds in which global temperature can exceed 2°C warming which is 'better' for human well-being, political stability, and ecological integrity; for example, than other worlds in which, by all means and at all costs, global temperature was stabilized at 1.5°C but with political instability and human civilizational damage and ecological disintegrity." [3]

The Economic Survey of 2024, highlighted that prioritizing a strict temperature-bound climate goal of 1.5°C without balancing the developmental costs of such a goal on low-income and developing countries may not be morally ethical. From the perspective of human well-being, political stability, and ecological integrity, such an approach requires careful balance. This concern is further reinforced by Richard Tol's 2024 study, which indicates that the welfare-equivalent income loss due to a 2.5°C warming relative to pre-industrial times is consistently higher for developing countries.

Equity and People-Centric Energy Transition

A focus on income, wealth, equity and distribution goals is equally important for developing countries to create their future resilience to fight the adverse impacts of climate change and global warming. However, a narrow focus on temperature-based climate goals and energy transition can often overlook the equity and distributive justice aspects crucial for developing nations, deviating from people-centric energy transition

3 A balancing act in climate goals - Opinion News | The Financial Express

and climate action goals. A non-aligned, non-holistic approach and a focus on climate action through renewable energy transition may hinder the developmental goals of people in developing countries. As Vaclav Smil (2014) highlights — any transition from one dominant fuel to another, whether at the national, global, or local level is inherently a prolonged process. It might take 50 to 60 years to happen with constant perseverance by generations.[4] A transition from fossil fuels to renewable energy is not an exception.

Moreover, these transitions are often shaped by conflicts and may, whether intentionally or unintentionally, fail to be people centric. A study by Sovacool *et al.* (2022)[5] analysed that clean energy transition in seven carbon-intensive regions in Asia, Europe, and North America. Based on a data set of 130 case studies, the research shows how tactics (such as litigation or protest) can impact outcomes (such as remuneration, policy change, concessions, or labour protections) for different fossil fuels to clean energy transitions like solar, wind, hydro, and nuclear.

Role of Social Enablers and Institutional Responses in Clean Energy Transition

The research highlights the importance of actors, social nudges in terms of tactics like litigations, meetings, protests, and national and international institutional responses to national, supra-national, and global pressures impacting the fossil fuel to clean energy transition. The research through a cultural, sociotechnical, and comparative perspective based on the data of 130 case studies proves that goals of people-centric clean energy transition are often refracted through local, subnational, and national institutions catalysed through local mobilizations which are either in support or opposed to fossil fuel to clean energy transition.

These findings further substantiate Vaclav Smil's work in 2014 and strengthen the need to have strong social enablers and nudges for a clean energy transition in developing countries to happen which are generally time-consuming and can last for 50 to 60 years. However, as countries progress along the gradual pathway, a more strategic approach would be to reduce energy and material consumption in both developing and developed countries. This must be accompanied by the equitable wealth and income distribution between the developed and developing countries and within developing countries. In the long term, such measures can contribute to ecological integrity, political stability, and equity, helping to mitigate the adverse impacts of climate change on poverty and development in the future.

Balancing Degrowth, Energy Transition, and Social Transformation

Ecological integrity can be achieved through Mission LiFE of India, which focuses on reducing energy and material consumption. The degrowth literature suggests that a steady state of economic growth can be maintained by progressively reducing emission intensity, resource, and material consumption in the growth path. On average, India has achieved an economic growth rate of 7–8 per cent, alongside an increase in non-fossil fuel based generation along with an emission growth rate of 4 per cent showing that a country can degrow while simultaneously pursuing economic growth and a people-centric energy transition balancing the goals of climate action.

However, the long-term success of such a path will necessarily be a function of social nudges that progressively reduce energy and material consumption across the production, consumption and demand cycle of economic goods and services. Until this balance is fully realized, the question remains — energy transition for social transition or for climate action or for both? This dilemma will continue to be a double-edged sword for developing and the least developed countries. ■

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4 A balancing act in climate goals - Opinion News | The Financial Express

5 https://www.sciencedirect.com/science/article/pii/S0959378022000115

Accelerating Climate Action

Global Temperature Rise at Record High, Mitigation Falling Behind

Despite making significant strides in renewable energy and setting ambitious targets, India's climate commitments, including its aim for net-zero emissions by 2070, face challenges especially in the wake of energy efficiency and coal dependence. With the urgency to accelerate energy transition and adapt to climate impacts, India's path forward is crucial for both its own sustainability and its leadership in global climate action, **Ankit Todi** writes.

In 2023, global temperatures soared to 1.2°C above the 20th century average of 13.9°C, marking the warmest year since records began in 1850, a milestone that 2024 has already surpassed.[1] The impacts of climate change are becoming increasingly severe, not only through more frequent and widespread extreme climate events but also in everyday life, affecting weather patterns, food inflation, and more. A GlobeScan survey indicates that the percentage of people who feel personally impacted by climate change has risen sharply, from about 31 per cent in 2020 to 45 per cent in 2024 worldwide.[1] Despite global commitments and efforts, the current emission trajectory remains significantly misaligned — currently increasing at 1.5 per cent annually versus the 7 per cent annual reduction required to meet the 1.5°C threshold, underscoring the urgent need for accelerated action.

The climate crisis has severe consequences for the entire world, but it disproportionately affects developing countries like India. As one of the most nature-dependent economies, with 33 per cent of its GDP stemming from sectors such as agriculture, forestry, fisheries, and energy, India faces significant climate risks. Projections suggest that the crisis could further push 50 million people into poverty[2]. Accelerated action is hence essential to safeguard a sustainable, equitable future.

Global and National Efforts

Nationally Determined Contributions (NDCs) are national climate action plans submitted by each country under the Paris Agreement. These plans outline the signatories' climate action objectives, including GHG emission reduction targets and adaptation strategies to achieve these goals. After the original NDCs were submitted in 2015, a second round followed in 2020/2021.[3] The next iteration, referred to as NDCs 3.0, is due in early 2025 and will define countries' intended climate actions through 2035. However, the Global Stocktake, a process to track progress in NDCs reveals that current NDCs account for only about 5 per cent of the emissions reduction needed by 2030, falling significantly short of the 43 per cent required to meet global climate goals.[4] This highlights an urgent need for more ambitious NDCs. Several countries, including the UK and Brazil, recently announced updated NDCs at COP29 in Baku, signalling progress towards stronger commitments.[5]

India, as a developing economy facing significant social and environmental challenges, has demonstrated notable ambition in its climate commitments. Through its updated NDCs and Long-Term Low Emission Development Strategy (LT-LEDS), India aims to achieve net-zero emissions by 2070, establish 500 GW of non-fossil energy capacity by 2030, and reduce the carbon intensity of its economy by 45 per cent from 2005 levels,[6] having commendable goals. Other major emitters have also set ambitious climate goals. China, for instance, targets a 25 per cent share of non-fossil fuels in its primary energy consumption, plans to increase its forest stock volume by 6 billion cubic metres by 2030 compared to 2005 levels and increase installed capacity of wind & solar power to over 1200 GW by 2030 and carbon neutrality by 2060.[7] Meanwhile,

1 US Environmental Protection Agency - National Oceanic and Atmospheric Administration

2 WEF- A third of India's economy relies on nature

3 UN- All about the NDCs

4 WEF Letter to COP29 - Every fraction of a degree counts

5 WEF Blog - COP29: What are NDCs and why do they matter?

6 UNFCC- India's Updated First Nationally Determined Contribution

7 UNFCC- China's Achievements, New Goals and New Measures

the European Union is pursuing an economy-wide net reduction of at least 55 per cent in greenhouse gas emissions by 2030 compared to 1990 levels, with a net-zero target set for 2050.[8] These commitments highlight global efforts to address climate change, though much depends on effective implementation and collaborative progress.

Progress and Milestones: On the Right Track

Despite being the third-largest global emitter of greenhouse gases, India has managed to maintain low per capita emissions — around 2.8 tCO_2e[9] — significantly below the global average of 6.8 tCO_2e. This fact alone underscores the nuances of India's role in global climate discussions – highlighting the challenge of balancing development goals with climate action. However, it is evident that both can progress together.

India has made significant strides in renewable energy (RE). The country has successfully installed around 203 GW of non-fossil fuel-based electricity capacity, accounting for approximately 45 per cent of its total energy mix,[10] placing India fourth globally in terms of renewable energy capacity.[11] Additionally, solar energy has been a shining success for India, positioning the country as the third-largest solar power generator in the world.[12] Ambitious targets in the electric vehicle (EV) sector—like achieving 30 per cent of new vehicle sales from EVs by 2030[13]—show how the country is integrating climate action across industries.

However, as with any large-scale transition, some areas have seen slower progress. India's reliance on coal continues to remain high with coal accounting for 46 per cent of the total energy mix and oil taking up 26 per cent in 2022.[14] While India cannot immediately phase out coal, there is significant potential to improve efficiency in its use. The country is enhancing the efficiency of coal-based power generation by renovating and modernizing older plants, including retrofitting units with advanced technologies to enhance operational efficiency and reduce emissions. Furthermore, India's net-zero target of 2070 lags behind other developing nations like Brazil (2050), and China and Russia (2060), leaving scope for us to be more ambitious. Afforestation is another area where we can ramp up efforts to meet the goal of increasing forest cover for carbon sinks by 2030.

Scope for Improvement: Right Metrics and Annual Reviews

Meeting climate action is primarily driven by energy transition, which has 3 key sub-components: transitioning to renewable energy, focusing on energy efficiency, and increasing electrification. Choosing the right metrics for NDCs at the country level is also essential. For instance, renewable electricity targets should focus on generational share rather than solely installed capacity. This becomes critical since 1 GW of fossil fuel generation capacity and 1 GW of solar or wind generation capacity are not comparable in terms of generated electricity through the year. Similarly, establishing specific benchmarks for energy efficiency, particularly in manufacturing and building sectors, is necessary to track progress effectively. Electrification should not only prioritize the transport sector, which is crucial, but also address other industrial processes in manufacturing and hard-to-abate sectors. Instituting an annual performance review will further help ensure that progress is on track. This will help improve the NDCs for all countries, give clarity to their respective industries and help further accelerate progress.

Conclusion: The Road Ahead for India

Sustainability has always been deeply embedded in India's heritage. For centuries, we have lived in harmony with nature, with eco-conscious practices rooted in our culture and history. This legacy can be carried forward, as reflected in Mission LiFE (Lifestyle for Environment), which promotes collective action and encourages both societal and individual climate-conscious behaviours. Adopting climate-conscious technology and embedding it in our industry will help us move along rapidly. Collaboration among government, private sector and civil society is also essential.

India's climate commitments are robust, and the country is following through with clear actions and policies. However, the journey towards achieving these goals is not without its challenges. India must focus on accelerating all elements of energy transition, particularly energy efficiency in the short-term. As a nation highly vulnerable to the effects of climate change, greater emphasis must now be placed on adaptation strategies. The remainder of this decade will be pivotal. India can emerge as a leader for the developing world in the global fight against climate change. While we are moving in the right direction, we must now accelerate our pace. ■

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9 The Hindu: India needs climate justice, not just targets

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14 Energy System of India

Navigating Jharkhand's Energy Transition

Green Jobs, Technologies, and Sustainable Growth

Jharkhand, a key contributor to India's energy security, faces a transformative shift as the country moves towards its net-zero goals. **Md Tariq Habib** and **Saarthak Khurana** narrate how Jharkhand has the opportunity to lead in green job creation, focusing on renewable energy, clean mobility, and green hydrogen, while addressing social impacts and ensuring an equitable transition.

Jharkhand, a mineral-rich state in Eastern India, has been at the forefront of India's energy security and job creation in mining, transportation, and associated downstream industries. As India embarks on the challenging journey towards achieving its net-zero target of 2070, states like Jharkhand will experience a significant transformation in their economies and industries while balancing energy security and development. Greener sources, especially solar energy, will drive India's energy landscape shift, leading to a gradual decline in dependence on conventional fossil fuel-based energy sources. A decrease in fossil fuel consumption will benefit the environment; however, it can impact the most vulnerable section of the society dependent upon these resources for income & livelihood.

As the concept of Just Transition gains traction worldwide and becomes

increasingly integrated into policy and decision-making, it is essential to focus on creating new green jobs, especially in regions vulnerable to energy transition.

Leveraging Jharkhand's Workforce for a Green Transition

Jharkhand is well-positioned for a just transition, as its economy relies heavily on natural resource extraction with a limited base of advanced, new and emerging technologies. Approximately 60 per cent of Jharkhand's population falls within the 15–59 working age group, matching the national average of nearly two-thirds of Indians in this age bracket. However, unemployment and female participation in the workforce are worse than the national average. A well-planned transition could enable Jharkhand to capitalize on its rising working population, leveraging a demographic dividend. Considering the quantum leap envisaged by the country in new and emerging technologies, Jharkhand could create new green jobs in the state, potentially offsetting the impact on employment in conventional industries.

Estimates suggest that renewable energy in India will generate 54 million green jobs by 2030, with the solar and wind sector alone employing over a million people. Moreover, renewable energy projects generate 7.5 times more full-time jobs/dollars of investment than fossil fuels, as per the Renewable Energy & Jobs Annual Review 2030 of IRENA.

Unlocking Jharkhand's Green Economy: Key Sectors for Job Creation

Considering that Jharkhand lags behind other industrialized states, it could focus on creating the base by 2030 and then use the conducive business environment to develop investments and related job opportunities exponentially. The areas

where Jharkhand could focus to create jobs in the short to medium term are:

a. **Manufacturing of equipment for new and emerging technology**: The value chain and required ecosystem for new and emerging technologies- such as lithium-ion batteries for energy storage applications & mobility, solar panels, power & electric vehicle electronics, etc., are still in the early stages of development in India. Since Jharkhand is the country's largest producer of critical minerals, it could attract investments in integrated mining and manufacturing to reduce the logistics and other associated costs for interested companies.

b. **Clean power generation**: Currently, renewable energy sources concentrate on high-potential sites, with solar generation in the west, wind in the south and west, and hydro in the north and northeast of the country. Although Jharkhand has limited potential for wind and hydro, the state can capitalize on solar power generation. Power distribution companies (DISCOMs) and commercial & industrial (C&I) consumers prefer sourcing solar power from plants in high-irradiation zones in states like Rajasthan, Gujarat, and Maharashtra, benefitting from the current waiver on transmission charges for renewable energy. The sunset clause for this waiver ends in 2025, and imposing transmission and related charges on solar power sourced from these states will eliminate the trade-off between sourcing electricity from high-irradiation centres and generating renewable power near load centres within Jharkhand. This change will enable developers to build new solar projects within the state to meet the demand of Jharkhand and nearby states, including high-paying C&I consumers.

c. Jharkhand could also explore technologies with moderate technological readiness level (TRL) and higher potential closely knitted with its existing strengths, such as coal gasification, usage of end-of-life mines for gravity-based storage, pumped storage hydro, etc. Promoting these technologies now could help Jharkhand achieve a leadership position in the near future.

d. **Clean mobility**: Jharkhand's automobile industry is at the heart

of India's mobility sector, especially in commercial vehicles. Jamshedpur is the largest automobile cluster in eastern India. Approximately 1500 industries exist in the Adityapur industrial hub, with 85 per cent in auto parts manufacturing. Considering India's thrust on EVs and target of achieving 30 per cent of the same by 2030, the state can leverage its automobile experience to create a conducive environment. Creating an environment would require existing manufacturers to diversify into EV components and attract new manufacturers focused on EVs. A few initial steps could be a comprehensive EV manufacturing policy with additional perks such as dedicated land banks, financial/tax incentives, and capacity building.

e. **Green molecules**: Jharkhand produces nearly a quarter of the total steel produced in the country. Cities such as Bokaro and Jamshedpur depend almost entirely on steel production and related industries. The iron and steel industry, often called 'hard-to-abate' sectors owing to its processes being dependent upon coking coal for production, is increasingly looking towards green hydrogen to decarbonize the widely used BF-BOF route. The producers would need to shift to alternative technologies, including the ones using green hydrogen, considering regulations (CBAM, IRA, etc.) in target markets, green public procurement standards, and increasing demand for green steel by large downstream industries such as automobile manufacturers (Mercedes-Benz, Volkswagen, etc.). The state can widely benefit from the economy-wide decarbonization front and job creation by creating an enabling ecosystem to produce green hydrogen as a feedstock for these plants.

f. While these are broad areas where the state could focus, a few systematic actions on the part of the Government would be required, such as setting up a green skills training centre focusing on reskilling and upskilling the existing workforce, fostering collaboration between industry and academia, facilitating investments, and revising industrial policy to green industrial policy, amongst others. ■

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Navigating Gender and Climate Challenges

The Case for Gender-Responsive Budget in India

Alarming statistical evidence of women bearing the brunt of skewed social and gender dynamics, especially in the event a disaster strikes, calls for a change in the status quo. In this article, **Priya** and **Neha Khanna** advocate for gender-responsive climate budgeting in India to empower women, ensure climate resilience, and meet both gender equality and climate action goals.

Climate change disproportionately impacts women, particularly in rural areas where they bear responsibility for food security, household income, and livestock care. Rising temperatures and erratic rainfall force women to work harder, walk farther, and spend more time gathering essentials like food, water, and fodder. The farther they walk, the more exposed they are to significant risks of gender-based violence and adverse health risks. Women, often the poorest and most marginalized, face limited access to essential services including clean cooking facilities and potable water due to limited resources and decision-making power impacting their health. They are also at higher risk of mortality during extreme weather events; according to UNDP, women and children are 14 times more likely to die than men. Moreover, 4 out of 5 people displaced by climate change are women and girls, with disasters disrupting vital services like sexual and reproductive healthcare.

These differentiated vulnerabilities underline an urgent need for gender-responsive climate budgeting to ensure that climate action addresses systemic gender inequalities along with environmental challenges. By integrating gender considerations into climate budgets, governments can allocate resources more equitably, empower women, and mitigate the disproportionate burdens they face due to climate change. This is imperative for fostering both climate resilience and gender equality.

Integrating gender into the climate budget of India, however, is challenging on two fronts. One is the scarcity of empirical evidence on gender-differentiated impacts of climate change in India. Second, there is a lack of a holistic climate budget at the union level and varying methodologies to prepare climate/green budgets at sub-national levels.

Challenges in Integrating Gender into India's Climate Budget

Although data on the gender impacts of climate change is scarce, first-hand accounts of survivors extreme climate events shed some light on the precarious situations faced by women. A report by Dialogue Earth revealed the increased instances of violence against women (domestic violence, human trafficking, increased preferences for male children, and sexual harassment) in flood relief camps after the devastating floods in Bihar in 2017. Similarly, a 2020 study highlighted a surge in domestic as well as intimate partner violence following the deadly 2004 tsunami in four Indian states—Andhra Pradesh, Karnataka, Kerala, and Tamil Nadu. In Denganmal

village, Maharashtra, water scarcity has led to the emergence of a polygamous family structure, where men marry multiple women known as water wives — one wife manages the household, while others are responsible for securing water. India has made concerted efforts to address gender vulnerability and climate change, but these efforts largely operate in silos. The Government of India has included a gender budget statement as part of its Union Budget since 2005–06, while international commitments primarily drive climate action, forming the foundation for national-level action plans and strategies. These efforts have their shortcomings. The gender budget statement is merely an accounting exercise to track how much finance was allocated and spent under women-specific programmes. Gender budgeting, in its true sense, must entail assessing different impacts of all the schemes and programmes

on women, including aspects such as wage structure, workplace facilities, health and well-being, and women's participation patterns in the workforce. The lack of a climate budget at the Union level makes it difficult to track how many resources have been dedicated to climate action and measure the impact. Non-governmental institutions have attempted to fill this void with their estimates of requirements and finance flows to climate action, but methodological differences render such estimates incomparable. None of these estimates consider the nexus of gender and climate action. The states in India have taken lead in the preparation of a climate/green budget. Still, since each state uses different taxonomy and methodology, the allocations and expenditures on climate concerns are incomparable. Moreover, these documents are largely silent on gender.

Gender-Responsive Climate Budgeting for a Sustainable Future

Gender-responsive climate budgeting is essential for India to achieve its commitment to Sustainable Development Goals (SDGs), nationally determined contributions (NDCs), adaptation goals, and just energy transition. The framework will directly address SDGs on gender equality (SDG 5), climate action (SDG 13), life on land (SDG 15), and life below water (SDG 14). In contrast, it will indirectly address SDGs on poverty (SDG 1), inequality (SDG 10), and peace and justice (SDG 16). The framework will also address NDCs related to adaptation (NDC 6) and the mobilization of financial resources (NDC 7). The mandate to mainstream gender in climate action also comes from international frameworks in the form of technical guide for mainstreaming gender into climate action, Lima Work Programme on Gender, and the Gender Action Plan.

Kenya has taken significant steps to integrate gender into climate action. It submitted its progress in implementing the gender action plan for the Lima Work Programme. The Government of Indonesia, in partnership with UNDP, has released a handbook on gender-responsive climate budgeting in Indonesia. The Collaborative Africa Budget Reform Initiative (CABRI), the International Institute for Environment and Development (IIED), the International Budget Partnerships (IBP), and UNDP jointly have launched Inclusive Budgeting and Financing for Climate Change in Africa (IBFCCA), engaging with over 20 African nations on strengthening gender-responsive climate budgeting—these efforts, although in the nascent stage, are gaining momentum.

Challenges and Way Forward

The path to gender-responsive climate budgeting is a long and a complex one, but India must eventually adopt it to achieve climate resilience and gender equality. There would be challenges relating to lack of data availability, limited institutional capacity, and management of expectations of many stakeholders to the budgeting process. It is time to anticipate such challenges and promptly address them. India should leverage its partnerships with policy research institutions to gather empirical evidence on the gendered impact of climate change and the development of institutional capacity. It must also leverage its partnerships with multilateral organizations and institutions in Africa and Indonesia to learn from their initial experiences. Until fully-fledged gender-responsive climate budgeting is adopted, monitoring climate actions and initiatives based on gender-specific indicators is imperative. Understanding the nexus of climate action and gender would be a significant step towards developing an inclusive society.

In conclusion, while the Government of India has made commendable strides in promoting transparency and accountability through gender and climate-focused measures, the convergence of these efforts remains essential for maximizing their impact. By integrating gender considerations into climate budgets and monitoring initiatives with gender-specific indicators, India can build a more inclusive and equitable society. Embracing this framework will fulfil international commitments and pave the way for a sustainable future where gender equality and climate resilience are at the forefront of development priorities. ■

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The Nuclear Renaissance in India

Strategy for Clean and Reliable Energy Transition

With the role of nuclear-based energy in achieving net-zero energy emissions growing and technological advancements in the clean energy gaining momentum, all roads lead towards sustainable future in the energy sector. **K Ramanathan, Venkittu Sundaram** and **Dr Arunendra Kumar Tiwari** pen down their thoughts on why nuclear power is making its way back in India, the factors conducive for it and the big boom which it might see in the coming years.

The role of nuclear energy in achieving net-zero energy emission targets is gaining prominence globally. This is reflected in the resurgence of nuclear-based power in many countries, including India. Technological advancements, policy support, rapidly growing demand, and the associated alarming changes in the climate are driving this transition, besides a conducive international environment. At the COP28, held in Dubai in December 2023, it was officially endorsed that the role of nuclear energy is critical for reducing the effects of climate change and 22 countries were signatories to the 'Declaration to Triple Nuclear Energy by 2050'.[1] At the Nuclear Energy Summit held in Brussels in March 2024, India conveyed its ambition to triple nuclear power production by 2030, as a part of its commitment to expand clean energy.[2]

India already made a head start to the development of nuclear energy and progressed significantly in technology and human resources development. The country has one of the largest deposits of thorium in the world, a potential fuel source for nuclear power, and is poised well to move ahead on the nuclear route. The road is, however, not all rosy; challenges are to be met on many fronts — technological, geopolitical, financial, and policy related.

Drivers of Nuclear Power in India

The demand for clean and reliable energy is increasing rapidly in India, driven by accelerated economic growth, growing aspiration of the population, digitization of the economy, initiatives such as Make in India, etc. This calls for a needs-based expansion of the energy basket focusing on clean energy resources and ensuring requisite energy security and reliability. India has set an ambitious target of having a non-fossil energy capacity of 500 GW by 2030 and net-zero emissions by 2070. Towards this objective, there have been substantial additions to the renewable energy capacity, especially solar and wind. However, solar and wind being intrinsically variable and intermittent (VRE), would not alone be able to provide base load support

1 At COP28, countries launch declaration to triple nuclear energy capacity by 2050, recognizing the key role of nuclear energy in reaching net zero. (2023, December 1). https://www.energy.gov/articles/cop28-countries-launch-declaration-triple-nuclear-energy-capacity-2050-recognizing-key

2 India's statement at Nuclear Energy Summit Brussels 2024 | Department of Atomic Energy | India. (n.d.). https://dae.gov.in/indias-statement-at-nuclear-energy-summit-brussels-2024/

and ensure the required level of grid security and affordability of consumer electricity. Land availability, storage requirements, biodegradability of lithium-based batteries, transmission capacity utilization, and distribution adequacy power quality issues, etc., are also concerns as the VRE shares go up.[3]

Nuclear power is a relatively cleaner source of stable energy and recent technological advancements are making it potentially cost-effective and safe. It can also facilitate large-scale integration of VRE. Another factor is that the country has one of the largest thorium reserves in the world, which can be used for power generation along with a little uranium, thus helping to achieve energy independence and security. This is possible due to enhanced safety, reduced waste management requirements and nuclear proliferation risks as compared to uranium-based ones.

Nuclear Power Development in India

India has been working in the field of nuclear energy technology for over 60 years and has achieved significant progress in technology, fuel use efficiency, and human resources development. Several organizations like DAE, IGCAR, NPCIL, AMD, AERB and BARC have played a major role in this.[4] As of November 2024, 24 nuclear reactors with a total installed capacity of 8,180 MWe have been operationalized. 11 more reactors are under construction with a total capacity of 8,700 MWe. The government has also given administrative approval for 10 more indigenous 700 MWe Pressurized Heavy Water Reactors (PHWRs) to be built in fleet mode.[5] There are plans to expand capacity to 22 GWe by 2031.[6] The recent commissioning of the prototype 500 MWe Fast Breeder Reactor (FBR) in Kalpakkam (as part of its FBR programme) through indigenous design and construction is another major achievement. The plant has active and passive safety systems, passive cooling system could operate without personnel input and no power supply. Multiple diagnostic systems are also provided for permanent monitoring during operation to detect possible abnormalities in the early stage.[7] This will eventually help utilize the country's vast thorium reserves. It is possible that thorium-based nuclear power could meet up to 30 per cent of India's electricity demand by 2050, according to certain assessments. Yet another noteworthy achievement is the development of Bharat Small Reactors (BSRs), which will help faster deployment and reduce costs. These compact reactors are especially suited for powering remote areas and industrial hubs, including decarbonization of the hard-to-abate sectors.

India has also been focusing on fuel use efficiency, with High Assay Low Enriched Uranium (HALEU) as an example. Recently, NTPC entered a strategic partnership with US-based Clean Core Thorium Energy (CCTE) to explore the development and deployment of "ANEEL™" (Advanced Nuclear Energy for Enriched Life) fuel for PHWRs. This ground-breaking[8] initiative is subject to approval from the respective governments.

Some of the Recent Encouraging Developments

Recent announcements by the government have instilled added

3 NREL, 2013, Integrating Variable Renewable Energy: Challenges and Solutions, https://www.nrel.gov/docs/fy13osti/60451.pdf

4 About DAE | Department of Atomic Energy | India. (n.d.). https://dae.gov.in/about-dae/#:~:text=These%20developments%20called%20for%20an,power%20applications%20of%20atomic%20energy.&text=The%20Department%20has%20the%20mandate,processing%20of%20uranium%20resources%20and

5 GOVERNMENT OF INDIA, DEPARTMENT OF ATOMIC ENERGY, LOK SABHA, UNSTARRED QUESTION NO- 310
ANSWERED ON 27/11/2024, https://cdnbbsr.s3waas.gov.in/s35b8e4fd39d9786228649a8a8bec4e008/uploads/2024/11/20241129306759069.pdf

6 India's installed nuclear power capacity to triple by 2031-32: Union Minister Dr. Jitendra Singh. (n.d.). https://pib.gov.in/PressReleasePage.aspx?PRID=2037046

7 PM witnesses the historic "Commencement of Core Loading" at India's first indigenous Fast Breeder Reactor (500 MWe) at Kalpakkam, Tamil Nadu. (n.d.). https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2011347

8 Csr, I. (2024, December 28). NTPC and CCTE advance Thorium-Based ANEEL Fuel for Nuclear Energy i India CSR. India CSR. https://indiacsr.in/ntpc-and-ccte-advance-thorium-based-aneel-fuel-for-nuclear-energy/

momentum to India's nuclear programme. In her last year's budget speech, the finance minister said, "Nuclear energy is expected to form a very significant part of the energy mix of Viksit Bharat. Our government will partner with private firms to set up Bharat Small Reactors (BSRs), conduct research and development on Small Modular Reactors (SMRs), and explore newer technologies for nuclear energy." This year's budget had proposed setting up a Nuclear Energy Mission to promote research, and development of SMRs with an outlay of INR20,000 crore, and changes in Atomic Energy Act and Civil Liability for Nuclear Damage Act for greater private participation.

As a follow-up to this, the government has already approved a joint venture of NTPC's JV company with NPCIL for taking up nuclear power generation.[9]

Interests in setting up nuclear power plants to achieve their net-zero targets are also seen at the state level. Kerala is one example where government officials are discussing setting up BSRs in the state and utilizing its thorium resources with the Union Power Ministry.[10] NTPC has recently announced plans for a nuclear power project in Bihar and has requested land from the state government and permission to conduct feasibility studies.[11] NPCIL has also recently opened the door to the nuclear sector for Indian private firms with certain caveats.[12] Hard-to-abate industries like cement and steel and big tech firms like Google, Amazon, and Microsoft are also showing interest in nuclear power as a stable 24X7 power supply alternative.

International and Bilateral Cooperation

India is also strengthening its nuclear capabilities through international collaborations with the International Atomic Energy Agency (IAEA) and countries like Russia, the USA, and France. India is also a member of the 35-member collaborative effort project — the International Thermonuclear Experimental Reactor (ITER), for advancing magnetic fusion. Prospects of bilateral collaborations are also increasing with India and Russia exploring further avenues for

9 Market, C. (2024, September 18). NTPC's JV company with NPCIL gets govt nod for taking up nuclear power generation. www.business-standard.com. https://www.business-standard.com/markets/capital-market-news/ntpc-s-jv-company-with-npcil-gets-govt-nod-for-taking-up-nuclear-power-generation-124091800533_1.html

10 India Today. (2024, December 24). Kerala looks at nuclear power to address state's electricity demands? India Today. https://www.indiatoday.in/india/kerala/story/kerala-eyes-thorium-potential-nuclear-power-during-centre-state-energy-talks-2654609-2024-12-24

11 ETMarkets.com. (2024, December 20). NTPC shares in focus as company plans nuclear project in Bihar. The Economic Times. https://economictimes.indiatimes.com/markets/stocks/news/ntpc-shares-in-focus-as-company-plans-nuclear-project-in-bihar/articleshow/116488636.cms?from=mdr

12 Kalyan Ray, & Kalyan Ray. (2024, December 31). For the first time, NPCIL opens door to nuclear sector for Indian private firms. Deccan Herald. https://www.deccanherald.com/india/for-the-first-time-npcil-opens-door-to-nuclear-sector-for-indian-private-firms-3337668

collaboration;[13] India and France have plan to launch a cooperation programme on SMRs and advanced modular reactors. President of the World Nuclear Exhibition (WNE), Sylvia Bermann has recently acknowledged India's nuclear supply chain as 'an asset not only for the country but for the world' and has sought the country's participation in WNE 25.[14]

Challenges in Moving Forward

In the past, the relatively long gestation periods for regulatory approvals and construction, high capital investment required for the construction, maintenance, and eventual decommissioning, safety of waste disposal, import of uranium, potential radiation and health, and risk of proliferation of fuel have been major deterrents in moving forward. These are getting eased out with the developments on the technological front (including the recent discovery of substantial deposits of uranium around the existing Jaduguda mines[15]), and improvements in monitoring, protection, and safety features. Public apprehension about human safety concerns and environmental impacts remains a tough challenge. High-profile nuclear disasters like Chernobyl (1986) and Fukushima (2011) have heightened fears in this regard and are influencing public opinion. This is, despite the fact that Indian nuclear plants adhere to stringent safety standards set by the Atomic Energy Regulatory Board (AERB) and also have IAEA guidance.[16]

Land acquisition is another significant challenge. Securing suitable sites for nuclear plants often encounters resistance from local communities concerned about displacement, environmental impacts, and safety risks. These obstacles, however, unique to nuclear projects only, are seen in varying degrees in other infrastructure projects too.

Way Forward: Some Suggestions

India is looking at the resurgence of nuclear-based energy and keeping up the momentum would be imperative to achieve the country's vision to achieve decarbonization of the energy sector before 2070. There is a need for a pragmatic roadmap for capacity building, which should include both large-sized reactors (that can help in accelerating the capacity addition), and small, modular reactors. Standardizing and easing regulatory approvals would be important and R&D efforts must focus on improving fuel use efficiency and waste disposal, mitigating risks of radiation hazards, etc. Accelerating the mining and utilization of thorium, coupled with policy support from the government, would be critical. Additionally, fostering bilateral and international collaborations and exploring innovative financial mechanisms for nuclear power development are essential to drive progress in the sector. High priority should be given to public outreach programmes and community engagement. These can help assuage concerns regarding safety and health hazards. The media along with R&D organizations and academia can play a key role in this. There should be a progressive introduction of private sector participation (as recently proposed by NPCIL) along with JVs, with foremost consideration of national interests. These could help in mobilizing finances and in technology transfer. ■

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13 Siddiqui, H. (2024, November 29). India-Russia strengthen nuclear cooperation: Key visit fosters energy collaboration. Financial Express. https://www.financialexpress.com/business/defence-india-russia-strengthen-nuclear-cooperation-key-visit-fosters-energy-collaboration-3680143/

14 "I want to have strong representation of India at World Nuclear Exhibition 2025": Former envoy Bermann. (2024, November 22). ANI News. https://www.aninews.in/news/world/asia/i-want-to-have-strong-representation-of-india-at-world-nuclear-exhibition-2025-sylvie-bermann20241122163930/

15 Indigenous Nuclear Reactors Achieve Milestones: Kakrapar and Rawatbhata PHWRs Begin Commercial Operations – Indian Defence Research Wing

16 AEA mission concludes peer review of India's nuclear regulatory framework. (n.d.). IAEA. https://www.iaea.org/newscenter/pressreleases/iaea-mission-concludes-peer-review-indias-nuclear-regulatory-framework

Rural-Urban Migration and Climate Change

Necessity of Urban Planning in Indian Cities

India's rapid urbanization, driven by rural-to-urban migration, has led to significant socio-economic challenges, with almost half of urban dwellers living in slums. Climate change, resource scarcity, and environmental degradation exacerbate these issues, putting pressure on cities' infrastructure and health systems, **Chetana Chaudhuri** and **Amit Mitra** write.

Between 2011 and 2021, India's urban population grew by 27 per cent, with rural-to-urban migration accounting for a significant portion of this increase. As migrants flock into cities, the urban demographic landscape is undergoing dramatic shifts. According to the 2024 World Population Review, Delhi's population grew from 22.7 million in 2011 to 31.2 million in 2021, with a significant proportion of this increase attributed to migration. Similarly, Bengaluru and Hyderabad recorded migration rates of 43 per cent and 39 per cent, respectively, during the same period. However, this rapid urbanization has not translated into equitable living standards. As of 2022, over 41 per cent of the Indian urban population lived in slums, and this figure is expected to rise sharply as migration accelerates. These slums often lack basic amenities, with over 40 per cent of residents lacking access to clean water and 60 per cent living without proper sanitation facilities. The human cost of migration is staggering, with health issues such as waterborne diseases and respiratory illnesses rising by 23 per cent in urban slum populations between 2015 and 2022 (Krishna & Raj, 2022).

Migration and climate change are closely linked. The reasons for migration are not solely limited to climate impacts, such as rising sea levels and extreme weather, but also include displacement due to livelihood challenges caused by droughts, frequent flooding, land degradation, food insecurity, and resource scarcity. On the other hand, cities are facing environmental, social, and economic challenges due to this influx. Cities like Delhi, Mumbai, and Chennai experience amplified temperatures due to dense infrastructure and limited greenery. Increased heatwaves are leading to heat-related illnesses and fatalities, especially among vulnerable populations. Higher temperatures are driving up energy consumption for cooling, straining resources and increasing greenhouse gas emissions. Urban growth, combined with the mismanagement of water resources, has also led to water shortages in cities like Bengaluru and Delhi. Rising temperatures exacerbate air pollution by intensifying ground-level ozone formation, aggravating respiratory and cardiovascular issues. Despite these challenges, there continues to be a significant influx of migrants into Indian cities every year. Urgent action is required to build resilience against these impacts and to balance development with sustainability.

Rural-Urban Migration Trends in India

According to the PLFS Report on Migration in India (2020–21), 28.9 per cent of India's population are migrants. In rural areas, the migration rate is 26.5 per cent, while in urban areas it is staggeringly high at 34.9 per cent. This means that for every 10 people in urban areas, around 4 are migrants. Of the urban migrants, 54.4 per cent have migrated from rural areas. Among the migrated workers, 34 per cent of male migrants and 16 per cent of female migrants have moved from rural to urban areas (Figure 1). Notably, 63 per cent of female migrants relocated due to marriage, contributing to more rural-to-rural migration among women. However, 57 per cent of male migrants in urban areas reported migration due to employment-related reasons, including searching for better job opportunities, proximity to workplaces, and job loss or lack of employment opportunities (Figure 2). Additionally, 21 per cent of male migrants and 19 per cent of female migrants relocated due to the migration of parents. Although less than 1 per cent of migration is driven by extreme events like natural disasters, a significant portion of migration is driven by the lack of livelihood opportunities, which can often be attributed to climate impacts.

The 2021 PLFS report highlights that 67 per cent of migrants were excluded from welfare programmes due to the absence of local identity documents. Urban planning has struggled to keep pace with this influx. In Delhi, for instance, the urban housing shortage stood at 1.1 million units in 2022, forcing many migrants to live in hazardous conditions. Meanwhile, peri-urban areas—villages on the fringes of cities—are witnessing haphazard development as they absorb overflow populations without adequate infrastructure. These zones, which housed 35 per cent of India's urban migrants in 2021, are emerging as hotspots of socio-economic inequality.

Challenges for Indian Cities

Economic challenges compound the problem. Migrants often take up precarious jobs in the informal sector, which employs over 90 per cent of India's workforce. A study by Srivastava and Sutradhar (2016) revealed that the construction sector absorbed 36 per cent of migrant workers, yet wages in the sector remained stagnant, averaging just INR300 per day. Meanwhile, rural regions suffer from the outflow of skilled labour. Bihar, one of the states most affected by migration, saw a 15 per cent decline in agricultural output over the last decade as young, able-bodied individuals left in search of better opportunities. This demographic imbalance is creating pockets of aging rural populations, intensifying economic stagnation and social vulnerability in these areas.

The environmental implications of urban sprawl are equally alarming. The loss of green cover in cities like Bengaluru and Chennai has accelerated, with Bengaluru losing 4 per cent of its vegetation cover between 2006 and 2019. Urban water bodies, essential for sustainable urban living, are also under threat. Anna University projects that by 2030, around 60 per cent of the city's groundwater will be critically degraded, partly due to the growing demand from its expanding migrant population.

Cities also face significant climate change challenges, including urban heat islands, increased flooding from sea-level rise and heavy rainfall, and air pollution that harms public health. For instance, the 2023 floods in Delhi

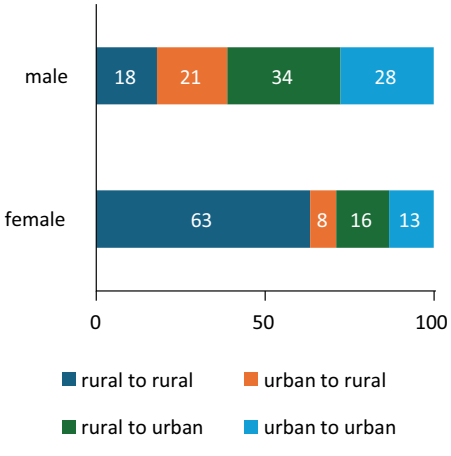

Figure 1: Distribution of migration stream (%)

Source: Migration in India 2020-21

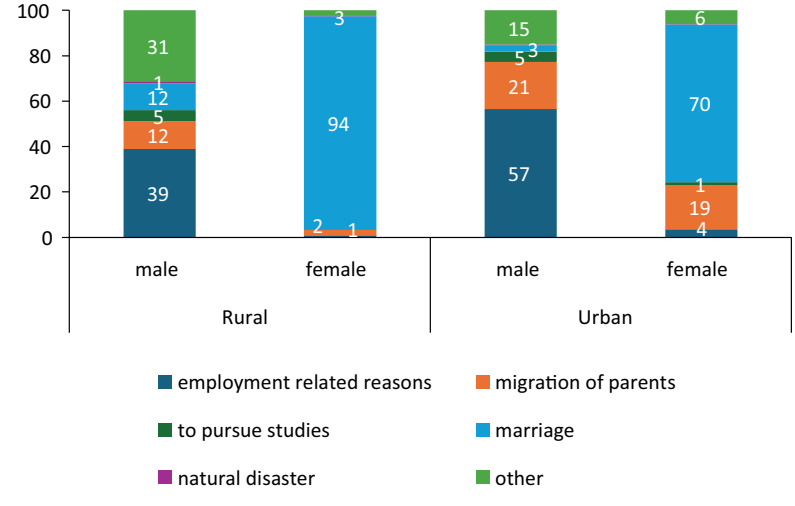

Figure 2: Reasons of migration (%)

caused the inundation of 5 districts, with 35,000 residents having to be evacuated. Water scarcity, extreme weather, and rising energy demands continue to strain resources and infrastructure, while disruptions to food supply chains threaten food security. Vulnerable populations, particularly those living in informal settlements, are disproportionately affected, exacerbating urban inequality. Poor waste management further contributes to greenhouse gas emissions, and urban expansion leads to biodiversity loss. To address these issues, cities must adopt climate-resilient infrastructure, sustainable planning, and policies aimed at reducing emissions and protecting vulnerable communities.

Role of Urban Planning in Managing Migration and Building Resilience

Migration presents both challenges and opportunities for urban planning, particularly in the areas of housing, infrastructure, and social integration (Ray et al., 2020). Increased migration often leads to the growth of informal settlements, a higher demand for affordable housing, and pressure on public services and transportation systems. Urban planners must also address economic integration by creating job opportunities and promoting sustainable planning practices to manage growth and the environmental impact of expanding cities. Effective urban planning should focus on designing sustainable, efficient, and resilient cities (Table 1).

Table 1: Key areas of urban planning

Approach	Areas of emphasis for urban planning and design
Integrated Planning Approaches	Emphasis on holistic urban planning combining land use, transportation, energy, water, and waste management. Collaboration among stakeholders, including governments, private sectors, and communities
Sustainable Infrastructure Development	Promotion of green building practices, renewable energy systems, and efficient transportation networks. Guidance on using existing infrastructure to enhance sustainability.
Resilience and Climate Adaptation	Strategies for mitigation and adaptation of climate change impacts, like heatwaves, flooding, and resource scarcity Promotion of nature-based solutions like urban forests and wetlands
Economic and Social Inclusion	Policies to ensure equitable access to housing, services, and economic opportunities. Programmes to empower marginalized communities and integrate them into urban development plans.
Governance and Policy Frameworks	Supportive legal and institutional frameworks Tools for monitoring and evaluating the success of sustainability initiatives
Innovative Financing Mechanisms	Approaches to funding sustainable urban projects, such as public-private partnerships, green bonds, and international development funds, etc.
Technology and Data-Driven Solutions	Use of smart technologies and data analytics to improve urban management and decision-making Deployment of digital tools for citizen engagement and service delivery

Source: Handbook of Sustainable Urban Development Strategies

Sustainable urban planning promotes adaptation and contributes to mitigation efforts. A significant reduction in carbon emissions from transportation can be achieved through effective urban design. Policies and planning should focus on promoting public transit,

constructing cycling paths and walkways to reduce transportation emissions, implementing energy-efficient buildings and renewable energy systems, and creating green infrastructure, such as parks and green roofs, to combat urban heat and sequester carbon. It should also emphasize the preservation of natural areas, sustainable waste management practices, and community engagement to raise awareness about these issues.

Implementing sustainable urban planning is challenging due to rapid, unplanned growth, inadequate

infrastructure, and high resource demand in cities—issues further exacerbated by social inequities and resistance to sustainable practices. Addressing these problems requires integrated policies, enhanced funding, capacity-building, and community engagement to create low-carbon, sustainable cities. Strengthening governance, enforcing regulations, and leveraging technology, such as GIS and digital platforms, can ensure the effective implementation of these strategies. However, these policies should also be accompanied by efforts to promote balanced regional development and job opportunities in rural areas to ensure long-term sustainability

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Building Smart in the Himalayas

Sustainable Design Lessons from Sikkim

Sikkim's innovative building designs offer valuable insights into sustainable construction in cold climates. **Priyanka Kochhar** explains how projects like Khangchendzonga State University and Vrindavan Dham eco-tourism complex combine traditional knowledge with modern technology to create energy-efficient, comfortable spaces.

As climate change continues to challenge construction practices worldwide, Sikkim, a northeastern state in India, offers innovative solutions for sustainable building in cold climates. These solutions are particularly relevant to the Hindu Kush Himalayan region, where temperatures can drop below freezing, and terrain conditions challenge conventional construction methods.

Design for Cold Climates

The Himalayan region poses unique challenges for architects and builders, especially in areas where the weather is harsh, and the terrain is rugged.

Two significant projects in Sikkim — Khangchendzonga State University and the Vrindavan Dham eco-tourism complex — showcase how thoughtful design can create comfortable, energy-efficient buildings that blend traditional wisdom with modern technology.

Innovative Building Features

The buildings incorporate several key features that work with natural conditions rather than against them.

Heat-Smart Surfaces: Roads and pathways are paved with black tar felt, which absorbs heat during the day and releases it slowly at night. Similarly, thick concrete walls with gravel panels act as thermal batteries, storing warmth for later use.

Windows Designed for Efficiency: A carefully designed window-to-wall ratio of 20–30 per cent ensures natural light without excessive heat loss. The special glass chosen for windows balances light transmission and heat retention.

Water Management: Leveraging glacier water and utilizing small canals around buildings to manage water flow, these projects combine modern water treatment systems with traditional water management techniques.

Technology Meets Tradition

These projects seamlessly integrate traditional knowledge with modern technologies. Heat pumps replace conventional heaters, and ventilation systems have been designed to provide fresh air while minimizing heat loss. The use of local materials further supports sustainability.

The lessons from Sikkim's sustainable building practices are not just relevant for India but for other regions worldwide facing similar challenges. The approaches used in these projects could be especially beneficial for neighbouring countries like Bhutan, which shares similar geographical and climatic conditions.

Policy Pathways for Sustainable Building

To scale these sustainable building solutions across the Hindu Kush Himalayan region, several key policy recommendations can be looked at.

Building Codes and Standards: Region-specific building codes should be developed that focus on thermal performance and passive solar design for cold climates.

Material Standards: Guidelines for locally sourced materials and thermal insulation should be established.

Financial Incentives: Tax incentives, subsidies for green heating/cooling systems, and financing schemes for mountain regions can help promote sustainable building practices.

Capacity Building: Training programmes for architects and builders on cold-climate design and sustainable building practices should be implemented.

The success of these projects proves that sustainable buildings in cold climates are both technically feasible and economically viable. By adopting supportive policies and practices, governments can accelerate the transition to energy-efficient, climate-resilient infrastructure in mountain regions.

Key Takeaways

There are several takeaways from building sustainably in the region. These include focusing on passive design elements that reduce energy needs. Locally available materials can be utilized in innovative way along with implementation of water management systems. Amalgamation of traditional knowledge and modern technology and designing buildings for year-round comfort can be the key. Creation of supportive policy frameworks for sustainable building practices and investment in capacity building and knowledge sharing is another important enabler for sustainable building.These insights from Sikkim offer a roadmap for sustainable infrastructure development in challenging environments. They demonstrate that with appropriate policies, careful planning, and innovative design, we can create buildings that are both comfortable and environmentally responsible.

The success of these projects, supported by enabling policies, suggests a promising path forward for sustainable development in mountainous regions. As climate change continues to pose new challenges, such adaptive and resourceful approaches to building design become increasingly vital. ■

Priyanka Kochhar is the Chief Executive Officer of The Habitat Emprise. This article is based on implementation data from projects by The Habitat Emprise in Sikkim, India.

Bio-Input Resource Centres

Scaling Sustainable Agriculture in India

Aimed at providing farmers with locally prepared, cost-effective, and environmentally friendly bio-inputs as alternatives to chemical fertilizers; BRCs are emerging as crucial components in promoting sustainable agriculture in India. While the government has announced support for BRCs under the National Mission on Natural Farming, challenges such as lack of standardization, short shelf life, and financial sustainability must be addressed, **Shweta Nikam** reports.

The concept of Bio-Input Resource Centres (BRCs) has gained prominence in India with the Central Government's announcement of establishing 10,000 BRCs under the National Mission on Natural Farming (NMNF). These centres are seen as key factors in transitioning towards sustainable agriculture, especially in promoting the use of bio-inputs. However, to fully understand how BRCs can help scale up sustainable farming, it is crucial to address the challenges they face.

Need for Bio-Inputs in Sustainable Agriculture

One of the primary obstacles to scaling sustainable agriculture is limited access to bio-inputs. In 2023–24, agricultural subsidies in India amounted to INR4051.56 billion, with chemical fertilizers accounting for 43.2 per cent of this total. By popularizing bio-inputs among farmers, a portion of these subsidies can be redirected towards supporting more sustainable farming practices. This would, in turn, benefit the environment by reducing the damage caused by conventional chemical agriculture.

What is a Bio-Input Resource Centre (BRC)?

A BRC is a facility where locally prepared bio-inputs — such as *Jeevamruth, Panchgavya, Neemastra,* and others— are made available to farmers. These bio-inputs are created using natural ingredients like cow dung, plant leaves, ginger, garlic, and other locally available materials. Preparation methods often include fermentation, boiling, grinding, and soaking, and the final products are stored in simple containers such as plastic bottles or earthen pots. BRCs aim to make bio-inputs accessible, affordable, and convenient for farmers, serving as a sustainable alternative to chemical fertilizers.

BRCs come in various forms, including individual, community-based, and cattle shelter (*gaushala*) models. The individual model prepares bio-inputs on a small scale for specific farmer needs, while the community-based model centralizes the preparation, sale, and sometimes decentralizes production. Key factors for a successful BRC include understanding local crop patterns, ensuring a year-round supply of bio-inputs, proper storage, pricing strategies, and labour management. The government has

announced INR1 lakh in support per BRC for initial setup, but several challenges remain in making them truly impactful.

Challenges Faced by BRCs

BRCs face several challenges, these include challenges with standardization, shelf life, storage, and finance.

Lack of Standardization: There is no uniform method for the preparation, formulation, or application of bio-inputs, leading to inconsistencies in quality.

Short Shelf Life: Some bio-inputs need to be used within 24–48 hours, while others can last for up to six months. This limits the ability to store and sell products year round.

Storage Issues: Most BRCs use non-ideal storage methods, which can impact the shelf life and effectiveness of the products.

Financial Limitations: BRCs often rely on grants for funding, and without a solid entrepreneurial approach, many struggle to sustain themselves financially.

Furthermore, BRCs must adopt an entrepreneurial model to ensure sustainability. Accurate forecasting of demand, especially considering seasonal fluctuations, is essential. Additionally, pricing should be standardized across states, and marketing strategies should be defined to increase the reach of bio-inputs. Farmers and community resource persons (CRPs) involved in selling bio-inputs should be incentivized with margins similar to those of conventional agricultural input dealers.

Role of Women SHGs and FPOs

Incorporating self-help groups (SHGs) and farmer producer organizations (FPOs) into BRC operations could enhance their impact. SHGs can be responsible for production, while FPOs can focus on branding, marketing, and distribution. This collaborative model could improve the efficiency and reach of BRCs.

Institutions like ICAR, KVKs, and agricultural universities play a critical role in researching the effects of bio-inputs on crops, soil health, biodiversity, and the overall environment. Research can help refine bio-input formulations and improve their effectiveness, making them more viable and appealing to farmers.

Finally, the concept of BRCs has the potential to accelerate India's shift towards sustainable, natural farming practices. However, for BRCs to achieve their full potential, they need an entrepreneurial mindset, consistent quality control, effective marketing, and strong institutional support. With proper planning, these centres could help farmers transition away from chemical fertilizers and adopt more eco-friendly and sustainable farming practices.■

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Unseen Connections

How Small Partnerships Drive Big Change in Sustainability

In the world of global sustainability, not all impactful collaborations are visible. While major initiatives often make headlines, it is the smaller, less-recognized partnerships that truly drive long-term change. In this article, **Siya Chopra** and **Mohd Shehwaaz Khan** explore how organizations play a vital role in facilitating these hidden yet powerful partnerships.

In the intricate landscape of global sustainability, high-profile collaborations — climate summits, billion-dollar green funds, and corporate pledges — dominate the headlines. However, there is a quieter, often overlooked side to these efforts: smaller partnerships that are critical to driving real, long-term change. These collaborations are invisible structures supporting large-scale sustainability goals, created through trust, shared vision, and persistent cooperation.

The Strength of Smaller, Resilient Partnerships

Despite their lack of visibility, these partnerships tend to be more resilient and adaptable than larger ones. By connecting stakeholders across various sectors and geographies, they often tackle the most pressing sustainability challenges in innovative ways. These partnerships foster a culture of collaboration, where diverse groups can set aside differences, find common ground, and work towards shared objectives.

Successful partnerships are grounded in trust and equality, enabling all parties—governments, businesses, civil society, and local communities—to engage as equals. However, building such trust requires careful facilitation and the willingness to work through conflicts, make compromises, and think collaboratively.

CRB's Role in Facilitating Unlikely Partnerships

Centre for Responsible Business (CRB) plays a key role in facilitating partnerships between seemingly disparate stakeholders. Through platforms like the India and Sustainability Standards (ISS) Summit and initiatives like the Sustainable Palm Oil Coalition for India (I-SPOC) and the Alliance of Cotton & Textile Stakeholders on Regenerative Agriculture (ACRE), CRB connects unlikely allies who share a common sustainability vision.

At the heart of successful collaborations lies the ability to facilitate and translate differing priorities into common goals. Effective facilitation ensures that stakeholders understand their roles, set clear expectations, and remain accountable throughout the process. Building long-term relationships, rather than seeking quick solutions, is key to these partnerships' lasting success.

Impact of Small-Scale Collaborations

Smaller-scale collaborations often begin as pilot projects or knowledge-sharing platforms, but their effects can be far-reaching. These initiatives unite stakeholders from various sectors — small farmers, large corporations, local businesses, and community members — creating a shared sense of responsibility

and accountability for interrelated issues. Such partnerships have the potential to bring about significant change by influencing policy, inspiring industry shifts, and improving local economies.

Initiatives like I-SPOC and ACRE demonstrate the power of building trust and aligning diverse actors towards a shared sustainability goal. For instance, I-SPOC has successfully brought together producers, businesses, and policymakers to foster sustainable palm oil practices in India, while ACRE works to promote regenerative cotton and sustainable farming across the textile value chain.

Why Small Partnerships Matter More Than Large Initiatives

While large-scale initiatives may promise greater attention, smaller partnerships often offer more resilience and adaptability. These alliances can pivot when circumstances change — be it a policy shift or a global crisis — and often act as catalysts for broader transformations. By nurturing these grassroots collaborations, businesses, governments, and communities can create deeper, lasting impacts.

Platforms designed to foster dialogue and collaboration—like industry summits and regional coalitions—are essential to the success of these partnerships. They provide neutral spaces for diverse stakeholders to come together, share knowledge, and build trust. These platforms often serve as the breeding grounds for transformative partnerships that shape the future of sustainable practices.

Often, the most significant collaborations begin in quiet, informal moments—policymakers and grassroots leaders finding common ground, small business owners discovering funding opportunities, or sustainability leaders connecting with community organizations. These organic interactions grow into powerful partnerships that drive impactful initiatives.

Lessons Learnt from Years of Facilitating Partnerships

Through years of facilitating collaborations, several key lessons have emerged. Collaboration thrives

in impartial environments where every voice is heard. Micro-interventions, like pilot projects or trust-building exercises, can spark larger transformations. Partnerships that evolve to meet changing needs are more successful than rigid agreements. Tangible, measurable outcomes are essential to ensure the success of these collaborations.

The true strength of the sustainability movement lies in its invisible web of partnerships. These partnerships, though often overlooked, are the foundation of systemic change. By prioritizing trust, adaptability, and long-term collaboration, these smaller partnerships can bring about transformative, lasting solutions. At CRB, we recognize that our role is not to dominate these conversations but to facilitate them, creating spaces where trust and collaboration can flourish.

Final Thoughts

In the ever-changing world of sustainability, bold declarations and grand gestures make headlines, but the most impactful change often comes from the quiet, unseen collaborations that lay the groundwork for systemic transformation. True change starts with authentic connections, one conversation at a time, one partnership at a time. ■

Siya Chopra is Assistant Director, Marketing & Communications and Mohd Shehwaaz Khan is Senior Communications Officer at Centre for Responsible Business.

Empowering Youth for Sustainability

The Role of Higher Education Institutions in Climate Action

By engaging students in green skills like renewable energy and waste management, higher education institutions are fostering innovation and promoting hands-on solutions to environmental challenges. **Ravi Sankar Das**, **Monmi Barua** and **Taru Mehta** detail how strategic collaborations with local schools and communities ensure that these initiatives have long-lasting impacts, empowering youth to sustain and expand these efforts.

In the age of climate emergency and environmental depletion, partnerships have emerged as a promising tool in the fight against environmental degradation. The alliance between higher education institutions (HEIs) and sustainable development efforts plays a crucial role in nurturing actions that sensitize the public to urgent environmental concerns. As centres of innovation and knowledge, these HEIs are uniquely equipped to lead initiatives that tackle pressing environmental challenges and advance climate solutions.

A prime example of such collaboration is the OTBL (ONGC TERI Biotech Limited) Campus Impact Challenge (CIC) Project. This initiative has united colleges and institutes across Assam in advocating for sustainability and environmental stewardship, focusing on equipping youth with essential green skills, such as renewable energy systems, waste management, and conservation practices – all vital for the workforce of the future.

OTBL CIC Project

OTBL CIC underscores the critical role that HEIs play in advancing sustainability initiatives. By inviting institutions from Assam to submit campaign ideas focused on sustainability on their campuses, the initiative not only fostered creativity and innovation but also cultivated a competitive drive aimed at enhancing best practices for the environment. Among the numerous applications received, six exemplary ideas were selected, each rooted in unique environmental challenges and proposing innovative solutions. This demonstrates the breadth of ideas and commitment embedded within higher education institutions' youth and communities.

The initiatives undertaken by Swahid Peoli Phukan College, Sibsagar, emphasize the power of awareness and capacity-building in addressing plastic pollution. The college's efforts not only focus on educating students about waste management practices but also actively involve them in practical solutions, such as crafting eco-brick benches from waste plastic bottles collected from the community. This initiative encouraged students to take responsibility and helped them develop practical skills essential for a sustainable future.

Initiatives Undertaken by HEIs

Meanwhile, Tezpur University's project showcases a holistic approach to waste management by repurposing organic waste into valuable products. This initiative not only reduced the waste

generated on campus but also promoted local employment and economic empowerment among self-help groups (SHGs). By linking environmental sustainability with social responsibility, Tezpur University exemplifies how youth can create a substantial impact on their communities while addressing critical environmental issues.

Assam University's initiative on menstrual hygiene illustrates the profound impact HEIs can have on community health and awareness. By addressing a topic often shrouded in stigma, university students engaged with approximately 500 adolescent girls in surrounding villages, raising awareness about menstrual hygiene, providing essential sanitary products, and installing three automatic sanitary pad vending machines. Not only did this project educate young individuals, but it also engaged teaching and non-teaching staff within schools, showcasing a comprehensive outreach strategy that reached over 200 villagers. This is an example of how academic institutions can harness their resources and networks to create substantial social change.

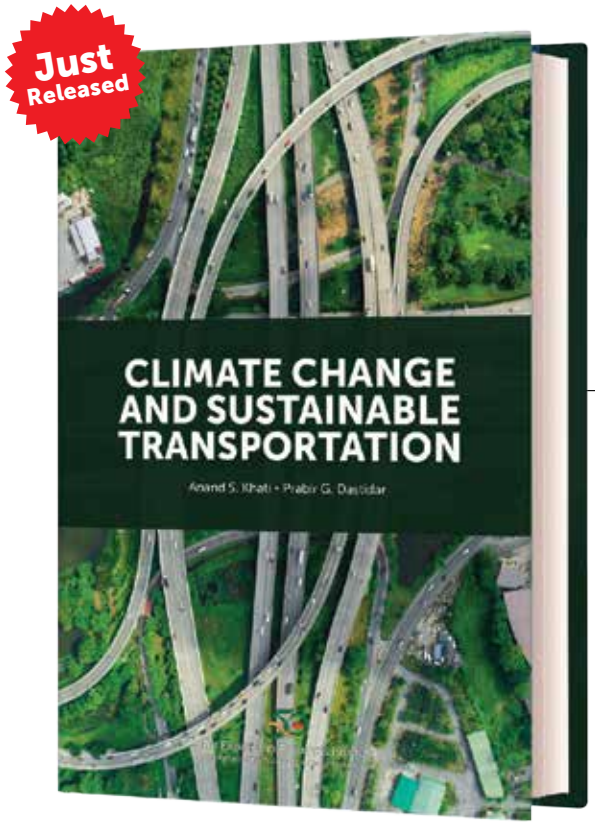
Youth as Drivers of Change in Society

To ensure the sustainability of their efforts, the participating HEIs have adopted several strategic approaches, including signing Memorandums of Understanding (MoUs) with nearby schools and communities. These collaborations focus on delivering capacity-building training and workshops aimed at enhancing green skills among participants. In this initiative, youth have trained members of SHGs in their localities, empowering them to apply sustainable practices that can also improve their financial situations. Importantly, senior students have actively involved their younger peers in this training process, ensuring that the knowledge and skills acquired are passed on and retained within the community. This approach fosters continuity, enabling future generations to carry forward the initiatives and maintain momentum, even after the seniors complete their studies and transition out of the institutions.

HEIs are proving to be invaluable catalysts for sustainable development and climate solutions in today's pressing environmental landscape. Initiatives like OTBL CIC illustrate the power of collaborative efforts in fostering innovative ideas and engaging youth in meaningful action towards sustainability. By addressing diverse environmental challenges through hands-on activities and awareness campaigns, institutions can enhance green skills among students and demonstrate that education can extend beyond the classroom to create tangible benefits for local communities. Furthermore, the strategic partnerships formed with schools and SHGs ensure the longevity of these initiatives by equipping future generations with the skills and knowledge needed to sustain momentum in environmental stewardship. ■

Ravi Sankar Das, Associate Fellow, TERI; Monmi Barua, Fellow, TERI; and Taru Mehta, Senior Fellow, TERI.

Discover the Impact of Climate Change on Sustainable Transport



Major topics covered

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Can Carbon Market Be a Credible Source of Climate Finance in India?

Readers will agree, potential of carbon market as a source of climate financing for India is quite substantial, and very much forms the subject matter of this article. Penned by **Gopal K. Sarangi** and **Shingle Sebastian**, the contents make us aware of both the need and relevance of the climate finance, notably in the Indian context. In other words, how India can capitalize on this market.

In Need of Climate Finance: size and magnitude

The net-zero emissions trajectory set by many countries including India, cannot be achieved without adequate financial resources. IEA (2023) estimates suggest a sizeable magnitude of clean energy investment to be made to meet stated goals of net zero by countries. Projections indicate that it has to be tripled by 2030 and further to be scaled up by five times annually from 2030 to 2050 to keep countries on net-zero trajectory. Other estimated numbers indicate the ballpark figure to be around USD 8 to 9 trillion dollars by 2030 (Monar, 2024a). These projected figures may escalate to new highs depending on the degree of climate inactions and future uncertainties associated with climate hazards. India is no exception to these realities. Our country is highly vulnerable to climate hazards due to its unique geography characterized by highly fragile mountainous regions like the Himalayas and long coastlines prone to cyclonic disturbances and storm surges. Studies point to the fact that 80% of the districts in India are highly vulnerable to climate hazards and extreme climate conditions (Mohanty and Wadhawan, 2021). Given the degree and intensity of climate vulnerability, the size of climate funds required for meeting the climate-related costs is projected to be quite humongous. In order to achieve Net-zero Goal by 2070, India requires a sizeable quantum of funds estimated to be around USD 10 trillion. Even the much prioritized and policy emphasized energy transition implementation trajectories require more than 2 trillion USD for the country (Singh, *et al*., 2024). However, there is a significant dearth of the required funds to meet such ambitious climate goals for the country. Though there has been a rise in the climate funding flows in recent years mostly directed towards climate mitigation activities, it still constitutes only 1% of the global gross domestic product or GDP (CPI 2023). It is contended that the current climate financing options from all possible sources in India could only meet a meagre 25% of its total climate finance requirements. The funds shortfall is often attributed to the credit market failure conjugated with issues with priority sector lending by the Reserve Bank of India (RBI) (Bhatnagar and Sharma, 2021) and further accentuated by high-capital costs of such investments combined

with high costs of borrowing for green projects and technologies (Dhruba, 2018). Besides, the funds shortfall may be further accentuated by the recent global developments. Apprehensions run that pulling out from Climate Accord by US would further jeopardize the effort to mobilize the required resources for climate change at the global scale. This may have repercussions for India's effort to source international as well as domestic funding for climate change.

Nature and Character of Climate Finance

While the global financial commitments with regard to funds flow to developing countries decided at COP29 Baku through the mechanism of New Collective Quantified Goal (NCQG) got caught in the controversy with regard to the nature and size of the funds, similar uncertainties exist with regard to the future funds flow for climate actions in developing countries. The current framing of climate finance source apportions indicates that funds flow from multiple sources including budgetary support from both the federal government and subnational governments, loans, and grants from banking and non-banking financial institutions, funds mobilized from financial markets such as bonds and equity markets, resources sourced from private investors and through innovative financing routes such as crowdfunding. Climate finance strategy, in the Indian context, largely revolves around four key sources of funding—mobilization of private sector funding, funds drawn from international institutions and partnerships, funds mobilized through a blend of innovative financing, and other climate innovative financing (Suri 2023). Within these, private financing is increasing, taking the centre stage as a core source of financing, given the budgetary constraints being increasingly felt with the public exchequer and limited funds flow from the multilateral

and bilateral international bodies. However, it is strongly put forward that in order to spur private investments, adequate incentive mechanisms are to be brought in place by the public authorities to materalize the crowding in effects of government funding. For instance, renewable energy investments, which are largely private investor driven, both globally and in India, are primarily incentivized by the public authorities.

Whether Carbon Market Could be a Source of Climate Financing?

While the potential of the private sector in mobilzing climate financing is proven, of late, the role and importance of carbon market as a potential source of climate financing has received a renewed thrust after its adoption in COP29 in November 2024. It is asserted that if effectively designed, carbon markets could be a prospective source of climate finance while meeting the emission reduction goals (Monar, 2024b). It is argued that mechanisms through which the carbon credits could support the financial requirements for climate change would depend on the regulatory architecture of the country and the typology of carbon market, that is, voluntary or regulatory. The revenue gathered through the carbon financing mechanisms could augment the fiscal space for the country governments, which is much needed particularly in developing countries like India which encounter budgetary constraints for supporting the climate finance requirements. Available statistics indicate that around 74 carbon-pricing instruments have been introduced in various countries worldwide and the total revenue generated through these sources is close to USD100 billion in 2022, a four-time jump from a value in 2015. Country-specific emission trading schemes (ETS) have emerged as an effective source of mobilizing climate finance in many countries (Singh, *et al*., 2024). For instance, selling of emissions allowances through auctions could act as a source of revenue for the government (Burtraw and McCormack, 2017). It is reported that EU-ETS has generated more than USD200 billion through auctioning of emission allowances since 2013. The collated amount has been spent on various climate and energy purposes by member states and supported in creating various funds at the centralized level such as modernization fund's for accelerating energy transition, innovation funds for promoting low-carbon innovative technologies, and social impact funds for extending the much-needed support for poor and vulnerable households. In similar vein, several other country-

level and regional ETS schemes such as Japan ETS and California Cap and Trade Programme, The Washington State Cap and Invest Programme and Regional Greenhouse Gas Initiative have used the proceeds collated through allowances in supporting climate actions. For example, Japan has an ambitious plan to generate $120 billion through the auction of power sector allowances to be spent through Climate Transition Bonds.

Can India Use Such a Market Form as a Source of Domestic Climate Finance?

Though, India is the third-largest emitter globally in absolute terms, per capita emissions in the country is less than half of global average with 1.8 tonnes of CO_2 per person. Total emissions of India constitute 8% of the global emissions, approximated to be 4 billion tonnes of CO_2, though the share of cumulative emissions is much lesser. While emissions are projected to rise for India by 30% by 2050 (IEA, 2023), the question is whether the conventional emission financing is adequate and what alternative options are available for financing of emissions. It is posited that innovative financing sources such as carbon markets could act as an additional source of financing.

India's proposed Carbon Credit Trading Scheme (CCTS) is a pivotal step in leveraging market-based mechanisms to combat climate change impacts and attract climate financing. Proposed under the Energy Conservation (Amendment) Act, 2022, the scheme aims to create a robust domestic carbon market where businesses and entities can trade carbon credits. Unlike earlier initiatives like the Perform, Achieve, and Trade (PAT) scheme, which was limited to energy efficiency, this broader framework extends to various sectors and aligns with global carbon trading mechanisms under the Paris Agreement. This trading system not only enables India to meet its Nationally Determined Contributions (NDCs) but also attracts investments in sustainable technologies. By pricing carbon, the scheme sends a clear signal to industries to innovate and transition towards low-carbon operations.

However, given that India is entering to its own domestic carbon market and structuring it alignment with Article 6 of the Paris Agreement, a successful design and operation of such market needs to be aligned with the domestic CCTS market. Central Government on the basis of recommendations of NDAIAPA has approved the list of 14 activities under Article 6.2 mechanism which can be considered for trading of carbon credits under bilateral/cooperative approaches. These activities will facilitate adoption/ transfer of emerging technologies and may be used to mobilize international finance in India. This will enable setting up of projects in sectors with emerging/ cutting edge technologies and/ or high investments. This will facilitate viability gap funding resulting in adoption

of these technologies and bringing economies of scale.

Another important question is how to use the proceeds generated through the carbon revenue. It has been emphatically pointed out that the use of the proceeds generated through the carbon revenue shall be used carefully, largely depending on the context. India's CCTS can drive climate action by channelling proceeds into renewable energy projects, energy-efficient technologies, and climate adaptation measures. These funds should also support green technology R&D, subsidies for SMEs, and sustainable initiatives to ensure an inclusive and low-carbon economy.

Under Article 6.4 of the Paris Agreement, 2% of the proceeds from carbon credit transactions are mandated to be contributed to the adaptation fund. Additionally, a separate 5% of issued credits is set aside and cancelled to ensure an overall climate benefit, further reinforcing the mechanism's goal of supporting both mitigation and adaptation efforts. Hence, the potential of carbon market as a source of climate financing for India is quite huge.

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Pioneering Climate Finance in India

TATA Capital's cleantech finance arm is leading India's efforts to decarbonize

Traditionally, climate finance has been perceived as a public sector endeavour on a global scale. A diverse class of investors globally are eager to contribute towards the war against global warming, but they require credible local platforms to effectively channelize funds. India's ambitious plans, however, faced limitations due to the insufficient capacity of such institutions to match the agility, innovation, and profound understanding required. A significant void exists in sector understanding, hindering the flow of channelled capital into the sector. This void and its suitable filling form the subject matter of this article by **Manish Chourasia.** Tata Capital Limited (TCL), the flagship financial services company of the Tata Group, has been instrumental in this endeavour. The author explains how TCL's Cleantech Finance arm has established itself as an ideal intermediary to connect global climate funds with Indian climate projects and companies.

The bygone year breached the 1.5°C global warming threshold, making it the warmest year on record. According to a report based on six datasets from the World Meteorological Organization (WMO), global temperatures remained more than 1.5°C above pre-industrial levels for over 90% of 2024. Adding to this alarming trend, global emissions continue to rise, further intensifying the climate crisis. Additionally, ocean heat content and sea levels have continued their upward trajectory, highlighting the ongoing and escalating impacts of climate change.

The COP29 highlighted that the challenge of energy transition is not macroeconomic in nature because, while global annual savings reached over USD 28 trillion in 2023, which is about 5–6 times higher than the funds required to fight climate change. However, most of these savings are concentrated in the Global North, whereas the need for climate finance is much greater in the Global South, which is poised for rapid growth. As a result, carbon emissions from these regions will rise significantly due to their increased energy consumption and industrial activity. Since climate change is a global problem, impacting everyone, it requires global cooperation for effective solutions.

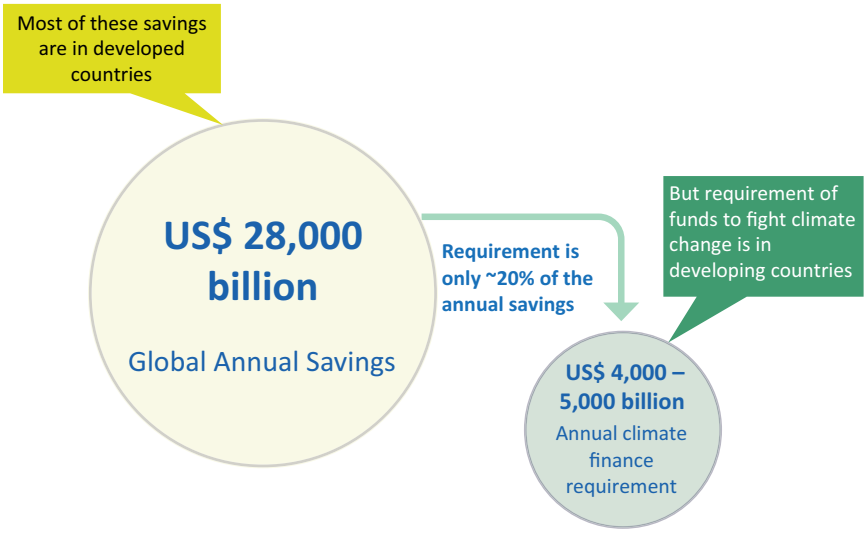

Figure 1 Fund required for climate finance v/s global savings

Source: World Bank, Energy Transitions Commission (ETC)

Traditionally, climate finance has been perceived as a public sector endeavour on a global scale. A diverse class of investors globally are eager to contribute towards the war against global warming, but they require credible local platforms to effectively channelize funds. India's ambitious plans, however, faced limitations due to the insufficient capacity of such institutions to match the agility, innovation, and profound understanding required. A significant void existed in sector understanding, hindering the flow of channelled capital into the sector.

Tata Capital's Role in Cleantech Finance Space

Tata Capital Limited (TCL), the flagship financial services company of the Tata Group, has been instrumental in this space. TCL's Cleantech Finance arm has established itself as an ideal intermediary to connect global climate funds with Indian climate projects and companies. Climate finance was traditionally seen as a public sector initiative. However, TCL has successfully made it more appealing for increased capital participation. Over the last six years, TCL's Cleantech Finance arm has consistently maintained a return on assets (RoA) of around 3%, attracting numerous lenders to join in the cleantech sector. The company's Cleantech Finance division has disbursed more than double of its total portfolio (disbursed over ₹350 billion and a portfolio of over ₹140 billion (as of 31 December 2024), setting a framework for other players to enter in the segment.

TCL has successfully steered climate financing through its Cleantech Financing arm by mainstreaming the cleantech sector through private capital by delivering tailored solutions during the early stages of development. As of December 2024, over 500 projects have been sanctioned in cleantech segment. TCL takes pride in its commitment to take calls to fund nascent technologies to mainstream them, which may not be appealing to traditional banks and financial institutions. It is working aggressively to develop markets for emerging sectors such as electric vehicles, solar rooftop, energy efficiency, waste to biogas, green hydrogen, green ammonia, biofuels and water treatment. In each of these sectors, Tata Capital has actively supported emerging climate startups that are debt-ready and have developed viable business models.

TCL has taken efforts to develop in-depth understanding of the rapidly evolving sectors encompassing technical, commercial, regulatory, contractual, and ESG aspects. A dedicated research vertical was established to enhance this understanding, coupled with the implementation of a robust risk diligence, and monitoring framework for complex transactions and efficient asset management. The company has integrated ESG assessment into every project appraisal process. TCL has progressively embraced cutting-edge technologies for making its business digital friendly and competitive. The company's recruitment strategy involved bringing in experts not only from financial services but also the renewable industry, forming a specialized research team with unparalleled segment expertise.

From the outset, the company embraced a collaborative strategy with investors, clients, and regulators. The company stands as the first private sector institution in India to secure a USD 100 million line of credit facility,

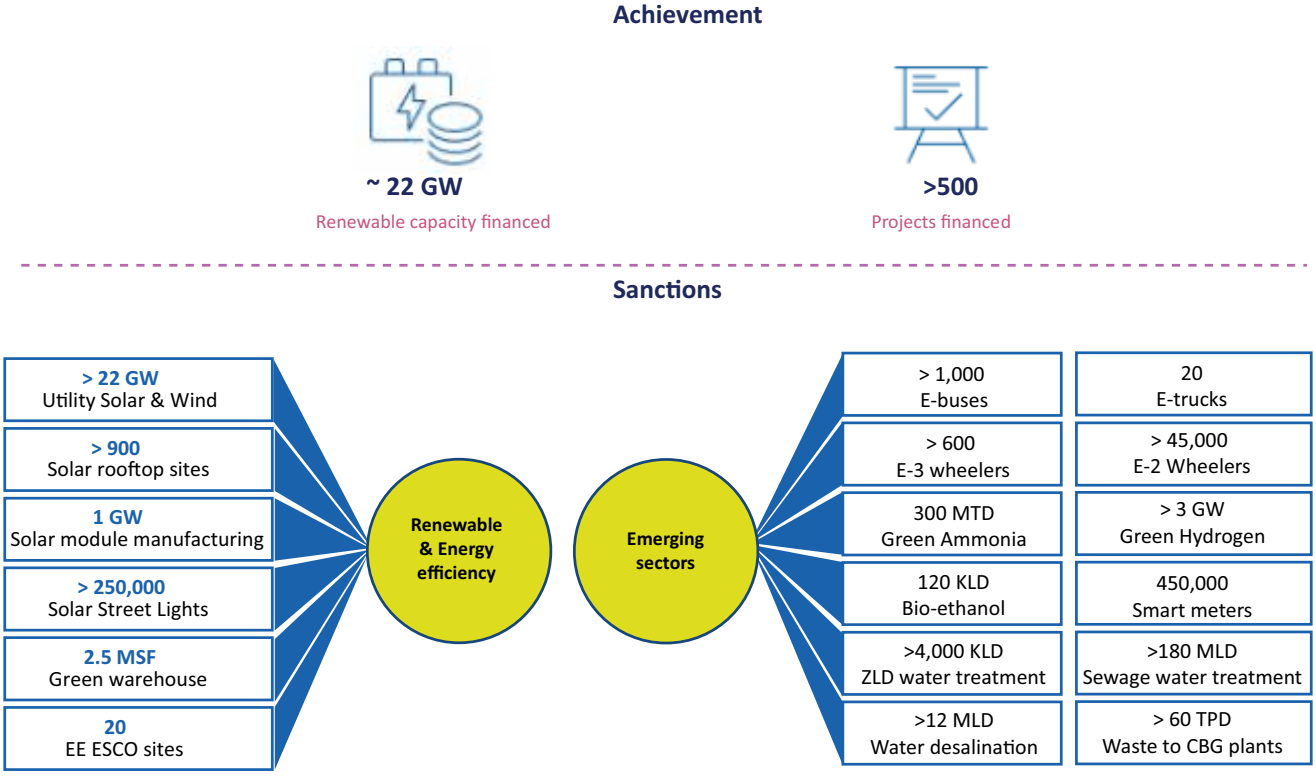

Figure 2 Achievements and mainstreaming activities of TCL's Cleantech Finance arm

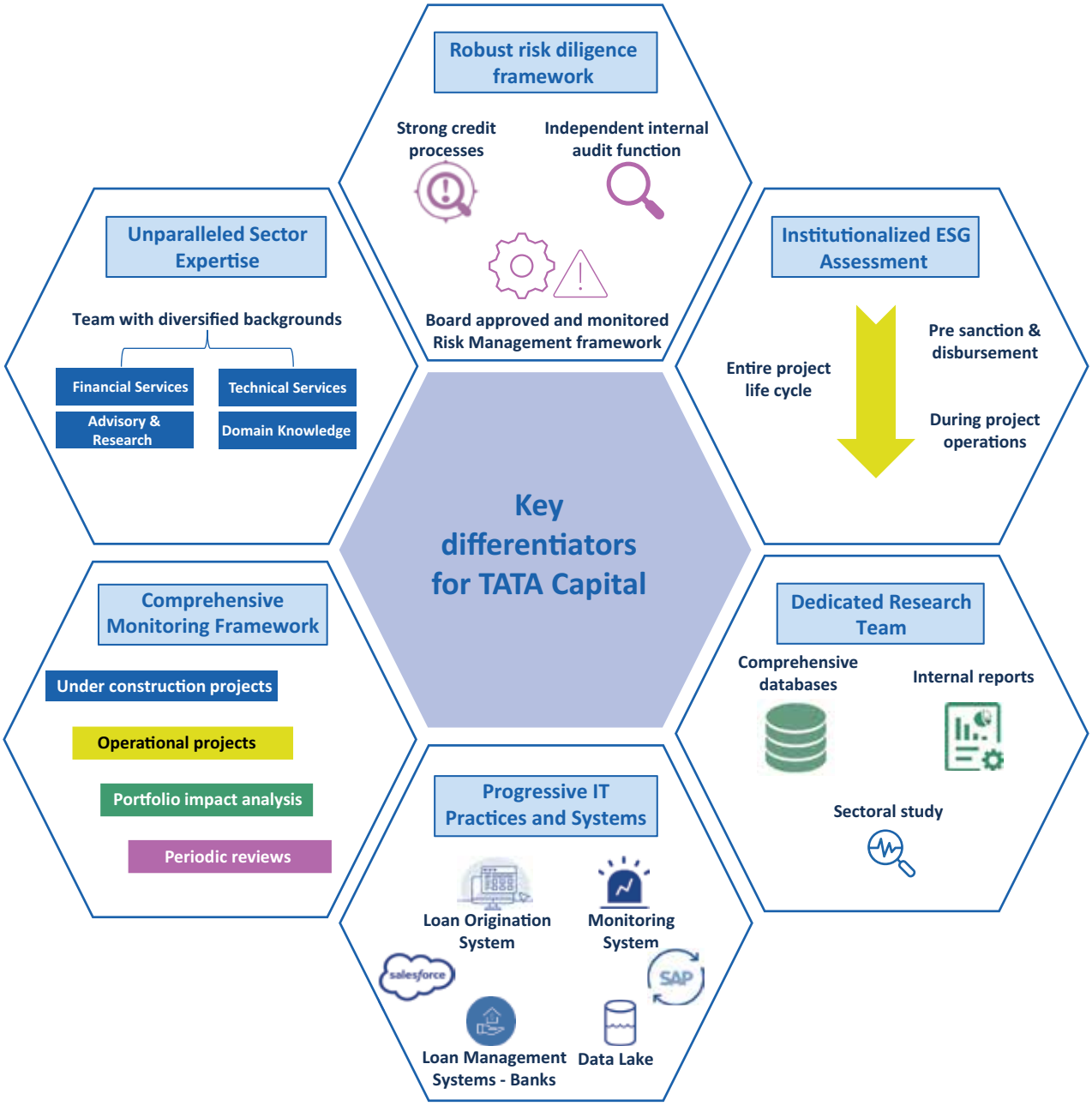

Figure 3 Key differentiators of TCL's Cleantech Finance

from the Green Climate Fund (GCF), to finance rooftop solar projects in India. TCL, as a knowledge partner, has also become a part of marquee committees for promotion and support of climate finance. By adding honours and recognition to its coveted list, TCL has gained respect in the sector. TCL has received multiple esteemed accolades.

Climate Opportunity in India

India has already taken a leap in initiating green transition. The country has a huge untapped potential in cleantech sector with numerous emerging technologies gaining prominence. But it will have to attract climate investments of at least 10 times over the next seven years compared to the last seven to meet its targets. This vast fund requirement makes up 35–55% of the loan book of all commercial banks in India (as of March 2024). Given the magnitude, relying solely on the public sector is impractical, necessitating private sector investment.

While financing green transition is

Figure 4: External recognition for stellar effort

tricky, developing countries face two additional fundamental challenges compared to their developed counterparts. First, green technologies have higher capital requirements in contrast with the conventional technologies. Second, the cost of capital is higher in developing countries, making green investments more expensive. Even if developing countries can raise low-cost international capital, these savings are often offset by the high cost of hedging. Additionally, for tenures beyond the average maturity of over 10 years, the hedging market itself is limited, leaving projects exposed to currency risk in

the medium to long term. A de-risking mechanism is crucial to finance energy transitions.

India will also need to strengthen the domestic bond market to facilitate more green bond issuances, a product largely dependent on global pools of green capital as of now. In addition to domestic reforms, emerging economies like India will continue to depend on collaboration from all international climate investors given the scale of climate finance required. Effective channelization of diverse global capital is critical to create a meaningful impact, and this involves both public and private funds, as well as development finance institutions.

The Cleantech industry and financial markets have seen sustained reforms, from feed-in tariffs to auctions that scaled renewable energy. Public–private partnership (PPP) models have advanced transmission, water treatment, and electric mobility projects. Platforms like IDFs, AIFs, and InvITs are drawing domestic and international investments. But for substantial scaling up, strengthening of public institutions such as electricity distribution companies, municipalities, and urban local bodies is required. Weak financials and rising liabilities of these institutions create threat of non-payment. Cleantech projects have higher upfront costs and require longer contracts for viability. However, nature of technology is such that, future prices could be much more attractive than that of today. In the absence of contract enforcement framework, viability of cleantech

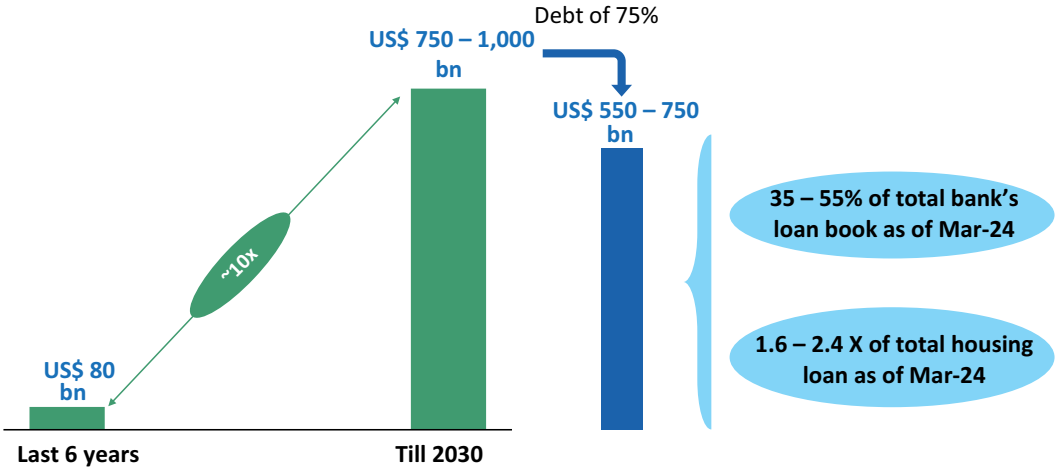

Figure 5: Investment required in cleantech by 2030 (USD bn)

Source: RBI and TCL's Cleantech Finance Research

projects could be jeopardized. Thus, strong project execution frameworks, robust payment security mechanisms, viable business models for emerging technologies, and harmonized taxonomies are critical pillars for achieving India's decarbonization goals.

Despite challenges, this scenario presents unprecedented opportunities in scale and longevity. TCL has played a pivotal role in mainstreaming the renewable energy sector and is working to make the emerging cleantech segments more attractive. The company is focused on its chosen sectors and markets, working with partners to channelize necessary expertise, capital and realize India's climate goals.■

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Tribals and Tribulations

Environment Preservation by India's Tribes

Contributed by **Astitva Rai** and **Dr Ruchi Agrawal**, the present article has roots in tribal traditional knowledge. The authors haven't left an iota of doubt how this wisdom that has passed through generations is an environmentally benign pathway towards realization of sustainable development in true means.

The hum of native Brazilian folk instruments and chants fill the air once you tune into 'Amazonia', a single by the French metal band Gojira. What shortly follows is a burst of guitar riffs, drums, and a pneumatic bass line. It all paves way to a shattering yet aching cry, "The greatest miracle is burning to the ground!" In an effort to drive not just awareness but conservation efforts against Amazonian genocide and ecocide with the Articulação dos Povos Indígenas do Brasil (Brazil's Indigenous People Articulation or APIB), Gojira wrote Amazonia.

They are one of the many metal bands that urge through an evidently rageful form of music, one to act against the unheeding end of environment by the abject failure of governing bodies across the globe. Intricate ecosystems like the Amazon rainforests, at their current rate of depletion and exploitation, will perish in the next 15 years. Such deeply introspective and driven music had to spark some curiosity, and so it did.

Delicate reserved and protected areas with their indigenous lives exist across India, all with their own practices, folk artistry, and conservation practices. When it comes to partnerships for accelerating sustainable development and climate solutions, seldom are our indigenous forces given the voice they so deserve, let alone the means to drive sizeable change. What follows is a brief look into some of the indigenous tribes within India driving sustainability we have long contemplated.

The Ritual

Indigenous rituals and folklore, as well as the festivals they often lay roots for, can seem primitive and orthodox to some. After all, venerating mere stones and artefacts in hopes of a successful harvest or disease-free cattle hardly makes a case for conservation from an informed and pragmatic lens. However, the same lens lacks the depth and the thought of the humility placed here in front of nature's forces.

Santals, Jharkhand

For the *Santal* community in Jharkhand, the harvest festival of *Baha* demarcates collection of any portion of the trees, plants or grasses left standing or grown in the sacred grove or *Jahera* of a village. The *Jahera* is where they believe their deity or *Marangburu* resides. The refrain is also placed on any harm one can inflict on the wildlife in the grove the people swear their allegiance to. The *Santals* also have a very intricate understanding of their agricultural calendar.

Throughout the first half of the year up until the first monsoon arrives, they avoid any major cultivation. For them, it is only after they partake in the *ero sim* ritual will they be graced with a healthy monsoon. The ritual aligns with the month of *Asar* (June–July) and what this patient wait for monsoon entails for the crops is noteworthy. The moisture the soil would have otherwise lost owing to premature overturning is avoided. The paddy doesn't suffer from lack of water.

Jenu Kuruba, Betta Kuruba, Kuruba and Yerava, Karnataka, and Kerala

Travel south enough to Kodagu, Karnataka and a tale of Lord Ayappan and Goddess Bhadra Kali is told. The tribes of South Kodagu, Hunsur, and Hanagodu that surround Nagarahole Tiger Reserve believe Ayappan betrayed them and in an act of rebellion, they gather cross-dressed on the occasion of *Kunde Habba*. Profanities, abuses, and slurs against Ayappan are rife in the air as a sign of discontentment with the god over abandoning his people for the goddess.

Lately, a newer rebellion brews. The tribes—displaced and bound as labourers at the growing number of exploitative plantations in Coorg—have found a new direction for the rage of Kunde Habba. Sidelined and failed by the authorities to assure them of a respectable life, fair compensation and just working conditions, they hurl abuses at the capitalist forces that exploit them and thwart their environment.

Worship, as it turns out, is part veneration and part denigration. And though uprisings have been urged to be civil in nature throughout history, certain messages are just better screamed.

Soliga, Karnataka

A bellow of "There's fire in the sky!" pierces through the chorus of Amazonia. One could wish it were a hyperbole but it isn't. Wildfires continue to ravage acres of land globally. There are those whose livelihood stems from these intricate forest ecosystems and they assert that fire must be fought with fire. Practices of controlled and informed burning called cultural burning—intentful burning of land to revitalize it and propagate the needful species of flora—had a sizeable impact in minimizing wildfires but were curbed by regulatory bodies.

In Karnataka, the prohibition

placed on intentful burning practices of the *Soliga* tribe by the Karnataka government proved to be the antithesis of conservation. Curbing this practice meant that the invasive and flammable species of lantana plant could grow unchecked. Where we stand now is a 350% increase in forest fires in Karnataka. Not only are the *Soliga* better equipped with the knowledge of local flora, it is laughable to see the apathy shown towards wisdom the state possesses but the government forsakes for tech-driven solutions.

Art Within Tribes

When it comes to creative expression and artistry, Dhimsa dance from Andhra Pradesh or Kummi dance from Tamil Nadu mimic harvesting and agricultural cycles. Siddi Dhamal dance of the *Siddi* community in Gujarat and Karma dance from Central Indian tribes form a medium of expression for the local ecological and biodiversity harmony. *Adim Sangeet* (tribal music), a likewise accompaniment on days of celebration, gives another outlet to a tribe's preservation practices.

The assimilation of the local climate, agrarian understanding and even class struggle with festivities—some definitely having inexcusable patriarchal undertones—continue to take shape and form in whatever context they are put in. Not only do the practices of environment conservation traverse generations through these festivals and artforms, indigenous ideas also become more palatable for minds accustomed to a standardized model of conservation.

The Conservation

The World Bank states that "indigenous people comprise only around 6% of the global population but they protect 80% of biodiversity left in the world." As the climate crisis continues to deepen and soar, one can easily grasp the ineptitude of western ideas of conservation—"narrow, short-term perceived interests making truly effective international cooperation on climate change extraordinarily difficult," states Paul Harris in "What's Wrong with Climate Politics and How to Fix It."

A single template cannot work for every nation, especially those that are starkly different from the West. A nation as staunchly boastful of its culture, if looking within itself, can find ways to lead climate action.

For instance, the UN Food and Agriculture Organization (FAO) took cognizance of the new practices *Adivasi* farmers in three districts of southern Rajasthan (Pratapgarh, Dungarpur, and

Banswara) undertook to revitalize the health of the soil in their region. The nutrition-sensitive farming involved 'mixed cropping with legumes as natural fertilizers, crop rotation, agroforestry, mulching, plantation in homestead and growing hedgerows and grassy strips around agricultural fields'.

Ensuring food and crop safety can be learned from the *Bonda* tribe's women in Odisha. Growing a climate-resilient native strain of millets has aided them in mitigating the effects of erratic rainfall. Local tribal communities such as the *Bugun*, the *Miji,* and the *Hrusso* agreed to share their rich ethnobotanical traditions in order to conserve the orchids endemic to The Sessa Orchid Sanctuary, situated in Kameng district of Arunachal Pradesh.

In Tamil Nadu, the *Kadars* pluck fruits and vegetables from the mature stems of the plant so as to replant them for future harvests and the *Irulas, Muthuvans, and Malayalis* adhere to a mixed cropping system. Such practices circumvent the overexertion of resources. Fortifying one's produce against erosion and degradation by planting fruit crops and trees on the peripheries of a field is a practice amongst the *Gond, Pradhan, and Baiga* communities of Madhya Pradesh.

It is definitely not the case that tribes and their practices left all on their own won't survive. Such forces have long survived and will continue to survive. The only thing threatening them is unending zeal of urbanization to not yield as it consumes another forest. With all our economic might and intellect, we are the ones that are in more of a need of wisdom for preservation, even more than tech.

"Burn the land, learn the end."

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Sustainable Cooling and the Montreal Protocol

A testament to successful global collaboration

Article contributed by **Shaurya Anand** enhances our comprehension of the cooling solutions. As per the author, cooling is no longer a luxury; it is a necessity integral to modern life. While early cooling technologies posed significant environmental risks, the Montreal Protocol exemplifies how collective action, innovation, and progressive policymaking can address global challenges. As we transition to next-generation cooling technologies, the lessons learned from the protocol can guide us in building a resilient and sustainable future.

The recent wildfires in Los Angeles starkly remind us of the worsening impacts of climate change. Each year, humanity grapples with intensifying heatwaves, forest fires, and droughts—events that increasingly disrupt daily life, particularly for vulnerable populations. As global temperatures rise, cooling solutions such as air conditioning and refrigeration become indispensable. However, these very solutions have historically contributed to the problem they aim to mitigate.

The Evolution of Cooling Technologies and the Ozone Crisis

In the earlier days of cooling systems, chlorofluorocarbons (CFCs) were commonly used as refrigerants due to their efficiency. However, in the 1980s, scientists discovered a massive hole in the ozone layer, primarily caused by the release of CFCs into the atmosphere. The ozone layer, located in the stratosphere, plays a vital role in absorbing harmful ultraviolet (UV) radiation. Without it, UV-B and UV-C rays can cause irreparable harm to living organisms, including increased risks of skin cancer, cataracts, and harm to crops and marine life.

CFCs, released from refrigeration and air-conditioning systems during their lifecycle, repair, and disposal, migrate to the upper atmosphere. With a lifespan of up to 100 years, they break down ozone molecules, disrupting the natural ozone replenishment cycle. This led to the

formation of the infamous ozone hole over Antarctica. This alarming discovery prompted global leaders, scientists, and policymakers to take collective action, leading to the signing of the Montreal Protocol on Substances that Deplete the Ozone Layer in 1987.

Montreal Protocol: a model for global collaboration

The Montreal Protocol is widely regarded as the most successful environmental treaty in history, with universal ratification by all 198 UN member states. Its primary objective was to phase out the production and consumption of ozone-depleting substances (ODS), including CFCs, in a systematic manner.

This treaty has achieved remarkable milestones:

1. **Complete phase-out of CFCs:** By phasing out CFCs in air-conditioning, refrigeration, and fire-suppression systems, the protocol has significantly reduced ozone depletion. According to United Nations Environment Programme (UNEP), this has averted more than 135 billion metric tonnes of CO_2-equivalent emissions.
2. **Healing the ozone layer:** The National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA) report that the ozone layer is on track to recover to 1980 levels by 2066.
3. **Preventing global warming:** The protocol has also indirectly mitigated climate change, as many ODS are potent greenhouse gases (GHGs).

Supporting Developing Nations: The Multilateral Fund

To ensure equitable implementation, the Montreal Protocol established the Multilateral Fund (MLF) to provide financial and technical assistance to developing countries. As of 2024, the MLF has supported over 8000 projects, enabling countries to transition to energy-efficient and environmentally friendly cooling systems. These initiatives include:

- Promoting low-global warming potential (GWP) refrigerants.
- Upskilling service technicians with gender-inclusive approaches.
- Enhancing cold chains for food and vaccine storage.

This innovative financial mechanism exemplifies how well-designed climate finance can drive transformative change. Under the guidance of the Montreal Protocol on Substances that Deplete the Ozone Layer (MLF), Article 5 (Developing) countries have successfully phased out the consumption of over 756,000 metric tonnes of baseline ozone-depleting substances. This achievement translates to an estimated avoidance of 2.2 billion tonnes of CO_2 emissions.

Challenges with HFCs and the Kigali Amendment

While the Montreal Protocol successfully phased out CFCs, their replacements—hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs)—posed new challenges. Although HCFCs and HFCs have low ozone-depleting potential (ODP), they are potent GHGs with high global warming potential (GWP). For instance, HFC-134a has a GWP of 1430, meaning its impact on global warming is 1430 times that of CO_2 over 100 years.

In 2016, the Kigali Amendment to the Montreal Protocol was adopted to phase down HFCs. It aims to reduce HFC consumption by over 80% by 2047, preventing up to 0.4°C of global warming by 2100. This amendment is a testament to the evolving nature of the protocol, ensuring it remains relevant in addressing emerging climate challenges.

The Role of Natural and Next-generation Refrigerants

The focus has now shifted to natural refrigerants like hydrocarbons (propane and isobutane) and ammonia, which have negligible GWP and minimal environmental impact. These alternatives are being adopted in various sectors, from commercial refrigeration to cold storage.

India has been actively exploring the adoption of next-generation refrigerants, such as hydrocarbon-based refrigerants (R-290), in room air conditioners which are now commercially available in the market. R290 refrigerant possesses a GWP of 3, signifying a significantly lower impact on global warming compared to many other refrigerants. The Government of India has undertaken several innovative measures to promote sustainable cooling. The India Cooling Action Plan (ICAP), the first of its kind, launched by the Ozone Cell, Ministry of Environment, Forest and Climate Change outlines a visionary road map to reduce cooling demand by 25–30% by 2037–38 through energy-efficient technologies and sustainable refrigerants. The Energy Efficiency Labelling Programme, spearheaded by the Bureau of Energy Efficiency, ensures star-rated appliances like air conditioners and ceiling fans meet high-performance standards. Additionally, India is actively transitioning to low-GWP refrigerants in line with the Kigali Amendment to phase down HFCs. Efforts to explore district cooling systems and develop energy-efficient cold chain infrastructure for agriculture and health care further highlight the government's commitment to climate-resilient cooling

solutions. Such initiatives demonstrate a commitment to sustainable cooling solutions. Additionally, innovations such as desiccant-based cooling and thermally driven systems are gaining traction.

The journey of sustainable cooling: from Montreal Protocol to next-generation solutions

Cooling Beyond Refrigerants

Cooling isn't just about refrigerants. Ancient Indian architectural designs, like Jaipur's Hawa Mahal, leveraged passive cooling techniques such as natural ventilation, courtyards, and shading to maintain thermal comfort. Such passive cooling solutions remain relevant today, especially in rural and resource-constrained settings.

Even cutting-edge technologies, like the NASA's recent James Webb Space Telescope (JWST), employs an innovative cryogenic cooling system using a five-layer sunshield and helium-based cryocoolers to maintain its instruments at ultra-cold temperatures. These examples underscore the importance of interdisciplinary approaches to cooling innovation.

Cooling as a Necessity, Not a Luxury

The COVID-19 pandemic highlighted the critical role of cold chains in preserving vaccines and ensuring food security. According to the Food and Agriculture Organization (FAO), 14% of the world's food is lost due to inadequate cold storage, costing billions annually and exacerbating hunger. Investments in sustainable cold chain infrastructure can mitigate these losses, enhance food security, and combat climate change.

Conclusion

Cooling is no longer a luxury; it is a necessity integral to modern life. While early cooling technologies posed significant environmental risks, the Montreal Protocol exemplifies how collective action, innovation, and progressive policymaking can address global challenges. As we transition to next-generation cooling technologies, the lessons learned from the protocol can guide us in building a resilient and sustainable future.

Web Resources

https://earthobservatory.nasa.gov/world-of-change/Ozone

https://www.unep.org/ozonaction/who-we-are/about-montreal-protocol

https://ozone.unep.org/sdg13#:~:text=The%20Montreal%20Protocol%20protects%20our%20climate%20as,around%20135%20billion%20tonnes%20of%20CO2%20emissions.

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Decarbonizing the Built Environment

Partnerships for collective action

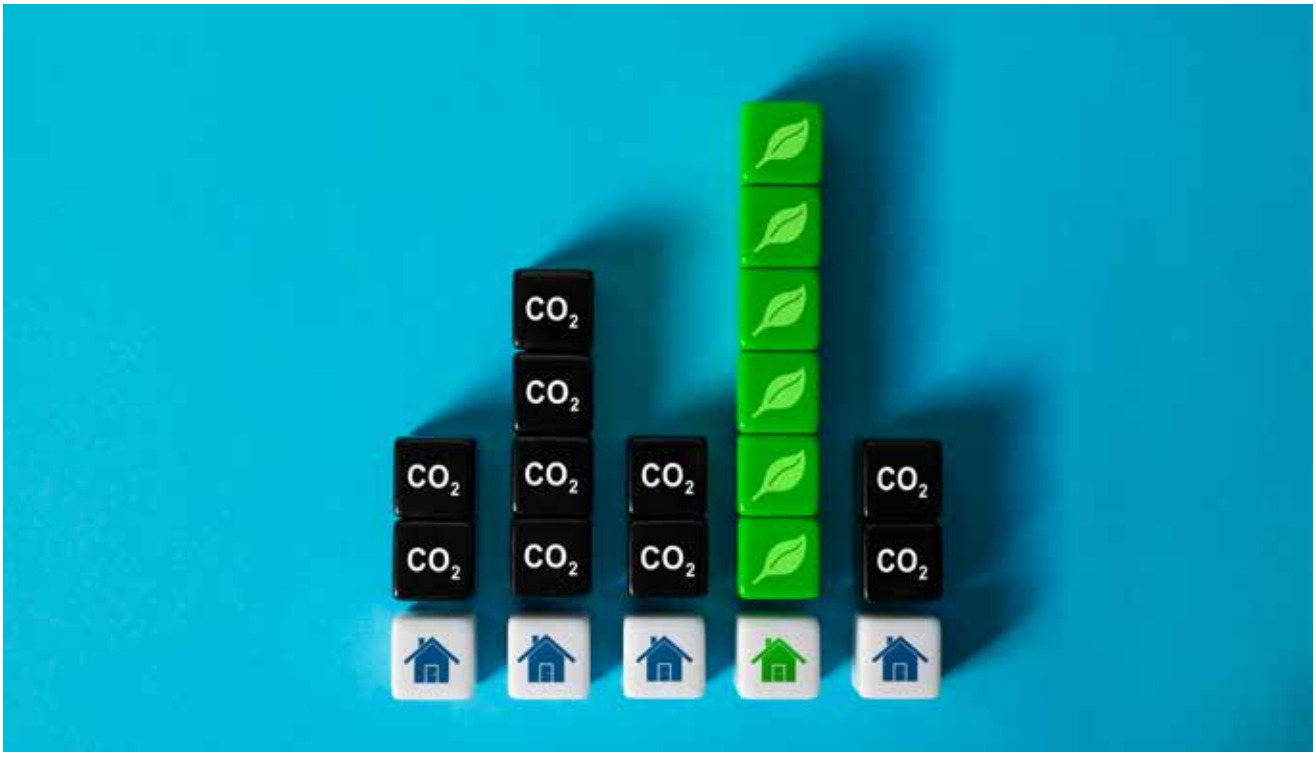
This piece of writing by **Sanjay Seth** and **Sheen Pandita** encapsulates the necessity of decarbonization of the built environment. The authors establish, the built environment must not only stand as a testament to progress but also to sustainability, resilience, and a shared vision for realization of net-zero future.

The built environment, a symbol of progress, now stands as one of the largest contributors to global emissions. As Swiss French architect Le Corbusier once described it, the built environment is a 'living machinery' where materials, technologies, and human ingenuity converge to create spaces of shelter and comfort. However, this very system, designed to serve humanity, now demands urgent transformation to reduce its carbon footprint and mitigate the climate crisis.

The Living Machinery

Buildings are more than bricks and mortar—they are complex systems made up of materials, water, electrical networks, heating, ventilation, and air-conditioning (HVAC) technologies, and human interaction. Their creation and operation require collaboration among architects, engineers, urban planners, policymakers, construction material producers, green tech innovators, landscapers, facility managers, and end-users. Each component contributes to the building's overall carbon footprint.

According to International Energy Agency's (IEA) latest reports, globally the built environment is responsible for nearly 40% of energy-related CO_2 emissions, with approximately 10%



attributed to the production of building materials and 28% to energy consumed during building operations. In 2022 alone, direct CO_2 emissions from buildings were around 3 gigatonnes (Gt), while indirect emissions—linked to electricity heating and cooling production—rose to nearly 6.8 Gt. Additionally, another 2.5 Gt of CO_2 emissions were associated with building construction materials. These figures highlight the urgent need for systemic change.

India's Role in the Global Transition

Modern buildings are built in steel and concrete—the backbone of modern construction. With rapid urbanization and a projected 15% increase in building stock by 2030—equivalent to North America's total floor area—India faces immense sustainability challenges. Government initiatives like Pradhan Mantri Awaas Yojana (PMAY) and growing economic demands drive this expansion, making India one of the most critical players in the global decarbonization effort. Emerging economies like India are expected to account for nearly 80% of global floor area growth, further intensifying energy demand.

India, as the world's second-largest cement producer, the country boasts a relatively moderate emission intensity of 0.627 tCO_2/tonne, an achievement that surpasses the global average and contrasts sharply with the higher intensities of 0.781 in the United States and 0.739 in the United Kingdom. However, as demand rises, the cement sector will need to adopt innovative solutions to maintain this trajectory while reducing its overall carbon footprint. Similarly, the steel industry, contributing to 12% of India's emissions, highlights another layer of challenge. Steel production is expected to expand, predominantly through the carbon-intensive processes. Emissions from the steel sector are projected to rise until 2050, reinforce the urgency for technological and policy interventions to mitigate its environmental impact.

A Multifaceted Challenge

The built environment's heavy reliance on cement and steel—two industries currently with limited scalable alternatives—presents a significant challenge for decarbonization. The cement and steel industries must accelerate the adoption of sustainable alternatives, such as bio-based composites, recycled steel, and low-carbon cement, while transitioning to cleaner energy sources like hydrogen, solar, and wind. Additionally, exploring advanced carbon capture, utilization, and storage (CCUS) technologies could play a critical role in mitigating emissions. Architects and planners need to embrace passive design strategies and circular design principles, focusing on resource efficiency and retrofitting existing structures to reduce environmental impact. Facility managers and end-users also have a key role to play by adopting energy-efficient operational practices and fostering a culture of sustainability in building management. Achieving decarbonization will require a concerted effort from all stakeholders, driven by innovation and shared responsibility.

India has already made strides with market-driven climate solutions like the Perform, Achieve, and Trade (PAT) scheme, which incentivizes energy efficiency in high-emission industries.

The Renewable Energy Certificates (RECs) promote clean energy adoption, contributing to reductions in industrial carbon footprints. The Indian Carbon Market (ICM), with its compliance framework and voluntary offset system, offers promising solutions, although the delayed launch of the Carbon Credit Trading Scheme (CCTS) in 2025–26 has slowed its full potential. India's ability to harness innovative financial instruments and enforce progressive policies will determine how effectively it can lead the global shift toward a net-zero built environment.

An Urgent Call to Action

The urgency is undeniable. The IEA warns that building sector emissions must decline by 9% annually to stay on track for net zero, with a 50% reduction required by 2030. With global temperatures surpassing the 1.5°C threshold in 2024, the demand for energy-intensive cooling is rising due to heatwaves and extreme climate events. Balancing thermal comfort—an essential factor for public health, productivity, and economic growth—against escalating operational costs will further complicate India's decarbonization efforts. As a climate-vulnerable nation, India faces mounting pressure to align its *Viksit Bharat 2047* mission with global climate goals.

However, India's rapid urbanization presents a unique opportunity to lead the transition towards a sustainable built environment. At this critical juncture, the decisions made today will shape the future of our cities, determining whether they evolve into climate-responsive, resilient spaces or remain trapped in a costly cycle of inefficient structures requiring frequent retrofits. While the upfront costs of sustainable interventions may seem significant, failing to act now could result in far greater financial burdens from retrofitting and rebuilding in the face of climate risks. A forward-thinking approach is essential to avoid this structural and financial burden. Success in this transformation hinges on intensive collaboration among policymakers, architects, urban planners, construction stakeholders, and material producers. Achieving this vision requires strong leadership, bold policies, coordinated action and partnerships.

The Power of Partnerships

Collaboration is the cornerstone of implementing sustainable future. The theme of this year's the World Sustainable Development Summit, 'Partnerships for Accelerating Sustainable Development and Climate Solutions', highlights the transformative power of collective action. In the face of climate challenges, strategic partnerships serve as a catalyst for innovation, bringing together diverse stakeholders—architects, engineers, construction workers, urban planners, policymakers, material producers, green tech innovators, landscapers, facility managers, and end-users—around shared objectives. By fostering cross-disciplinary collaboration, we can unlock innovative solutions, scale sustainable practices, and drive meaningful change throughout the building and construction industry.

Initiatives such as GRIHA's rating systems and TERI's collaborative efforts play a vital role in setting sustainability benchmarks and pushing for policy integration. Through programmes like the Sustainable Infrastructure Programme and the Mahindra-TERI Centre of Excellence, India is advancing research in low-carbon materials and climate-responsive design. Public–private partnerships will be crucial in transforming research into real-world solutions, driving investment, and ensuring long-term climate resilience. As a key player in the Global South, India's decisions in the next decade will determine whether it leads the way in sustainable construction or faces the costly consequences of inaction. The path India chooses today will not only shape its journey towards *Viksit Bharat* but also define its economic future and commitment to achieving net-zero emissions by 2070.

The built environment must not only stand as a testament to progress but also to sustainability, resilience, and a shared vision for a net-zero future.

The time to act is now. ■

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Energy Transition in Indian Transport Sector

The Role of Clean Fuels and Technologies

India's transport sector faces a significant surge in energy demand, driven by urbanization, economic development, and population growth. Despite its relatively low per capita emissions, the sector contributes about 12% of the country's total carbon emissions. With the demand for transport energy projected to grow exponentially by 2070-71, **Akshaya Paul**, **Rahul Chakraborty** and **Shreya Gupta** share how a multi-faceted approach including cleaner technologies and strategic policies will be critical to decarbonize the sector.

Between 1990-91 and 2024-25, India's transport energy demand has increased by an astounding 13 times due to growth in population, urbanization, and economic development. As the nation pursues its vision for Viksit Bharat 2047 and Net-Zero emissions by 2070, a further rise in transports energy demand is inevitable. For an emerging economy like India with staggering inequality in income and energy access along with regional imbalance, it is of utmost importance to strike a balance and address the energy trilemma between providing equitable access to affordable energy for all, guaranteeing energy security, and providing environmentally sustainable energy usage systems. The growth and development of the transport sector in the long run should be in consonance with the energy trilemma the country faces.

The transport sector contributes to about 5 per cent of gross value added (GVA) per annum and has a wider implication on the country's

development. In 2024-25, passenger demand was estimated at 10,161 billion passenger kilometres (BPKM), and freight demand at 4,193 billion tonne kilometres (BTKM).[1] The transport sector is responsible for about 12 per cent of India's total carbon emission from energy use. However, India has one of the lowest per capita emissions from transport at 0.24 tonnes of CO_2 in 2023, as compared to China (0.8), Germany (1.7), and the United States (5.1).[2]

Transport energy demand in the country is further expected to grow from 5.2 exajoules (EJ) in 2019-20 to 34.4 EJ by 2070-71 in business-as-usual (BAU) scenario.1 This is largely driven by rising passenger and freight transport demand, which is projected to increase fourfold in passenger and elevenfold in freight transport by 2070-71 as compared to 2019-20. The number of vehicles on the road is also expected to increase five times, making this a crucial area of concern for energy management. Currently, India has 35.7 vehicles per 1000 population, compared to other developed countries such as 166 in China, 634 in Germany, and 811 in the US.[3]

The Fossil Fuel Dilemma

Historically, the source of transport energy has been predominantly petroleum products; 80 per cent of high-speed diesel (HSD) and 99 per cent of petrol are consumed in the sector and the consumption of HSD and petrol has increased by 2.4 and 5 times, respectively during the last two decades. ITransport decarbonization is hard-to-abate, and if left unchecked, the transport sector is projected to see a 42 per cent increase in greenhouse gas emissions (GHG) by 2070-71.

Despite the manifold surge in the consumption of alternative fuels and technologies even under the best possible scenario, fossil fuel demand would persist in 2070-71. It is projected that natural gas would replace petroleum products as the dominant fuel for road transport, as shown in Figure 1. However, post-2050 period, the fossil fuel consumption would decline due to greater use of cleaner technologies like electric and hydrogen fuel cells.

The decarbonization efforts such as electrification of on-road vehicles, biofuel blending across all modes, efficiency improvements of vehicles, a modal shift to railways, and grid decarbonization have the potential to reduce well-to-wheel transport emissions by 78 per cent in the best possible scenario as compared to BAU scenario.

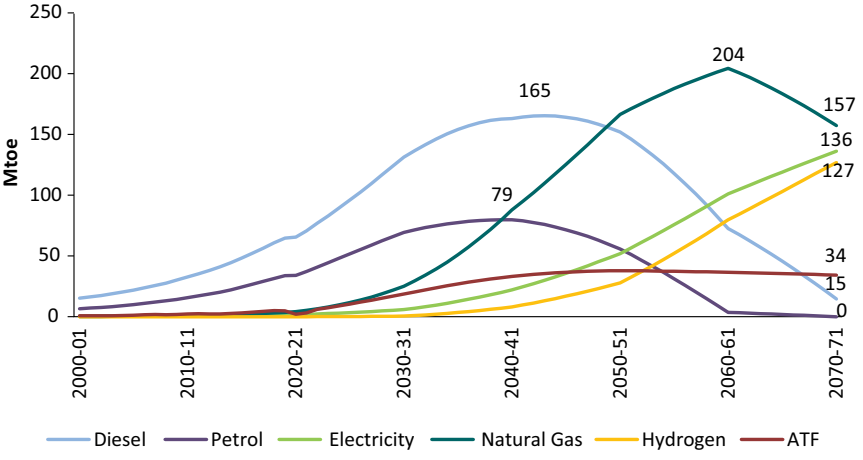

Figure 1: Fuel demand in the highly ambitious scenario

Technology of Present—Electric Vehicles (EVs)

Electrification has emerged as a key transportation fuel, with electric vehicles (EVs) gaining popularity especially in passenger segments. Government policies that support customer demand as well as domestic production have accelerated EV adoption. However, challenges remain, including the need for extensive charging infrastructure and advancements in battery technology to address the range anxiety and upfront costs that currently hinder widespread adoption.In an aggressive growth scenario, the demand for electricity as a fuel is expected to reach 136 million tonnes of oil equivalent (Mtoe), 6 times as compared to the BAU scenario, and would be the dominant fuel with 29 per cent of total fuel demand by 2070-71 (Figure 1). This fuel demand is projected from 858 million EVs and correspondingly 23.5 terra-watt hour EV battery demand by 2070-71. Out of this, it was estimated that 52 per cent of battery energy demand would be from four-wheelers and 29 per cent from medium and heavy goods vehicles (MHGVs). And the critical mineral requirement would correspond to 2.6 million tonne of lithium and 17.6 million tonnes of nickel in 2070-71. As compared to the global mine production in 2023, 14 times of lithium and 5 times of nickel mine production would be required to meet this 2070-71 critical mineral demand for EVs in India.[4] Therefore, strategic sourcing and recycling of the critical minerals and innovation in alternative materials would be required for a stable and secure supply of critical minerals.

1 Details available at Roadmap for India's Energy Transition in the Transport Sector

2 Details available at EDGAR - Emissions Database for Global Atmospheric Research

3 Details available at Road Transport Year Book (2019-20)

4 Details available at Mineral Commodity Summaries 2024

In addition, the development of solar rooftop charging stations for EVs should be promoted as solar-powered EV charging stations could reduce reliance on the grid, lowering emissions associated with electricity generation.

Hydrogen as a Fuel

Hydrogen, particularly green hydrogen, holds immense potential as a clean fuel for hard-to-abate sectors like heavy-duty freight and long-haul transportation. However, only post 2060-61, hydrogen as a fuel would have more than 15 per cent total fuel demand in the most aggressive scenario. In the transition to affordable green hydrogen, in the short-to-medium term grey hydrogen (produced from natural gas without carbon capture) and blue hydrogen (produced from natural gas with carbon capture and storage) would likely play a transitional role. These technologies would bridge the gap till green hydrogen production gets scaled up and becomes more affordable.

Alternate Fuels—Role of Biofuels

Biofuels have seen limited application in India's transport sector but hold significant potential for decarbonization. Therefore, in the best possible scenario, 20 per cent of ethanol, 10 per cent biodiesel, 15 per cent compressed biogas (CBG), and 50 per cent sustainable aviation fuel blending must be achieved for transport decarbonization. It requires extensive infrastructure development and a steady supply of feedstocks to avoid potential conflicts with food security.

Railways for Transport Decarbonization

In 2024-25, with large volumes of passenger and goods transportation, railways contributed to only 3 per cent of the total emissions. On the contrary, MHGVs were the major contributors with 30 per cent of total emissions (Figure 2). Therefore, a modal shift to railways would be an instrumental strategy to target transport emission reduction.

Indian Railways has already made strides in mitigating emissions with more than 90 per cent electrified route length, reducing its reliance on fossil fuels. If aggressive attempts towards a modal shift would be undertaken, expanding rail freight share to 45 per cent by 2030–31 and 50 per cent by 2040–41 would reduce fuel demand by 38 per cent from 468 Mtoe to 340 Mtoe by 2070–71. And the resultant would be 26 per cent further GHG emission reduction, as shown in Figure 3.

Moreover, high-speed trains for intercity travels have the potential to contribute to the reduction of emissions from the aviation sector, as they are an attractive alternative to short-haul flights, which are among the most carbon-intensive forms of transport.

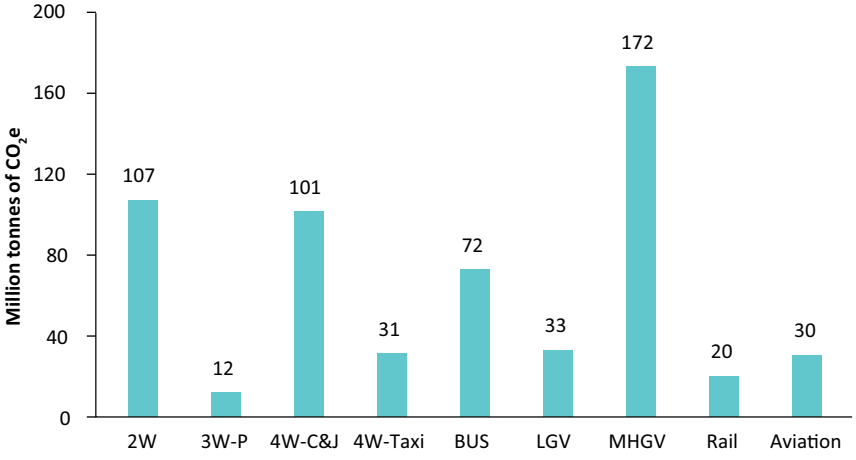

Figure 2: Transport emissions from different modes in 2024-25

The Road Ahead: Decarbonizing Transport by 2070

As the transport demand continues to grow, proactive measures for infrastructure and policies should align with the national goals. Currently, the sector faces immense challenges as it

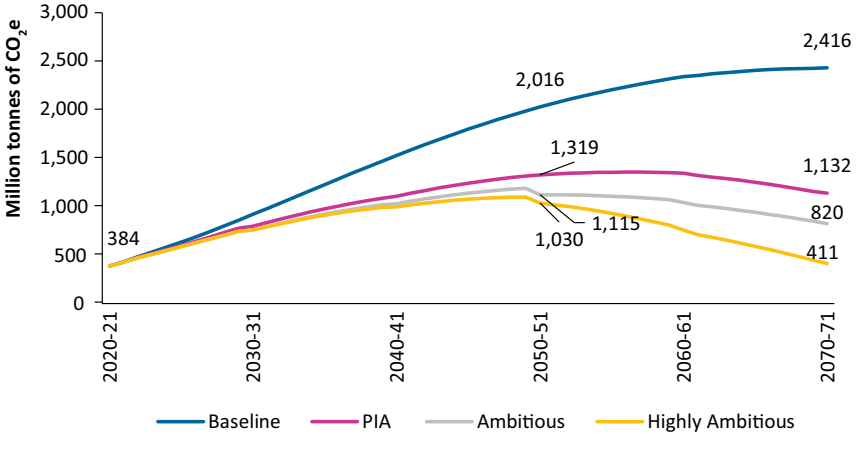

Figure 3: GHG emission impact of expanding share of railways in freight

prepares to meet the rising demand for both passenger and freight transport. With private vehicle ownership expanding, promoting public transport would be critical to avoid overwhelming urban areas with road congestion and increasing emissions. Fuel-mix will play a crucial role in reduction of GHG emissions and fossil fuels will continue for the foreseeable future. The government's role in setting policies and infrastructure development plans encouraging the adoption of cleaner fuels, enhance fuel efficiency, promote biofuel blends, and push for a modal shift to railways are crucial. These necessitate a multi-sectoral approach, collaboration between private players, government bodies, and international partners. Further, the role of carbon credits and carbon-offsetting measures will also be decisive to offset the remaining hard-to-abate emissions from the transport sector. ■

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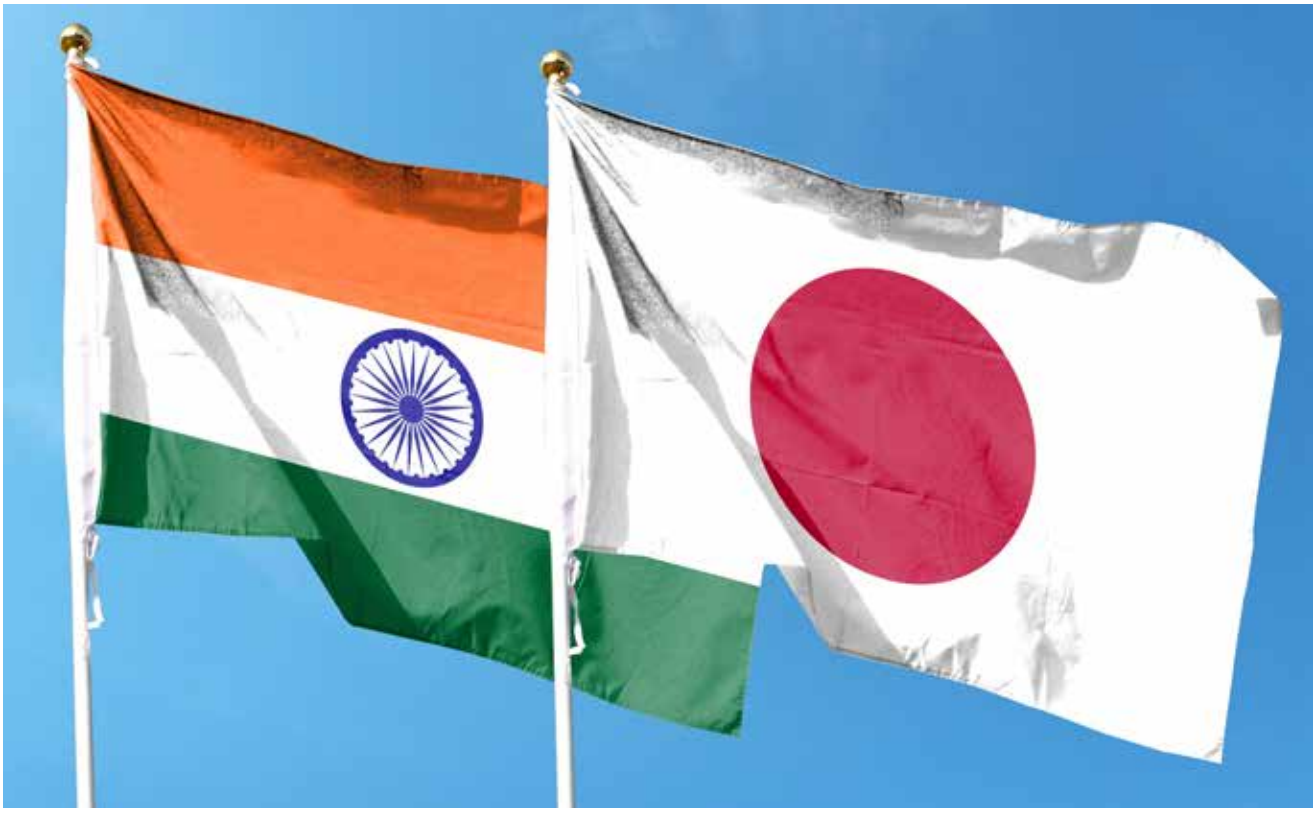
Greener Industries, Stronger Economies

Japan-India Collaboration on Technology Transfer for a Sustainable Future

In India's ambitious bid to achieve net-zero emissions by 2070, a collective and concerted approach, involving multiple industries and stakeholders, is the need of the hour. With Article 6 of the Paris Agreement emphasizing on international collaboration, the project teams at **IGES**[1] and **TERI**[2] detail how India and Japan are engaging towards the goal by knowledge-sharing and technology transfer.

India is the world's most populous country with approximately 1.43 billion people and is also the world's fastest growing economy. This acts as a big deterrent in promoting economic development in a sustainable manner so that India can address environmental problems and meet its target to become a net-zero economy by 2070. Overcoming this challenge requires a large-scale switchover from less efficient and highly polluting technologies and practices to highly efficient, environment-friendly technologies (ETs).

The switch to ETs need to be undertaken not only in the materials, equipment and processes that are used in India's industrial sector—which is a prime driver of India's economic development, accounting for about 28 per cent of GDP—but also must



1 Satoshi Kojima, Toshinori Hamaguchi and Mika Tachibana, Institute for Global Environment Strategies (IGES), Kansai Research Centre
2 Girish Sethi, Prosanto Pal and Kapil Sunil Thool, Industrial Energy Efficiency Division, The Energy and Resources Institute (TERI)

extend to all the other sectors of the economy that are witnessing rapid expansion in pace with India's overall growth—airports, commercial buildings, communication, housing, power, roads and railways, shipping, etc.

A significant portion of industrial energy demand in India is powered by fossil fuels, especially in hard-to-abate sectors like steel, cement, chemicals, and petrochemicals. The industrial sector alone consumes about 56 per cent of the country's energy and is responsible for 53 per cent of CO_2 emissions. It also contributes to environmental challenges such as air and water pollution. To meet India's net-zero targets, it is crucial for the entire industrial sector to adopt energy-efficient technologies (ETs). However, this is a major challenge due to the vast diversity in operations, product types, and energy use across industries, which include both large-scale enterprises and small and medium-sized enterprises (SMEs). SMEs are particularly important, representing over 90 per cent of industrial enterprises, 45 per cent of industrial output, 40 per cent of exports, and employing a significant workforce.

JITMAP

In order to address this challenge, The Energy and Resources Institute (TERI), India and the Institute for Global Environmental Strategies (IGES), Japan have partnered to successfully implement a model titled Japan-India Technology Matchmaking Platform (JITMAP) since 2016 for the transfer of ETs from Japanese technology suppliers to Indian industrial end-users—particularly to Indian SMEs, which tend to lack the technical capacities to achieve energy efficiency and emissions reduction on their own. The JITMAP has essentially been undertaken in bilateral (Japan–India) mode, involving public and private entities in both the countries with a focus on enabling business-to-business (B2B) transactions between the technology suppliers in Japan and the industrial end-users in India. The ETs include low-carbon technologies (LCTs), energy-efficient technologies (EETs), technologies for monitoring and reducing pollution/contamination of air, water and other natural resources (e.g., continuous emission monitoring systems (CEMS)), and best operating practices (BOPs).

JITMAP activities are structured to bridge the awareness and knowledge gaps that act as barriers to direct

(B2B) transactions between Japanese technology providers and Indian end-users. In many cases, the Japanese manufacturers/suppliers have limited knowledge regarding the (often-unique) needs and local conditions of the Indian end-users, making it likely that the Japanese companies often do not view Indian industries—except, perhaps, large-scale enterprises—as potential customers for their ET products. The Indian end-users too—particularly SMEs—are often unaware of Japanese companies that can provide them with a range of high-efficiency ET options that could bring them significant benefits, both in terms of increased profits with attractive paybacks on investments, as well as reduction in emissions and other forms of pollution, improved productivity, better working conditions, and so on. Also, Indian SMEs are marked by low technical expertise and meagre financial resources, which have further hindered their implementation of Japanese ETs.

JITMAP identifies and addresses these knowledge barriers on both sides in the broad and overlapping domains of awareness generation, technical assistance, and creation of a supportive policy & regulatory environment for technology transfer in India. The primary JITMAP activities comprise seminars and workshops, feasibility studies, training-of-trainer programmes, and stakeholder meetings covering a number of ETs for various industrial sectors and applications.

Feasibility study enables SME to save over ₹16 million in annual electricity cost on compressed air system

In September 2017, a technical feasibility study was conducted by a Japanese expert of the technology under JITMAP in a SME in Maharashtra engaged in manufacturing automobile parts. Based on the study, the SME was advised to implement improved operations in its compressed air system including the replacement of its old air compressor with an energy-efficient inverter compressor and reduction of air leakages, etc. A follow-up survey in January 2024 found that the SME had implemented most of the recommendations, thereby, achieving energy savings of about 30 per cent and reducing electricity consumption by approximately 1.79 million kWh per year—equivalent to around ₹16.1 million.

By December 2024, JITMAP had conducted 56 feasibility studies, 18 seminars/workshops, 8 training-of-trainer programmes, and 5 stakeholder meetings in different locations in India covering a range of industrial processes and systems including compressed air systems, electric heat pump (EHP) refrigeration systems, steam management systems, energy saving transmission belts, continuous emission monitoring systems (CEMS), etc.

Indian stakeholders' understanding of Japanese ETs was deepened for reducing air and water pollution

A workshop was held in February 2023 in Pune, Maharashtra, to showcase Japanese ETs that reduce air and water pollution, and to discuss the opportunities for implementing these ETs in the state of Maharashtra. The event was attended by about 65 participants including representatives from state government organizations and energy-intensive industries.

A Japanese presenter introduced ETs such as flue gas monitoring technology, process gas analysers, and air and water quality monitoring equipment to enhance the understanding of the participants. During the discussion, the state government organizations welcomed Japan–India collaborative initiatives to help solve environmental problems, while industry participants requested that capacity-building programmes be implemented under JITMAP to increase their awareness and improve their technical skillsets on ETs.

Way Forward

In the coming years, new opportunities for scaling up the mutually beneficial technological cooperation in ETs between India and Japan under JITMAP can be expected, with two key avenues formally opened to incentivize the transition from fossil fuels to low/zero emission options.

At the global level, Article 6 of the

Paris Agreement enables member countries to utilize technology transfer with trading carbon credits and carbon offsets to achieve mitigation targets of countries involved. Countries and entities including their industries and businesses, can derive benefits in terms of energy and cost savings, as well as reduction in carbon emissions and pollution of air and water.

At the bilateral level, steps have been initiated to create a new mechanism for technology cooperation between Japan and India—Joint Crediting Mechanism (JCM)—for which an aide memoire was signed in March 2023 between Ministry of the Environment, Japan (MoEJ) and Ministry of Environment, Forest and Climate Change, India (MoEFCC). The JCM, as one of the cooperative approaches under the Article 6, will help both countries achieve their respective targets on emission-reduction as well as on solving environmental issues through carbon credits/carbon offsets that will accrue from the transfer and implementation of Japanese ETs in India.

To drive India's sustainable transition, increased participation from both Japanese technology suppliers and Indian end-users in global and bilateral initiatives is essential. JITMAP will play a pivotal role in facilitating B2B transactions between the two countries, fostering bilateral environmental cooperation. The platform will expand its outreach in both India and Japan to enhance the adoption of target ETs and broaden the network of implementing partners. Additionally, JITMAP will actively engage in the formulation of JCM projects once the agreement is officially signed, ultimately contributing to sustainable, long-term transactions between India and Japan. ■

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Fighting Urban Heat

How Cities can Brace the Warming World

This article discusses the rising threat of urban heat, particularly in India, exacerbated by climate change and the El Niño effect. Penned down by **Abhishek Acharya, Rajasree Ray** and **Sutanuka Sarkar,** the article explores Urban Heat Island effect, outlines India's adaptation efforts and emphasizes on the importance of local-level planning.

Amid the relentless rise of urban temperatures, the battle against urban heat phenomenon has never been more critical. Cities across the globe, especially in developing nations like India, are grappling with the alarming consequences of climate change, where each heatwave brings forth escalating challenges that threaten livelihoods, ecosystems, and public health.

Recent Heat Incidents and Trends

Since 2023, combined with the impacts of El Niño, urban heat has become an alarming phenomenon in South Asia, especially in India. According to a study by the World Weather Attribution Initiative, extreme heat in pre-monsoon India has been exacerbated by climate change, with 2024's mean temperatures showing extreme heat to be 45 times more likely and 0.85°C hotter than

before. Heat in India is not just rising but steadily escalating due to human actions (Mitali Mukherjee, 2024). In 2024, India experienced 24 days of heatwaves across various regions, marking the longest heatwave spell recorded, resulting in significant socio-economic consequences and health risks (Indian Meteorological Department). A study by Saudamini Das and E. Somanathan (2024), involving nearly 400 workers in Delhi's slums, shows a clear correlation between rising temperatures and reduced earnings, increased sickness, and a decrease in workers' attendance.

In May 2024, ten of India's 65 cities with over one million people experienced more than 100 hours of 'heat stress'—a dangerous combination of heat and humidity. Nearly 85 per cent of these cities experienced increased levels of heat stress as compared to the previous year (Mint, May 29, 2024). Heat stress is classified into two categories: humid heat stress (when relative humidity exceeds 50 per cent) and dry heat stress (when humidity is below 50 per cent). Humid heat stress was particularly high in coastal cities.

Urban Heat Island Effect and the Need for Urban Planning

The lack of effective urban planning and the reduction of green spaces in cities have led to a significant rise in temperatures as compared to surrounding non-urban areas. Rapid urbanization, changes in land use, and the depletion of vegetation contribute to the Urban Heat Island (UHI) effect. Heavily built-up areas, concrete structures, and increased air conditioning loads make cities warmer than non-urban surroundings (Prasad, 2017; Şekertekin *et al.*, 2016; Burak *et al.*, 2004). Urban growth and sprawl lead to thermal changes, further exacerbating the heat burden on cities. The intensity of UHI risk is higher in cities with a single, continuous urban structure, increasing greenhouse gas emissions.

Adaptation Efforts under the Global Climate Regime

The UNFCCC has played a key role in creating frameworks to support countries in implementing effective climate adaptation strategies, including measures for heatwaves. Article 7 of the Paris Agreement focuses on global climate resilience, aiming to enhance adaptive capacity, strengthen resilience, and reduce vulnerability to climate change. This international commitment requires countries to present formal plans detailing their adaptation strategies, with National Adaptation Plans (NAPs) serving as a critical tool for achieving these objectives.

The urgency of adaptation planning has been highlighted in the Global Goal on Adaptation (GGA) under the Paris Agreement and the UAE Framework for Global Climate Resilience, adopted at COP28 in December 2023. This framework emphasizes science-based approaches to enhancing adaptive capacity and reducing vulnerabilities. Additionally, the outcome of the first global stock take at COP28 urged countries to implement NAPs by 2025 and progress in their execution by 2030. India is actively working on developing a comprehensive adaptation framework through its NAP.

Domestic Adaptation Efforts on Heatwaves

Even before the Paris Agreement in 2015, India had already taken steps to mainstream adaptation actions. The National Action Plan on Climate Change (NAPCC) was launched in 2008, followed by State Action Plans on Climate Change (SAPCC), that proactively pursued adaptation strategies. India's Nationally Determined Contributions (NDCs) in 2015 and its updated version in 2022 also emphasized the importance of adaptation measures.

In 2019, India introduced the India Cooling Action Plan (ICAP), which provided an integrated vision for cooling across sectors. The ICAP's recommendations focused on reducing cooling demand, transitioning refrigerants, enhancing energy efficiency, and improving technology options,

aiming for a 20-year time period. It also provided an implementation framework, linking various government programmes aimed at ensuring sustainable cooling and thermal comfort.

Managing Urban Heat Stress

The extensive spatial diversity of urban areas calls for targeted actions to manage the heatwave phenomenon. Addressing heat stress requires focused planning that considers city-specific vulnerabilities, engages local stakeholders, and implements tailored adaptation measures.

Buildings contribute significantly to India's cooling demand, driven by rapid urban growth. However, with the low penetration of air conditioners, many households rely on fans, air coolers, or passive cooling techniques. A significant portion of the population may not be able to afford air conditioning in the near future. Therefore, designing thermally comfortable buildings is not only vital for reducing cooling demand but also crucial for building climate resilience.

Urban areas, due to their lack of passive cooling, thermally comfortable housing, and common cooling services, are especially vulnerable to heat impacts. In 2024, there were 32 fire incidents caused by air conditioner malfunctions during extreme heat events, underlining the need for climate-resilient urban infrastructure.

A Systematic Approach to Combat Urban Heat

To address urban heat challenges, some instrumental steps must be adopted. These include, but are not limited to, assessment of vulnerabilities, stakeholder engagement, mitigation and adaptation measures, community adaptation, etc. Heat mapping using satellite data, temperature sensors, and GIS to identify heat islands and hotspots. Engaging with communities and stakeholders through public consultations, multi-stakeholder committees, and awareness campaigns. Implementing resilient urban design through green infrastructure, urban forestry, radiant cooling technologies, and heat-resilient building codes. Drawing from experiences of the Covid-19 pandemic, effective dissemination of heat-related health warnings (e.g., through SMS/WhatsApp) should be implemented. Local municipal and district authorities must play a crucial role. Developing cross-sectoral and interdepartmental coordination to streamline health services and emergency responses. Enhancing community adaptability and optimizing social-institutional networks to support vulnerable groups, as highlighted by Tandra Mandal *et al.* (2024).

Need for Immediate Action

As urban heat intensifies, the urgency for innovative and resilient adaptation strategies cannot be overstated. Communities must come together to adopt sustainable urban planning and health measures to ensure cities can thrive in the face of rising temperatures. Prioritizing sustainable urban design and community-based initiatives will not only mitigate the effects of increasing heat but also lay the groundwork for resilience and liveability. The time to act is now—cities' sustainability depends on it. ■

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Empowering India's Climate Action

Leveraging GCF for Sustainable Development

Despite substantial progress, the Green Climate Fund's support for large developing nations, like India, remains insufficient. Reforms in the GCF's processes and a focus on de-risking private investments will be essential to support India's climate actions and meet global climate commitments, **Abhishek Acharya, Pooja Verma** and **Rajasree Ray** write.

Access to credible, predictable, and affordable climate finance for effective climate action has been a long-standing issue for developing nations. Since the early days of multilateral climate negotiations, the 'responsibility paradigm' and the 'polluter pays principle' have placed the burden of providing, mobilizing, and flowing climate finance on developed nations. Unfortunately, these countries have lagged in delivering the scope, scale, and speed of finance required.

Green Climate Fund: A Landmark Development

COP 16 (2010) in Cancun proved to be a turning point where the Green Climate Fund (GCF) was established under UNFCCC's financial mechanism. The GCF

was designed to mobilize resources to mitigate and reduce greenhouse gas (GHG) emissions and help developing countries adapt to climate change. It aims to support a paradigm shift towards low-carbon, climate-resilient development pathways in line with the goals of the Paris Agreement.

The Fund provides a wide range of financing options for both public and private sectors, including non-repayable grants, concessional loans, guarantees, and equity. These instruments are tailored to support adaptation and mitigation projects. GCF also offers direct access to the funds for countries and assists them in preparing for climate change through readiness and preparatory activities.

One of the key features of the GCF is its de-risking mechanism, which aims to encourage private sector investments in climate-smart initiatives. In addition, the fund focuses on capacity building and technical assistance, enhancing the ability of local authorities, civil society, and private sector stakeholders to effectively plan, implement, and monitor climate projects.

India's Role and Ambitious Climate Targets

India has been a leading advocate of climate finance, particularly in pushing for the establishment of a financing mechanism under the UNFCCC. The country is committed to transitioning towards a sustainable, low-carbon energy future while sustaining its economic growth. To meet this goal, India has set ambitious climate targets, which require substantial financial resources.

According to India's Third National Communication to the UNFCCC, the estimated cumulative cost for climate adaptation under a business-as-usual (BAU) scenario is ₹56.68 trillion by 2030, with additional climate-induced damages potentially incurring an extra ₹15.5 trillion. Other analyses, such as those by the Climate Policy Initiative and the International Energy Agency, indicate a need for about $170 billion annually through 2030.

Role of Accredited Entities and the GCF Toolkit

Accredited Entities (AEs) play a crucial role in the GCF business model. They enable countries to access resources directly through Direct Access Entities (DAEs), promoting greater country ownership. To assist stakeholders in navigating the GCF resources and implementing projects, India's Ministry of

Environment, Forest and Climate Change (MoEFCC) released a comprehensive GCF Toolkit in October 2024. The toolkit provided detailed guidance on preparing funding proposals and accessing support.

The GCF presents an important opportunity for India to achieve its climate objectives by providing financial support, capacity building, and collaborative partnerships. Through strategic utilization of GCF resources, India can implement transformative climate projects that integrate both mitigation and adaptation strategies into its national policies.

Challenges and Way Forward

Despite progress made by the GCF, with $15.9 billion approved for 286 adaptation and mitigation projects in 133 developing countries, support for large developing nations, like India, remains inadequate. Reforms within the GCF are necessary to improve direct access to funds and ensure that financial assistance is allocated where it is most needed.

One of the key challenges is the high cost of capital associated with transitioning to cleaner technologies, largely due to elevated technological risks. Attracting private finance and promoting innovative financial instruments, such as blended finance, will be essential to overcome this barrier.

Prioritizing India's Climate Needs

India's transition to a low-carbon pathway is hindered by resource constraints and insufficient financial commitments from developed countries. As one of the largest global economies, India's success in achieving its climate commitments is vital for the global mitigation efforts and for meeting the objectives of the Paris Agreement.

Therefore, GCF must prioritize financial support for India's climate initiatives to achieve global climate goals. Targeted funding for developing greener technologies in hard-to-abate sectors like industry, transport, and agriculture is crucial. Additionally, dedicated financing to address India's adaptation needs will enhance its resilience to climate change.

The success of India's climate journey depends significantly on GCF's support, as it would help the country overcome its unique challenges and seize opportunities to the path of sustainable development. As India advances towards a low-carbon future, the GCF's role will be pivotal in ensuring the country has the resources and partnerships needed to achieve its ambitious climate objectives. ■

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Partnering for Progress

Accelerating Biofertilizer Production for Sustainable Agriculture

In the article, **Shruthi SP** and **Dr Vatsala Koul** advocate for a multi-stakeholder approach to promote the use of biofertilizers, emphasizing the need for collaboration, innovation, and policy support to achieve sustainable and productive agriculture.

The growing global demand for food has placed immense pressure on the agricultural sector to increase yields. During the 1960s, the Green Revolution helped India achieve food self-sufficiency by relying heavily on chemical fertilizers. However, the indiscriminate use of these fertilizers has caused numerous environmental issues, such as soil degradation, salinity, water contamination, groundwater depletion, and climate change. To counter these challenges, biofertilizers have emerged as eco-friendly alternatives that not only enhance soil fertility and crop productivity but also reduce the reliance on chemical agricultural inputs.

Biofertilizers are formulations containing living microorganisms such as bacteria, fungi, or algae. These microorganisms include nitrogen-fixing bacteria (e.g., Rhizobium), phosphate-solubilizing microbes (e.g., Pseudomonas), plant growth regulators, and mycorrhizal fungi, all of which contribute to plant growth. These biofertilizers offer a range of benefits, including improved soil health, reduced ecological footprints, cost-effectiveness, resilience to climate change, and

alignment with global sustainability goals. As awareness about sustainable agriculture grows, the market for biofertilizers is expanding, driven by increasing demand for organic products and supportive government policies.

Challenges to the Widespread Adoption of Biofertilizers

Despite their potential, the widespread use of biofertilizers faces significant hurdles. These include insufficient supply, inconsistent product quality, inadequate infrastructure, and limited awareness among users. Addressing these challenges is crucial to promoting sustainable agricultural practices and ensuring food security. In India, scaling up biofertilizer production and adoption requires robust partnerships, enhanced quality assurance, farmer education, and supportive regulatory frameworks.

Types of Partnership Models for Promoting Biofertilizers

Several partnership models can help drive the adoption and scalability of biofertilizers.

Public-Private Partnerships (PPPs)

Public-Private Partnerships (PPPs) involve collaborations between the government, research institutions, and private companies. Research institutions can provide scientific expertise, while private companies manage large-scale production and distribution, ensuring that biofertilizers reach farmers efficiently.

Research/Academia and Industry Collaborations

Collaborations between academia and industry focus on translating research into commercial products. This ensures the wide availability of biofertilizer technologies to farmers, promoting their use in large-scale agriculture.

Farmer-Centric Collaborations

NGOs and Farmer Producer Organizations (FPOs) play a vital role in connecting farmers with biofertilizer producers. These collaborations help meet local needs, strengthen awareness, promote bulk purchasing, and provide feedback for continuous product improvement. On-farm testing of biofertilizers builds trust and credibility among farmers.

International Cooperation

Global partnerships bring diverse expertise and resources to improve biofertilizer technologies. These collaborations often involve the exchange of best practices, capacity-building, infrastructure development, and the creation of quality standards. Additionally, global financial instruments like green bonds and carbon credits can support these efforts.

Success Stories in Biofertilizer Partnerships

Several successful partnerships have contributed to the development and promotion of biofertilizers:

TERI and Chambal Fertilisers: In 2022, TERI and Chambal Fertilisers launched an advanced mycorrhizal biofertilizer product, 'Uttam Superrhiza', followed by a bio-nano phosphorus fertilizer 'Uttam Pranaam' in 2024.

World Sustainable Development Summit (WSDS): TERI's annual WSDS facilitates the exchange of information and sustainable practices, including the use of biofertilizers.

Fresh Del Monte & Vellsam Materias Bioactivas (Kenya): In May 2024, this collaboration focused on producing biofertilizers from pineapple fruit residues, promoting sustainable agriculture in Kenya.

Gujarat Government and IPL Biologicals: In December 2023, they signed an agreement to establish a biopesticide and biofertilizer production plant, aimed at reducing chemical fertilizer use.

Odisha University of Agriculture and Technology (OUAT): In January 2023, OUAT developed liquid nitrogen biofertilizers for pulses, supported by funding from the Rashtriya Krishi Vikas Yojana (RKVY).

EMBRAPA and Private Companies (Brazil): In 2022, EMBRAPA partnered with private companies to develop biofertilizers with nitrogen-fixing microorganisms, reducing the need for chemical fertilizers in soybean farming.

IARI and Industry Partners: Since 2011, IARI has worked with private partners to commercialize cyanobacterial biofertilizer technology.

N2Africa Programme (Africa): Partnerships between governments, universities, and local businesses in Africa have enhanced legume productivity through the use of high-quality rhizobium inoculants.

Asian PGPR Society: Founded in 2009, this platform fosters collaboration

between academic institutions and private enterprises worldwide to advance biofertilizer research.

Food & Agriculture Organization Initiatives: The FAO's programmes on sustainable soil management and SDG Partnerships support global cooperation on biofertilizer adoption.

Policy and Regulatory Frameworks for Biofertilizers

Government policies play a crucial role in standardizing quality, ensuring product reliability, and promoting biofertilizer adoption. In India, various schemes and initiatives have been launched to support biofertilizer production and distribution:

PM-PRANAM (2023): This scheme aims to restore and improve soil health, promoting biofertilizers as part of sustainable agriculture.

Mission Organic Value Chain Development for NE Region (MOVCDNER): Launched in 2015-16, this programme encourages organic farming and biofertilizer use in India's northeastern states.

Paramparagat Krishi Vikas Yojana (PKVY): Launched in 2015, PKVY promotes organic farming practices, including the use of biofertilizers.

BioE3 Policy (2024): This policy encourages sustainable agriculture through the promotion of bio-based products, including biofertilizers.

National Project on Organic Farming (NPOF): This initiative funds biofertilizer production units and trains farmers on their use.

Fertilizer Control Order (1985): This order mandates quality standards for biofertilizers, ensuring their reliability and safety for farmers.

Role of Partnerships in Overcoming Challenges

Partnerships play a critical role in overcoming the obstacles facing biofertilizer production, such as aligning diverse stakeholder interests, securing funding, and navigating regulatory hurdles. By mapping all relevant stakeholders—from researchers to policymakers—governments can incentivize collaboration and innovation in biofertilizer technologies. Robust mechanisms must also be established to assess the performance and impact of partnerships, ensuring continuous improvements.

Towards Sustainable Agriculture

The transition to sustainable agriculture is essential for ensuring long-term food security and environmental health. Biofertilizers offer a promising solution to reduce reliance on chemical fertilizers, improve soil health, and promote sustainable farming practices. By fostering strong partnerships between governments, industries, academia, NGOs, and farmers, we can address the challenges in biofertilizer adoption and unlock their full potential. These collaborations will not only enhance agricultural productivity but also contribute to a greener and healthier planet for future generations. ■

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Revolutionizing Renewable Energy

The Potent Uses of Plant Microbial Fuel Cells

This article explores the potential of plant microbial fuel cells as a green, eco-friendly, and sustainable energy source. **Dr Pranab Jyoti Sarma** explores the potential and applications of PMFCs and various advantages it offers including waste utilization, carbon neutrality and environment sustainability.

In recent years, mankind has been undergoing a massive transition due to increasing energy demands and environmental concerns. Issues like biodiversity loss and climate change have made the world a more challenging place to live in. Currently, most of the world's energy needs are met through fossil fuels. However, many nations are shifting towards green renewable energy sources for long-term sustainability. These efforts align with the UN's Sustainable Development Goals (SDGs) that aim to provide clean, secure, reliable, and affordable energy. This has led to the exploration of innovative technologies harnessing renewable resources.

Solar energy, wind energy, geothermal and hydrothermal energy are undoubtedly fast-increasing renewable energy sources and have provided promising results in shifting our dependence on the conventional non-renewable source. However, high energy-intensive processes, sizeable initial capital requirements, geographical constraints and landscape transformation creates ecological disturbances, which are some of the limitations associated with the kind of energies mentioned above.

Advancing towards newer forms of renewable energies, Plant Microbial Fuel Cells (PMFCs) represent a potential to be a renewable, self-sustainable, green, eco-friendly and an economical system requiring less energy-intensive process and needs no landscape transformation. It is a promising technology, which combines the principles of plant physiology and microbial electrochemistry to generate electricity. PMFCs offer a unique approach to harness the power of plants and microorganisms, to lower carbon footprints and to provide a green energy solution with simultaneous power generation and biomass production.

Working Principle of PMFCs

A plant microbial fuel cell consists of two compartments separated by a semi-permeable membrane. The anode chamber houses electrochemically active microorganisms, often derived from the rhizosphere, which utilize organic compounds released by the plant roots. These microorganisms, typically bacteria or fungi, break down the organic matter through anaerobic respiration, releasing electrons as a by-product. The released electrons then flow through an external circuit towards the cathode chamber, creating an electric current.

The cathode chamber, on the other hand, facilitates the reduction of electron acceptors, such as oxygen, by forming water or other benign compounds. This reaction completes the electron flow, closing the electrical circuit. Through this process, PMFCs efficiently convert the chemical energy stored in plant-derived organic matter into electrical energy, making them an attractive option for sustainable power generation.

Reactions occurring at anode and cathode:

$2C_6H_{12}O_6 + 6H_2O \rightarrow 6CO_2 + 24H^+ + 24e^-$ (Anode reactions)

$6O_2 + 24H^+ + 24e^- \rightarrow 12H_2O$ (Cathode reaction)

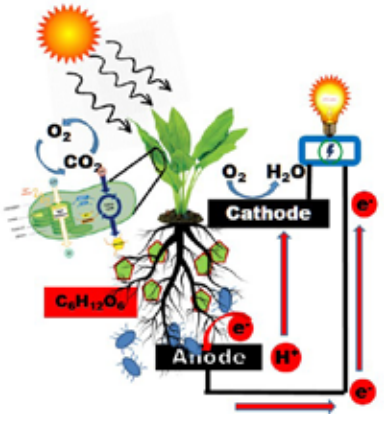

***Figure 1**: Principle of Plant Microbial fuel cell*

Combating Indoor Air Pollution and Generating Bioelectricity

Indoor air pollution is a significant yet often overlooked environmental health risk. Unlike outdoor air pollution, which is visible and widely recognized, indoor air pollution is insidious, affecting the air quality within homes, offices, schools,

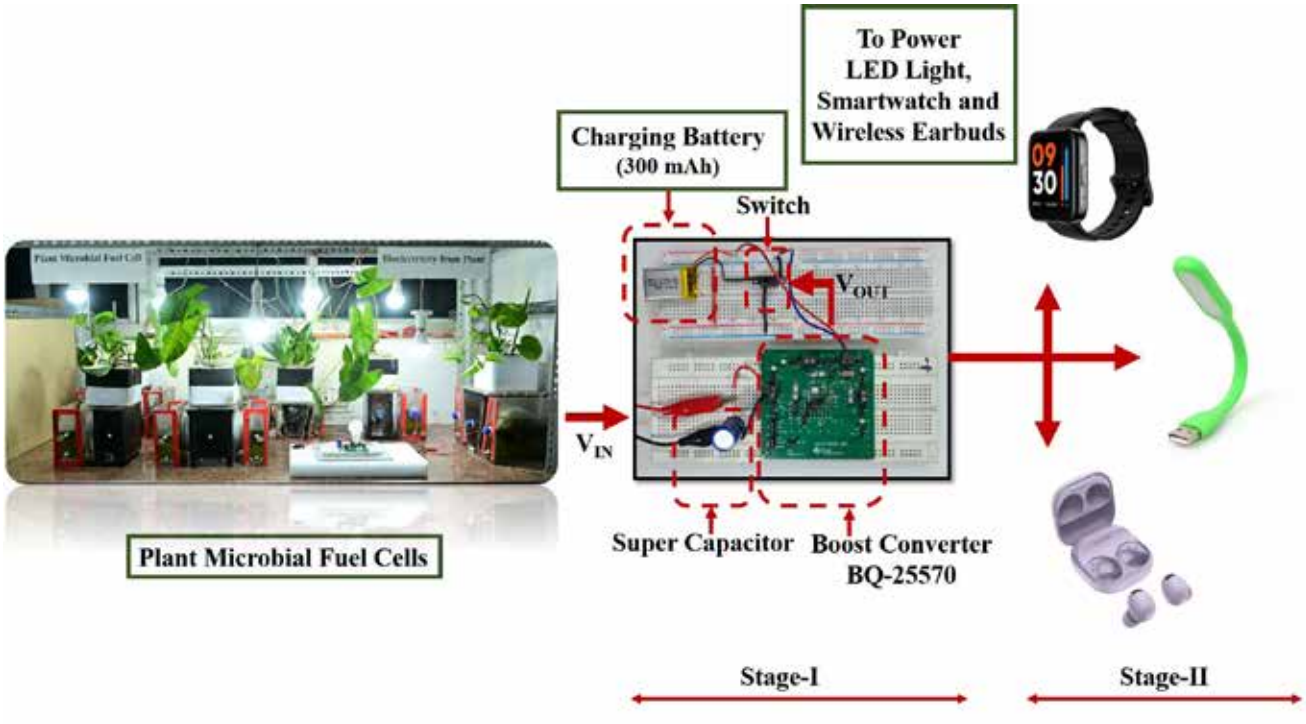

***Figure 2**: Bioelectricity generation from plant microbial fuel cell to power LED light, smartwatch and ear buds.*

and other enclosed spaces. Examples of some air pollutants include asbestos, formaldehyde, and volatile organic compounds (VOCs). Many indoor plants have the ability to mitigate various indoor air pollutants, and NASA recommends the use of indoor plants to improve air quality by removing toxic substances and absorbing CO_2. As these indoor plants are easy to grow, research is now exploring their capacity for bioelectricity generation alongside their environmental benefits. Therefore, as a part of our ongoing research work at The Energy and Resources Institute, Northeast Regional Centre, Guwahati, we are working on the design and development of indoor plant-based microbial fuel cell. We are using some of the widely known indoor plants such as Philodendron erubescens (Blusing plant), Epipremnum aureum (Money Plant) and Dracaena braunii (Lucky Bamboo) for large scale bioelectricity generation. It represents a cost-effective approach for the long-term sustainable bioelectricity generation, which is entirely green and operates 24×7, 365 days a year.

In today's world of advanced lifestyle, electronic gadgets are becoming increasingly widespread in daily life. Unlike our mobile phones, a smartwatch can make everyday life more accessible because of its multi-functionality including daily health monitoring. Similarly, at present a missing headphone jack in our mobile phones has pushed people to use True Wireless Stereo (TWS) to talk and stream music or audiobooks via Bluetooth. Therefore, our study is an effort to power LED lights and two crucial day-to-day use gadgets, i.e., smartwatch and wireless earbuds using plant microbial fuel cell. This innovative approach not only addresses indoor air pollution but also provides a sustainable solution for powering essential electronic devices.

Advantages of Plant Microbial Fuel Cell

The advantages of PMFCs are numerous and highlight the potential of this technology as a sustainable energy solution. Some key advantages are as follows. Renewable and Sustainable Energy: PMFCs utilize plants, which are renewable resources, as their primary fuel source. Unlike fossil fuels, which are finite and contribute to climate change, plants can be grown and harvested repeatedly, making PMFCs a sustainable energy option.

Waste Utilization: PMFCs can utilize various forms of organic waste, such as agricultural residues, food scraps, or wastewater, as fuel sources. This ability to harness waste materials not only provides an eco-friendly energy solution but also helps in waste management and reduces pollution.

Carbon Neutrality: PMFCs operate on a closed-loop system, where the carbon dioxide released during the plant's growth is offset by carbon dioxide consumed during microbial respiration. This carbon-neutral nature makes PMFCs environment friendly and helps reduce greenhouse gas emissions, contributing to mitigating climate change.

Low Environmental Impact: Compared to conventional energy generation methods, PMFCs have a significantly lower environmental impact. They do not require mining or drilling for fuels, and their operation does not produce air pollution or toxic by-products. PMFCs can be implemented in sensitive ecosystems without causing harm to the environment.

Scalability and Versatility: PMFCs can be scaled up to meet different energy demands, making them suitable for various applications. They can be deployed on a small scale to power individual devices or scaled up to power larger systems or communities. This scalability and versatility make PMFCs adaptable to different energy needs and locations.

Energy Access in Remote Areas: PMFCs have the potential to provide clean and sustainable electricity to remote or off-grid areas. In regions with limited access to traditional energy sources, PMFCs can utilize locally available plants and organic waste to generate power, improving the quality of life for communities in these areas.

Educational and Research Opportunities: PMFCs provide an excellent platform for educational purposes and scientific research. They allow students and researchers to explore the principles of plant physiology, microbial electrochemistry, and renewable energy generation. PMFCs can foster innovation, interdisciplinary collaboration, and the development of new technologies.

Integration with Green Infrastructure: PMFC technology can be integrated into green infrastructure projects, such as green roofs or vertical gardens. This integration enhances the sustainability of these structures by not only providing environmental benefits from declining urban landscape but also generating electricity, maximizing their potential as multifunctional systems.

Conclusion

Plant microbial fuel cells represent a groundbreaking technology with the potential to address multiple environmental challenges simultaneously. It provides a remarkable approach to renewable energy generation by harnessing the natural synergistic relationship between plants and microorganisms. Therefore, PMFCs offer a sustainable and eco-friendly solution to energy production, and climate change mitigation. As research progresses, PMFCs could play a crucial role in the global transition to a greener and more sustainable future. ■

Dr Pranab Jyoti Sarma works as a Research Associate in Agricultural and Rural Extension Area at TERI.

The Silent Hero of Sustainability

Lignin's Role in Reshaping Farming Practices

The potential of lignin, a natural polymer, in revolutionizing sustainable agriculture is being explored in this article. Often discarded as industrial waste, lignin offers a solution to the inefficiencies of conventional fertilizers. **Rohit Saxena** and **Dr Ruchi Agrawal** talk about the growing demand for slow-release fertilizers and lignin's cost-effectiveness, making it a promising alternative.

What if the secret to sustainable agriculture lies hidden in the heart of trees? Meet lignin, nature's wonder for controlled nutrient release. In an era where sustainability in farming is no longer an option, lignin offers a groundbreaking solution. By minimizing agricultural losses and maximizing efficiency, experts are turning to this natural innovation to reshape the future of farming and improve agricultural output.

Rise of Slow-Release Fertilizers

As agriculture embraces sustainability, slow-release fertilizers (SRFs) have risen to prominence. These innovations gradually release nutrients into the soil, reducing environmental runoff while enhancing crop productivity. At the heart of this transformation lies a surprising hero—lignin, a renewable byproduct of industrial processes. Lignin, a natural organic polymer found in the walls of plant cells, is attracting attention due to its distinctive properties and abundant availability.

Crop Residue Burning

In agrarian economies like India, the issue of crop residue burning persists. This practice releases up to 149 million tonnes of CO_2 annually, along with harmful particulates. However, lignocellulosic biomass from agricultural residues—rich in lignin—offers a sustainable alternative. By incorporating these residues into industrial lignin production, we could create a circular economy that both reduces air pollution and supports green agriculture.

Lignin, the second most abundant biopolymer after cellulose, is a complex polyphenolic compound often discarded as waste. Lignin is commonly generated as a byproduct in industries such as biorefineries, pulp, and paper, where it has limited use. Despite being treated as waste, lignin has remarkable properties that make it perfect for agricultural purposes. Its phenolic structure gives it resistance to microbial degradation, strength, and an ability to interact with plant growth-promoting bacteria (PGPR) and other beneficial soil compounds.

By diverting lignin from industries like biofuel and paper production, we could turn this waste into a high-value resource that enhances the sustainability of farming. Annually, industries generate millions of tonnes of lignin, with only a tiny fraction being repurposed. For instance, the pulp and paper industry produces approximately 50 million tonnes of lignin each year, with little being utilized. Second-generation bioethanol plants could yield up to 62 million tonnes of lignin by 2030, enough to coat billions of fertilizer granules.

Lignin for Sustainable Agriculture

The widespread use of conventional fertilizers often leads to inefficiencies. Fertilizers release nutrients too quickly, causing nutrient leaching, which leads to groundwater contamination and water pollution, including harmful algal blooms and oxygen depletion in aquatic ecosystems. Moreover, excessive use of fertilizers contributes to the emission of nitrous oxide, a potent greenhouse gas.

SRFs address these issues by gradually releasing nutrients, improving plant uptake, and reducing environmental damage. Historically, synthetic polymers like polyethylene and PVC have been used to coat fertilizers, but they come with significant drawbacks, such as environmental persistence, petrochemical dependency, and high economic costs. Lignin, however, offers a promising alternative. Its biodegradability, strength, and cost-effectiveness make it an ideal candidate for SRF applications.

Lignin's chemical structure can be modified to improve its binding capacity and interaction with fertilizers. This means lignin coatings can be customized to suit different crops, soils, and climate conditions. As a biodegradable polymer, lignin degrades slowly in the soil, releasing nutrients in a controlled manner with the help of microbes, moisture, pH, and temperature. This opens the door to innovations in precision agriculture, where nutrients are released exactly when needed. Additionally, nanostructured lignin

carriers could play a crucial role in improving precision farming, ensuring optimal nutrient release.

The SRF industry is currently valued at $2.3 billion (2021) and is projected to grow to $4.2 billion by 2030. This growth is fuelled by increasing demand for sustainable agricultural solutions that enhance crop yields while protecting the environment.

Synthetic Coatings Under Scrutiny: Regulatory frameworks are tightening globally, favouring biodegradable alternatives over synthetic materials.

Lignin's Edge: In addition to its environmental advantages, lignin enhances soil quality by adding organic matter as it decomposes naturally.

Closing the Loop

Imagine a system where industrial waste drives agricultural innovation. Lignin is the perfect embodiment of this vision, converting an undervalued byproduct into a high-impact resource. Not only does lignin offer an eco-friendly alternative to synthetic polymers, but it also contributes to a more sustainable planet by promoting circular economies.

It is time for the agricultural industry to embrace nature's genius by harnessing the potential of lignin-coated fertilizers. The innovation promises better crop yields and a more sustainable future for farming.

"As nature's own design for resilience, lignin reminds us that sustainable solutions often lie in the simplest, most organic places." ■

Rohit Saxena is a Research Consultant at TERI; Dr Ruchi Agrawal is a Fellow, Sustainable Agriculture Division at TERI.

Harnessing Nature

Role of Nature-Based Solutions in Sustainable Urban Development

This article highlights the potential of nature-based solutions to address climate change challenges and drive sustainable development in Indian cities. **Shivani Agrawal** explains how public-private partnerships can play a vital role in scaling up NbS, ensuring a climate-resilient future for urban areas.

As Indian cities grapple with unprecedented environmental challenges posed by climate change, urbanization, and biodiversity loss, conventional development approaches often fall short in providing effective and sustainable solutions. Nature-based solutions (NbS), with their multifaceted and integrated economic, environmental, and social benefits for ecosystems and communities, offer promising avenues for supporting planning approaches aimed at driving sustainable development and building resilience to climate change.

Despite their potential, NbS remain underutilized in mainstream development planning processes in India. This limited integration restricts ecosystems' capacity to build resilience and develop sustainable infrastructure capable of adapting to climate change. It becomes imperative to recognize the role of NbS in sustainable development, examine the limitations of current planning frameworks, and explore strategies for embedding the potential of NbS into development processes to enhance climate resilience.

Growing Relevance of Nature-Based Solutions

In the face of rising global temperatures, degrading ecosystems, and increasing extreme weather events such as floods, droughts, and heatwaves, the urgency to address climate change is becoming increasingly evident. These challenges are particularly prominent in the rapidly urbanizing regions of India, where the impacts of climate change are compounded by unsustainable development practices, high population densities, and inadequate infrastructure. In this context, NbS are gaining traction as essential tools for adapting to the impacts of climate change in cities.

NbS are nature-focused interventions designed to promote sustainable development while restoring natural systems and enhancing their capacity to deliver essential ecosystem services. They play a crucial role in achieving the United Nations Sustainable Development Goals (SDGs), offering holistic solutions that integrate and address social, environmental, and economic dimensions. For example, urban green areas can improve air quality and sequester carbon, while the restoration of urban blue areas can contribute to flood mitigation and groundwater recharge.

Environmental, Economic, and Social Benefits of NbS

NbS provide critical benefits for the protection and restoration of natural ecosystems, enhancing biodiversity and ecosystem service delivery. For instance, forests and wetlands are important natural assets that support carbon sequestration and reduce greenhouse gas emissions.

From an economic standpoint, NbS offer alternatives to resource-intensive engineered solutions by providing nature-driven approaches for risk mitigation, water management, and urban cooling. These solutions are often more cost-effective and sustainable in the long term.

Socially, NbS contribute to community resilience by providing ecosystem services that directly benefit local populations. For example, the restoration of mangroves addresses sea-level rise and storms, while reducing coastal erosion. Cumulatively, NbS present an effective strategy for advancing SDGs by enhancing economic resilience, environmental protection, and social equity. Therefore, integrating NbS into planning frameworks is vital for enabling climate action and promoting sustainability.

Integrating NbS into Development Planning Frameworks

Indian cities face a range of challenges that are further exacerbated by climate change. Despite the growing recognition of NbS, their integration into existing planning frameworks remains limited. Conventional infrastructure-driven planning at micro, meso, and macro levels often leads to ecosystem degradation and increased vulnerability to climate-related risks.

At the macro level, clear guidelines and incentives are needed for incorporating NbS into development strategies. At the meso and micro levels, state guidelines and development plans often overlook the value of ecosystem services and fail to account for the long-term benefits of NbS in mitigating climate impacts.

To effectively address climate change and promote sustainable development, integrating NbS into planning mechanisms at all levels is crucial. The planning framework needs to expand beyond the limited scope to include resilient, just, and inclusive development mechanisms that provide both environmental and socio-economic benefits. NbS should be integrated as central elements of development planning, not as supplementary solutions.

Guidelines for Policymakers

Policymakers play a pivotal role in driving integration of NbS into development processes. Several measures can facilitate the integration of NbS into planning mechanisms, some of them follow. Comprehensive Planning Guidelines: Policymakers must develop guidelines that incorporate NbS at all scales and stages of planning, from local zoning regulations to national-level policies.

Intersectoral Coordination: Integrating NbS requires coordination across sectors like water management, agriculture, and biodiversity conservation. Collaboration between government agencies, local communities, the private sector, and civil society is essential.

Assessment of Benefits and Feasibility: Policymakers should support tools and methodologies to assess the benefits, costs, and feasibility of NbS for climate adaptation and mitigation.

Monitoring and Evaluation: Continuous monitoring and evaluation of NbS projects are crucial for assessing their impact, adjusting strategies, and optimizing future outcomes.

Role of Participatory Mechanisms and Stakeholders

Participatory mechanisms can significantly enhance the uptake of NbS by fostering ownership and accountability. Involving local communities in both the design and implementation of NbS ensures that solutions are more targeted, appropriate, and widely accepted. By integrating local knowledge, participatory processes can improve the effectiveness of NbS initiatives.

The successful implementation of NbS requires collaboration among a diverse range of stakeholders. *Government*: Local and national governments play instrumental roles in providing frameworks, regulations, and financial resources to support NbS implementation.

Private Sector: The private sector can provide financing, technology, and expertise to develop and scale NbS solutions. Infrastructure and technology industries can push innovation and investments in green solutions.

Civil Society: Non-governmental organizations and environmental groups are crucial in advocating for NbS, ensuring their equity and inclusiveness, and raising public awareness.

Academic Institutions: Academic institutions can support the development of tools, conduct assessments, and generate evidence to guide NbS implementation.

Public-Private Partnerships and NbS

Public-private partnerships (PPPs) are powerful mechanisms for scaling up NbS in cities. By pooling resources from both the public and private sectors, PPPs can drive the development of NbS initiatives like urban green spaces, flood mitigation systems, and ecosystem restoration efforts. These partnerships can bring innovation, technology, and financing to overcome barriers to NbS implementation.

Government policies that promote NbS can signal opportunities for private-sector investment, encouraging businesses, philanthropies, and multilateral development banks (MDBs) to invest in green infrastructure, sustainable technologies, and climate-resilient initiatives at all scales. Therefore, PPPs can play a crucial role in supporting sustainable and climate-resilient development.

Conclusion

Integrating nature-based solutions into development planning presents a critical opportunity to address the dual challenges of climate change and sustainable development. By harnessing the potential of NbS, cost-effective and multifaceted approaches to climate adaptation and mitigation can be offered. Their integration into development planning at all scales is essential for creating resilient ecosystems and communities capable of enduring climate change impacts.

Key stakeholders from the government, private sector, civil society, and local communities are critical enablers of NbS on the ground. Policymakers play a central role in facilitating the necessary frameworks and incentives for NbS integration, while the private sector provides essential support through innovation, investment, and expertise. Through participatory processes and partnerships, NbS can be scaled up and embedded in development strategies.

In conclusion, the integration of NbS into development planning for sustainable development and climate change is not only an opportunity but an imperative. This approach will lay the foundation for sustainability from the ground up, fostering a resilient, equitable, and environmentally balanced framework for harmonized climate action in India. ■

Shivani Agrawal works as a Project Associate, Earth Science and Climate Change Division at TERI.

India's CSR Evolution

A Journey from Philanthropy to Sustainable Development

India's CSR spending trends from 2017 to 2023 reveal increasing participation, with education and healthcare remaining key focus areas. **Ayush Rai**, **Anjali Sachdev** and **Dr Amit Kumar Thakur** trace how India's CSR has evolved through four significant phases going from philanthropy-driven actions to strategic business initiatives aimed at mitigating social issues.

India's Corporate Social Responsibility (CSR) journey has evolved through four significant phases, shaped by socio-economic, cultural, and political contexts. Over time, CSR has shifted from philanthropy-driven initiatives to a more structured and strategic business function that aligns with both corporate goals and societal needs.

Phase 1: CSR Driven by Charity and Philanthropy (1850-1914)

During the pre-industrial era and early stages of industrialization, CSR was largely synonymous with charity and philanthropy. Influential business families, such as the Tatas, Birlas, and Godrejs, engaged in welfare activities, establishing schools, temples, and hospitals. The roots of CSR during this period were deeply intertwined with culture, traditions, family values, industrialization, and religion. The concepts of *dhan* (wealth), *dharam* (duty), and *dakshina* (charitable offering) were fundamental in shaping the CSR landscape.

Phase 2: Gandhi's Theory of Trusteeship (1914-1960)

Mahatma Gandhi's theory of trusteeship revolutionized CSR by linking it to social justice and nation-building. During this period, family businesses established trusts for building schools, colleges, and training institutions. Gandhi advocated that industrialists view themselves as trustees of society's wealth, promoting equitable distribution and contributing to India's independence movement and community development through initiatives in education, healthcare, and rural upliftment.

Phase 3: CSR in a Mixed Economy (1960-1980)

Post-independence, India adopted a mixed economy model where the state played a pivotal role in social welfare. Public sector undertakings (PSUs) were expected to lead CSR efforts, while private sector involvement dwindled due to a focus on growth and stringent regulations. This era also saw the emergence of several public enterprises and the introduction of corporate governance, labour, and environmental legislation.

Phase 4: Philanthropic and Business Approaches (1980 till present)

From the 1990s onwards, economic liberalization, privatization, and globalization transformed the CSR landscape in India. Businesses began to view CSR not just as a philanthropic activity but as a sustainable strategy. Companies integrated CSR with business objectives, addressing issues like sustainability, education, healthcare, and social development. CSR evolved from ad-hoc charity to strategic initiatives that aligned with corporate goals and long-term sustainability.

Evolution of CSR Legislation in India

The legal framework for CSR in India has undergone significant changes, driven by an increasing recognition of businesses' role in societal development.

***Figure 1**: Evolution of CSR Legislation in India (Ministry of Corporate Affairs, 2025)*

2007: The 11th Five-Year Plan introduced the concept of inclusive growth, which set the stage for integrating social objectives into economic development.

2009: Voluntary guidelines on CSR were released by the Ministry of Corporate Affairs, encouraging companies to voluntarily address societal concerns.

2010: The Parliamentary Standing Committee reviewed the 21st Report on the Companies Bill, 2009, proposing CSR as a key aspect of corporate governance.

2011: The National Voluntary Guidelines (NVGs) on social, environmental, and economic responsibilities of business provided a comprehensive framework for responsible business practices.

2012: Business Responsibility Reporting (BRR) was mandated for top-listed companies to disclose their CSR activities in alignment with NVGs.

2014: CSR became mandatory under Section 135 of the Companies Act, 2013, requiring eligible companies to allocate 2 per cent of their average net profits towards CSR activities, marking India as the first country with a legislated CSR mandate.

Mandatory CSR Provision under the Companies Act, 2013

Section 135 of the Companies Act, 2013, mandates that companies with an annual turnover of ₹1,000 crore or more, net worth of ₹500 crore or more, or net profit of ₹5 crore or more, must constitute a CSR committee. These companies are required to spend at least 2 per cent of their average net profits over the previous three years on CSR activities. This provision aims to supplement the government's efforts to ensure that corporate growth benefits society as a whole.

CSR Spending Trends

CSR spending in India between 2017 and 2023 has shown varying trends across different expenditure brackets.

- **₹0-50 lakh:** This category saw the highest participation in 2018-2019, with 21,986 companies contributing.
- **₹1-10 crore:** Maximum participation occurred in 2022-2023, with 5,025 companies contributing.
- **₹10-100 crore:** In 2022-2023, 337 companies participated, marking the highest number in this range for over six years.
- **₹100-500 crore:** The highest participation in this bracket occurred in 2022-2023, with 37 companies contributing.
- **Above ₹500 crore:** The maximum participation occurred in 2019-2020,

***Figure 2**: The CSR expense trends from 2017 to 2023 (Ministry of Corporate Affairs, 2025)*

with 6 companies making significant contributions.

These trends show that Indian companies' commitment to CSR is increasing, with varying participation based on financial capabilities.

Way Forward: CSR Beyond 2030

As CSR participation increases, the focus on education and healthcare remains strong, while emerging areas such as livelihood development, rural growth, and natural resource conservation are gaining attention. With concerns over climate risk and environmental sustainability, CSR spending is expected to rise in these areas. Regulatory amendments, such as allowing unspent CSR amounts to be carried over for three years for ongoing projects, are also shaping the future of CSR.

CSR in India is evolving into a more structured, collaborative effort involving the government, businesses, NGOs, and partner organizations. The focus is shifting towards long-term impact, with companies focusing on flagship programmes that align with both societal needs and corporate goals. CSR is poised to become a catalyst for societal change, driving new socio-economic models in the coming decades.

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Revenue Generation and Decarbonization

India's CCTS as a Model for Climate Action

By introducing a mandatory compliance mechanism and a voluntary offset system, the CCTS aims to help India meet its climate targets and support a low-carbon transition. The implementation of this scheme will help India contribute to the achievement of Sustainable Development Goals (SDGs), while positioning the country as a global leader in climate action, **Nishtha Singh** and **Alistair Ritchie** write.

The implications of rising greenhouse gas (GHG) emissions on social and economic dimensions of daily life are yet to be fully understood. Climate change is driving humanity into uncharted territory, with extreme weather events becoming increasingly prevalent. These changes impact communities differently and have cascading effects on various sustainable development goals (SDGs).

The social and economic costs of climate change, compounded by GHG emissions, are immense. Governments face increased expenditures due to damage from extreme weather, alongside revenue losses. Carbon pricing emerges as a pivotal mechanism to address climate change, creating financial incentives to adopt low-carbon solutions. A well-crafted carbon pricing policy not only drives decarbonization in a cost-effective way but also generates significant government revenue. This revenue can be allocated to support stakeholders transitioning to a sustainable, low-carbon economy and fund climate-resilient and sustainable development.

India's Carbon Credit Trading Scheme

India's Energy Conservation Amendment Act, 2022 set the stage for a Carbon Credit Trading Scheme (CCTS). This initiative includes a mandatory compliance mechanism (a credit-based emissions trading system) for energy-intensive industry and power sectors and a voluntary offset mechanism. These instruments aim to help India meet its nationally determined contributions (NDCs) targets under the Paris Agreement by facilitating decarbonization, attracting clean technology investments, and mitigating risks from international measures such as carbon border adjustment mechanisms (CBAMs).

Globally, auctioning emissions allowances in emissions trading systems (ETS) for sectors that can bear to pay carbon costs has proven effective. It aligns with the 'polluter pays principle,' creating a robust price signal to reduce emissions. Auctioning also generates revenue for governments, which can be channelled into clean energy investments, just transition for communities reliant on fossil fuels, and support for vulnerable households. The CCTS's compliance mechanism presents an opportunity to generate significant revenue, supporting a cost-effective and equitable low-carbon transition for India while setting an example for other economies.

Revenue Generation Potential of India's CCTS

India's CCTS could yield substantial revenue if it incorporates the auctioning of allowances, a practice seen in leading ETS globally. In the power sector alone, auctioning allowances could generate an estimated $700 billion to $1.4 trillion by 2050[1]. Additionally, with CBAMs being implemented and considered by multiple jurisdictions, introducing auctioning for a certain proportion of allowances in energy-intensive industrial sectors may also be beneficial, by reducing CBAM charges and increasing government revenue that could be recycled to facilitate industrial decarbonization.

The pace of decarbonization could be further accelerated by providing early finance for companies, in advance of auctioning, as demonstrated by Japan's Climate Transition Bond.

Learning from international ETS frameworks, India can design its system to balance industrial competitiveness with emission reduction. The revenue generated through CCTS can support a just transition and bolster India's position as a leader in climate action.

Key Pillars for Effective Auctioning in CCTS

Ensuring a Conducive Power Market Ecosystem

The ability of a sector to pass carbon costs through to product prices is crucial for auctioning allowances. Globally, the power sector is the primary sector where this cost pass-through is most feasible. It is also one of the most important sectors to include in an ETS due to the scale of available cost-effective GHG emission reductions. As such, ensuring that the power market integrates seamlessly with the CCTS is essential for an optimized system.

For effective integration, carbon costs should influence power station dispatch decisions encouraging a shift to lower-carbon fuels and renewables, and such costs should be reflected in retail electricity prices to promote emission reductions from demand-side management. Some of the auction revenue could be used to mitigate potentially higher electricity costs for vulnerable consumer groups. Furthermore, in India, where the power sector faces challenges such as subsidies, inefficiencies in distribution companies (DISCOMS), and limited investment in infrastructure, a cost pass-through mechanism can alleviate financial strain, which could reduce subsidies, enhance efficiency, and improve electricity access.

Designing a CCTS Optimized for Auctioning

India's CCTS, as proposed, is a credit-based ETS, similar to Australia's Safeguard Mechanism and the first phase of Japan's GX-ETS. While credit-based systems can generate revenue, there is much greater scope for this with an allocation-based system, as seen globally. As such, GX-ETS is expected to transition from a credit-based to an allocation-based system in the next phase to enable auctioning for the power sector.

India should develop a long-term plan for evolving the design of the CCTS compliance mechanism, taking into account the potential transition to an allocation-based system, as well as other options related to target/cap-setting and allocation. Such a plan would provide greater long-term certainty and predictability to obligated entities to help make effective decarbonization investment decisions.

Crafting an Effective Revenue-Earmarking Strategy

To maximize the benefits of auctioning under India's CCTS, the country will need a robust strategy for earmarking revenue that aligns with its broader decarbonization and equity objectives. This will involve identifying sectoral decarbonization targets and allocating funds to overcome specific economic and technical barriers, ensuring progress toward climate goals. The need of vulnerable stakeholders should be assessed, including industries and communities dependent on fossil fuels, to mitigate the social and economic

1 https://asiasociety.org/policy-institute/financing-just-transition-through-emission-trading-systems

impacts of the transition. Revenue distribution must be equitable and transparent, supporting stakeholders in achieving emission reduction targets while addressing potential energy cost increases for vulnerable populations. Additionally, selecting suitable financial instruments tailored to India's context is critical, drawing on best practices such as direct cash transfers, transition funds, and investments in alternative livelihoods for coal-dependent communities. Such a strategy would ensure that the transition is both just and effective.

Establishing Robust Governance for Auction Revenue

India's past experiences with initiatives like District Mineral Foundation and the coal cess highlight the importance of a robust governance structure to ensure that auction revenues are utilized effectively. Drawing lessons from global ETS frameworks, such as the EU ETS with its centrally and regionally managed funds, can provide valuable guidance for India. In a federal system, governance mechanisms must balance both national and state-level priorities. An effective partnership between key stakeholders within the state and national government can ensure efficiency and effectiveness of the system. For instance, a central decarbonization fund could be established to support the industrial and power sectors, aligning with overarching national objectives. Simultaneously, state-managed just transition funds could focus on addressing local needs, particularly in coal-dependent regions, ensuring an equitable and region-specific approach to transitioning to a low-carbon economy.

Carbon Pricing and its Impact on SDGs

Carbon pricing's ability to internalize the social costs of GHG emissions positions it as a powerful tool for achieving multiple SDGs. Its influence spans economic, social, and environmental dimensions. Some of the more obvious direct and indirect impacts of carbon pricing are summarized below.

Direct Impacts

SDG 13 (Climate Action): Carbon pricing incentivizes and ensures cost-effective GHG emission reductions, encouraging the adoption of cleaner technologies and achieving national and global climate targets.

SDG 9 (Industry, Innovation, and Infrastructure): Carbon pricing drives innovation by incentivizing a wide range of low-cost emission reduction techniques and by providing financial support to promote the adoption of advanced and innovative technologies that are not yet commercially viable.

SDG 7 (Affordable and Clean Energy): Carbon pricing enhances the economic viability of renewable energy, accelerating the transition away from fossil fuels towards clean energy systems.

Indirect Impacts

SDG 8 (Decent Work and Economic Growth): The shift to a low-carbon economy creates new markets and job opportunities in green sectors, contributing to sustainable economic growth. Carbon pricing could generate the revenue required to accelerate the achievement of these opportunities equitably.

SDG 10 (Reduced Inequalities): Revenue distribution mechanisms can alleviate the financial burdens on marginalized groups, promoting social equity.

SDG 3 (Good Health and Well-Being): GHG emission reductions are closely associated with improvements in air quality, leading to better public health outcomes and lower healthcare costs.

Conclusion

India's upcoming CCTS represents a transformative opportunity to address climate change while advancing achievement of SDGs. Through strategic design and governance, the system can generate substantial revenue, drive decarbonization, and support a just transition. Leveraging global best practices and tailoring them to India's unique context will be critical for the success of this ambitious initiative. By prioritizing inclusivity, equity, and sustainability, India can position itself as a global leader in climate action. ■

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Resource Reality

Mapping India's Critical Mineral Needs for Clean Energy Success

With India's ambitious eye on Net-Zero 2070, the demand for clean energy is seeing a surge. The newer technologies based on renewable energy has put stress on the demand for critical minerals like copper, lithium, cobalt, nickel, graphite, among others. In this article, **Animesh Ghosh** and **Soumit Pandey** estimate India's critical mineral demands in the years to come.

The global transition towards renewable energy has significantly increased the demand for critical minerals (CM), like copper, lithium, cobalt, nickel, graphite[1], and rare earth elements. These minerals are essential for manufacturing materials of clean energy (CE) technologies, including solar panels, wind turbines, battery energy storage systems, and electric vehicles[2][3]. As the adoption of these technologies accelerates, the demand for CM is projected to rise substantially in the coming decades, raising concerns about supply and sustainability[4][5]. As a fast-developing economy, India is actively

participating in this energy transition but has increasingly relied on imports to meet the demand for these essential materials[6][7]. Despite India's ample domestic resources, low and ineffective domestic production has hindered the establishment of a self-reliant supply chain, making imports indispensable. This dependency exposes India to significant geopolitical risks, including supply disruptions and price volatility arising from global competition and monopolistic control by mineral-rich nations[8]. As the global energy transition accelerates, these risks will likely intensify, further threatening India's CE aspirations and necessitating a robust and strategic approach to critical mineral management.

To address these challenges, India needs to develop a comprehensive strategy to secure the supply of critical minerals (CM) required for its clean energy (CE) transition. Possible

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approaches include diversifying import sources[9], investing in domestic exploration and mining[10], and developing recycling and circular economy solutions[11] to reduce reliance on primary resource extraction. Government initiatives like Viksit Bharat and Vocal for Local aim to strengthen domestic critical mineral exploration and supply chains, which are vital for achieving net-zero emissions by 2070. The 2024 budget underscores self-reliance, while India's membership in the minerals security partnership ensures global supply security. While the Ministry of Mines has identified 30 CM aligned with CE goals, reliance on imports and uncertainties in global supply persist. A coordinated strategy involving industry, government, and research institutions is essential to achieving a sustainable and resilient energy future.

Importing CM Key to India's CE Transition

To address ongoing concerns, importing CM is essential for India's CE transition. However, growing global demand and supply chain challenges require a strategic approach to ensure energy security and sustainability[12][13]. This necessitates focusing on domestic exploration, international partnerships, and circular economy solutions to address supply-demand imbalances[14]. It is crucial to assess the need for CM in significant milestone years: 2030 (short-term, aiming for 50 per cent of energy requirements from renewable sources), 2047 (mid-term, marking the 100th anniversary of India's independence under the Viksit Bharat initiative), and 2070 (long-term, targeting net-zero carbon emissions). Evaluating scenarios such as business-as-usual, deterministic, and heroic can provide valuable insights into the potential effects of these policies.

The ACPET team examined CE sub-technologies in generation and storage to assess import dependencies, domestic production capabilities, and strategies to enhance value chains. Unlike prior studies, this research linked critical mineral demand to sub-technologies with technology readiness levels (TRLs) above four, incorporating market share projections. It analysed three scenarios and identified the minerals required for solar (PV & CSP), wind (onshore and offshore), and battery energy storage systems (BESS). The study also explored recovery potential from end-of-life products and proposed policies for sustainable, effective technology adoption.

IESS 4.0 as the Basis of Study

The study's approach consisted of four key elements. Firstly, it is based on NITI Aayog's IESS 4.0 framework, which considers three scenarios: business-as-usual (Trajectory 2 of IESS), deterministic (Trajectory 3 of IESS), and heroic (Trajectory 4 of IESS). Secondly, the technology selection incorporated technology readiness levels (TRL) 4-9 and accounted for variations in market share. Thirdly, capacity projections analysed cumulative installed capacity, plant retirement capacity patterns, and technology-specific deployment scenarios. Lastly, the literature review provided specific insights into mineral requirements, including material intensity mapping, recovery rates,

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uniform circularity considerations, and yearly variations.

The methodology involved a three-step process. First, it evaluated CE technologies across various renewable energy segments (solar, wind, and BESS). Secondly, it estimated the total cumulative demand for CM required by each segment. Finally, it calculated the actual total requirement for CM, factoring in the effects of recovery of CM and circularity. This approach provided a comprehensive overview of the mineral needs for India's energy transition.

In the solar segment, both photovoltaic (PV) and concentrated solar power (CSP) technologies were analysed. The PV analysis incorporated eight sub-technologies that considered different cell architectures and manufacturing processes. At the same time, the CSP assessment covered two sub-technological variants based on thermal storage and power generation mechanisms. For wind energy, the research framework was structured to analyse both onshore and offshore installations. The onshore wind assessment included five sub-technologies focusing on different turbine configurations and generation capacities. Offshore wind analysis encompassed four sub-technologies, considering fixed and floating foundations besides varying power ratings. The most extensive battery storage analysis examined six fundamental chemistries: lithium, vanadium, sodium, lead, nickel, and bromine. This segment investigated 20 sub-technologies, accounting for different electrode materials, electrolyte compositions, and cell designs. Comprehensive categorization enabled a detailed assessment of material intensity and technological evolution pathways for each sub segment.

Copper-Critical Mineral with Highest Cumulative Demand

Although this study evaluates cumulative requirements and CM recovery across all three scenarios, the deterministic scenario was emphasized more. This aligns closely with India's realistic path towards achieving net-zero emissions and sustainability goals, representing a feasible and actionable

approach within the nation's context. Within this framework, our analysis reveals significant implications for the cumulative requirements of five prominent CMs—copper, nickel, cobalt, graphite, and lithium—that are integral to India's renewable energy transition by 2070. These materials are crucial in advancing CE technologies, underscoring the importance of addressing supply vulnerabilities and recovery potential.

Copper exhibits the highest cumulative demand in the deterministic scenario. Demand for copper is projected to increase ~18 times by 2070 to reach net-zero, compared to ~394 kilotonnes (KT) in 2023. This substantial increase reflects copper's critical role in electrical conductivity and thermal management across renewable technologies. Demand for nickel is projected to increase ~156 times by 2070 to reach net-zero, compared to ~14 KT in 2023. Graphite's requirements show aggressive growth due to the increasing market share of next-generation Perovskite Solar PV and BESS applications. Demand for graphite is projected to increase ~148 times by 2070 to reach net-zero, as compared to negligible demand in 2023. Finally, cobalt and lithium show significant cumulative demand by 2070 due to the increasing market share of various BESS applications. Demand for cobalt and lithium is forecasted to rise approximately ~104 times and ~148 times by 2070, respectively, compared to the negligible levels recorded in 2023.

The findings highlight significant supply vulnerabilities. Despite substantial domestic copper reserves (163.89 MT)[15] and graphite reserves (8.56 MT)[15], current imports of 2,097.82 KT[15] and 108.76 KT[15] indicate infrastructure, cost-effective technology, policy support, and processing capacity limitations. More critically, nickel, lithium, and cobalt show complete import dependence, with zero active domestic reserves and current imports of 158.41 KT[15], 1679.29 KT[15], and 1,484 tonnes[15], respectively. It is important to note that the import figures referenced encompass a range of industries across India and are not limited to the renewable energy sectors (solar, wind, and BESS) analysed in this study. Material recovery from end-of-life clean technologies presents a partial mitigation strategy. Copper recovery is expected to increase by ~92 times its current level of ~1.7 KT in 2023 by 2070, whereas nickel recovery is projected to grow by ~99 times by 2070 as compared to ~0.55 KT in 2030. In contrast, cobalt and lithium indicate minimal growth, with cobalt expected to rise ~10 times (in KT) and lithium anticipated to rise ~12 times (in tonnes) by 2070, compared to negligible recovery in 2023. However, graphite recovery faces technical constraints due to separation difficulties and structural complexity, necessitating exclusion from recovery projections.

15 Indian Bureau of Mines. (2024, December). Indian Minerals Yearbook 2022: Volume II (Mineral Reviews) (61st ed.). https://ibm.gov.in/writereaddata/files/17333871367516381eea84IMYB_2022_Volume_II.pdf

Way Forward Towards India's CE Mineral Transition

The study reveals critical challenges and opportunities in India's CE mineral transition by 2070. Despite limitations in data availability and modelling constraints, the research demonstrates that CM demand will increase dramatically, with materials like copper, graphite, and lithium projected to rise 18-156 times under the deterministic scenario. The findings highlight significant vulnerabilities in India's CE transition strategy, particularly the heavy import dependency on essential minerals like cobalt, lithium, and nickel. Key bottlenecks identified include limited graphite recoverability and the absence of domestic lithium production, which pose substantial risks to energy storage deployment. The analysis further reveals that current recycling capabilities are insufficient to address the projected supply gap.

Based on these insights, we recommend a three-pronged policy approach: promoting CE technologies with optimized mineral requirements, securing CM reserves through domestic development and sustainable import partnerships, and strengthening the mineral recovery ecosystem through appropriate policy support. Success in achieving net-zero emissions by 2070 will depend on establishing robust domestic supply chains and effectively implementing these policy measures. Future research should address the current limitations, particularly in data availability and technology trajectories, to provide more precise projections and policy guidance for India's CE transition. ■

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Green Public Procurement

Opportunities and Challenges for India

GPP prioritizes environment-friendly products in government procurement, aiming to reduce the nation's ecological footprint. India's efforts in this area began with the Draft Public Procurement Bill of 2012, followed by the formation of a Task Force on Sustainable Public Procurement in 2018. **Saon Ray** and **Agastya Kushari** delve into the requirements for successful implementation of GPP viz., robust policy framework, awareness, and scaling up of GPP tools.

The discussions at COP 29 highlighted that Green Public Procurement (GPP) is not just a policy tool but a critical lever for achieving broader climate goals through stimulating demand for greener products (UNFCCC, 2024). GPP is a practice where governments and central authorities prioritize procuring goods and services that minimize environmental impact throughout their lifecycle (EPA). This article examines GPP in India, where public procurement constitutes approximately 20 per cent of the GDP (Ministry of Finance, 2019). This provides vast potential for GPP for sustainable economic development and influences the nation's environmental footprint.

Early Initiatives and the Draft Public Procurement Bill (2012)

The introduction of GPP in India was seen when the government presented the Draft Public Procurement Bill 2012. This bill mandated the integration of environmental considerations into public procurement processes. By embedding environmental impact assessments into procurement decisions, it tried to align India's public spending strategies with its broader environmental objectives, fostering sustainable development through responsible resource allocation. India has previously attempted to reduce harmful environmental impact through prior initiatives such as the Ecomark Scheme in 1991. The Ecomark Scheme focused on labelling products that meet environmental criteria for consumers. Another initiative was the Standards and Labelling Scheme, which focused on energy efficiency. Neither initiative greatly impacted the nation's environmental footprint; both found limitations surrounding nationwide adoption, scale, and implementation issues. Subsequently, in 2018, the transition towards public procurement was initiated by establishing India's Task Force on Sustainable Public Procurement (Ministry of Finance, 2020). This task force is responsible for drafting a plan for the future implementation of GPP and for observing global practices while simultaneously assessing India's current status of GPP. By learning from international practices and altering them for an Indian context, the task force aims to build a framework for sustainable public procurement in multiple sectors. International experiences with GPP vary from voluntary standards of the EU to eco-labels environmental certification by the US and incorporating lifecycle costs in the case of Germany (TERI, 2024).

Focus on Steel and Cement Industries

Public procurement in India is currently heavily seen in the steel and cement industries, which are crucial for infrastructure development (RMI, 2024). Additionally, these sectors have a great impact on greenhouse gas emissions. The enhancement of GPP can significantly impact emission reductions in these specific industries.

Impact of Carbon Border Adjustment Mechanism (CBAM)

Another interesting point to consider is the implication of the Carbon Border Adjustment Mechanism (CBAM) on GPP. The EU has already introduced CBAM, in which tariffs are imposed on imports based on their carbon footprint. This mechanism will take effect in 2026 and has sparked considerable debate about its implications for global trade and climate equity. Through CBAM, a nation can promote cleaner practices in global trade. India can leverage its GPP initiatives to mitigate the impacts of CBAM while advancing sustainability. By prioritizing low-carbon materials in public procurement, India can comply with international standards and stimulate domestic markets for green technologies. This alignment could help reduce emissions in key sectors like construction and manufacturing (RMI, 2024).

The potential of GPP implementation is particularly significant in the steel and cement industries. These industries are also likely to face a significant impact of CBAM. They are primary sources of greenhouse gas emissions, and reducing carbon output from environmentally friendly practices will greatly impact India's overall ecological footprint. Therefore, with the implementation of GPP, the steel and cement industries have the potential to lead the nation in shifting the market to environmentally conscious production practices.

Encouraging Private Sector Participation Through Public Procurement

India's government could also set a strong example for the private sector by using green products and technologies in public procurement, which could expand the private sector's market for environmentally friendly products. For GPP to be successful in India, there must be a unified effort to embrace environmental concerns in public procurement. We can look to low-carbon technologies and materials for public construction projects as an example of potentially reducing India's environmental footprint. In addition,

India's demand for green products will grow and provide more demand for suppliers to create and adopt sustainable practices. Erizaputri and Bechauf (2024) recommend strengthening the policy framework, building awareness and skills for GPP, developing and scaling up GPP tools, and establishing robust monitoring mechanisms.

GPP holds the potential for sustainable economic growth. Notwithstanding the challenges (RMI, 2024), if India integrates environmentally conscious practices into public procurement, India will be able to make progress towards its carbon neutrality goals. Effective implementation of GPP will demand a united effort across various sectors and government bodies (Erizaputri and Bechauf, 2024), along with adopting initiatives such as the Ecomark Scheme and the Standards and Labelling Scheme. Along with transparency efforts, such as GeM, the government can promote environment-conscious practices and shift the market towards sustainable production.

Way Forward

Going forward, GPP will be essential for India's commitment to its environmental goals and sustainability objectives. If India spearheads the global idea to prove that economic growth and environmental degradation are not mutually exclusive, India's economy will be able to grow because of environment-conscious practices. GPP is a necessary first step towards establishing a greener future and will allow India to showcase its commitment to sustainability and environmental responsibility. Implementing GPP as a standard practice in India would ensure the nation can compete globally while simultaneously fulfilling its environmental responsibilities.

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Microbial eCBM Technology

The Future of Sustainable Coalbed Methane Extraction

Microbial eCBM technology provides numerous benefits, including environmental sustainability, cost-effectiveness, and improved productivity. **Dr Meeta Lavania** and **Dr Banwari Lal** discuss how through bio-stimulation and bio-augmentation, the process significantly increases methane production from coal seams, especially those with low permeability.

As the world increasingly shifts towards sustainable energy solutions, the search for cleaner, more efficient ways to extract coal bed methane (CBM) is gaining momentum. CBM has emerged as a significant unconventional natural gas resource, contributing to global energy production. Primarily consisting of methane, CBM is an atypical hydrocarbon gas. CBM is formed and stored in coal seams through adsorption. CBM extraction involves the recovery of methane gas trapped within coal seams, offering both economic and environmental advantages (Figure 1). Microbial eCBM is an innovative biotechnological approach that involves the use of microorganisms to enhance the production of methane from coal seams. It is considered a cleaner and more sustainable method for extracting methane, as it can unlock methane from non-extractable coal reserves. It has the potential to contribute significantly to natural gas supply, particularly in regions with large coal resources but limited traditional gas extraction methods.

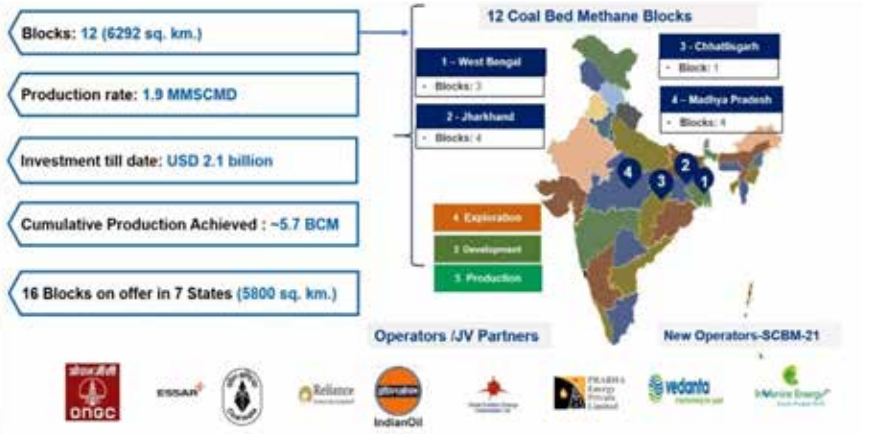


Figure 1: *CBM operations in India*

How does Microbial eCBM Work?

The two primary routes of microbial enhancement in eCBM technology are:

Bio-stimulation: This involves injecting nutrients into coal seams to stimulate the growth of indigenous methanogenic microbes that naturally produce methane.

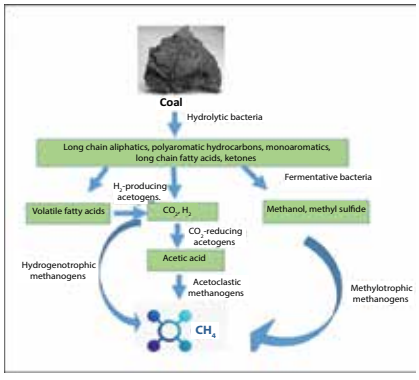


Figure 2: *Overview of the process of bio-methanation from coal*

Bio-augmentation: This involves the introduction of external methane-producing microbes along with nutrients to further increase methane production.

Microbes interact with the coal matrix and help to convert coal into methane gas (Figure 2). They primarily function by:

Methanogenesis – Methanogens can directly produce methane from coal through a process known as microbial methanogenesis.

Coal Degradation – Microbial communities help degrade the complex organic structures within the coal, making it easier to release trapped methane.

Water Reduction – Some microbes reduce the water saturation in coal seams, improving the permeability and allowing for easier methane release.

Synergistic Effects – The interaction between different microbial species can enhance the overall bioconversion process, maximizing methane production.

Benefits of Microbial eCBM Technology

Microbial eCBM technology boosts CBM production by enhancing methane yield, especially in low-permeability seams, while offering environmental and cost benefits. It reduces reliance on energy-intensive methods, minimizes water usage, and lowers operational costs by avoiding extensive modifications. Additionally, it improves well productivity and long-term production potential, making it a sustainable and efficient alternative to conventional CBM extraction techniques.

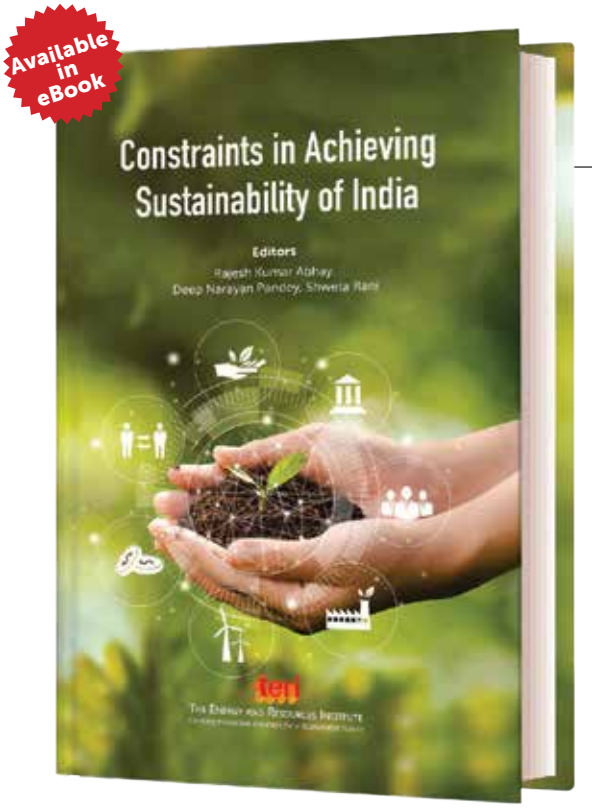
In field trials conducted by TERI, the bio-stimulation process resulted in a threefold increase in methane production from a CBM well. Bio-augmentation at Jharia led to more than a twofold increase. The microbial-enhanced CBM technology was successfully tested in over 12 CBM wells, including those operated by ONGC and Essar.

Conclusion

Microbial eCBM technology is a promising frontier in the field of coalbed methane production. By harnessing the power of microorganisms, this technology can significantly enhance methane recovery, reduce environmental impact, and offer a more cost-effective solution to the energy industry. As research and development continues, microbial eCBM has the potential to become a cornerstone of clean energy production, helping to meet global energy demands while advancing the goals of carbon neutrality and sustainability. ■

Dr Meeta Lavania is Senior Fellow, Environmental & Industrial Biotechnology Division, TERI; Dr Banwari Lal is Senior Fellow & Senior Director, Environmental & Industrial Biotechnology Division, TERI.

Study of the challenges to sustainable development via scientific means



Major topics covered

- Sustainable Development: concept, components and history
- Environment, Culture, and Sustainable Development
- Sway of Indian Cinema in Diffusing Environmental Sentience
- Poverty Lines and Poor in India
- Sanitation Workers and Associated Problems for the Sustainability of Religious Events
- Assessment of Basic Infrastructure Development and Associated Issues in India

ISBN: 9789394657120 • Price: ₹550.00

Purpose of the book is to develop, contribute, and disseminate scientific knowledge pertaining to the issues related to sustainable development. The chapters are developed so that the contents can facilitate comprehension of the major constraints in achieving sustainability including but not limited to environmental, social, economic, and governance-related issues from local, regional, to national level. Resource management, climate change, agriculture, population, education, women, poverty, infrastructure, crime, corruption, governance, are the other relevant topics that have been both identified and suitably discussed. *Constraints in Achieving Sustainability of India* can be utilized as a guiding tool for realizing sustainability in development, especially, in the Indian context.

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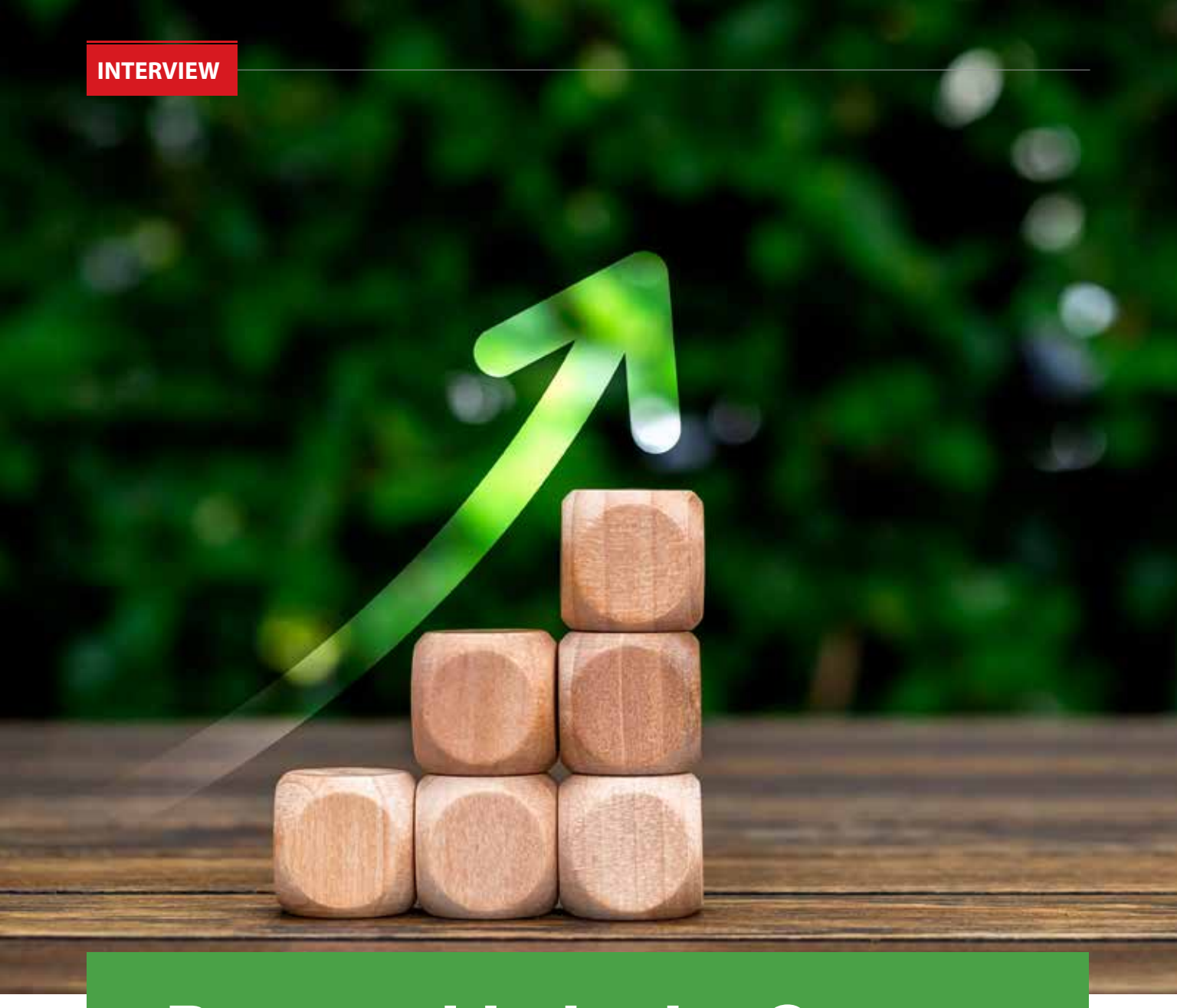


Partnership in the Context of Sustainable Development and Climate Solutions

In this conversation with *TerraGreen*, **Rushikesh Chavan**, Head, The Habitats Trust, outlines the role of partnership in the context of sustainable development and climate solutions. As per him—the most crucial enabler for partnerships is a shift in mindset. We must transition from being gatekeepers to being aggregators, co-creators, and facilitators. True partnerships require empathy, active collaboration, and a hands-on approach.

What, in your view, defines effective partnership in the context of sustainable development and climate solutions?

Effective partnerships in sustainable development go beyond transactional relationships. They require deep, transformative collaborations where partners may need to sacrifice short-term gains for long-term impact. These partnerships must involve diverse stakeholders—sometimes seemingly unrelated—who come together with a shared commitment to multi-solving. A holistic approach is essential, where solutions address interconnected challenges, offering a collective path forward to address the complex challenges arising from climate crisis.

How do you envision integrating climate solutions and sustainability across policies, industries, and sectors?

I personally believe that we are late for sustainable solutions because resources have dwindled, climate crisis may no longer offer us the luxury of time. What we need are regenerative solutions. These solutions will not only have to solve the issue but regenerate resources or functional natural processes. Thus, making policies across sectors very important. We will have to address the aspirations through regenerative solutions, which should address the spirit of policies at multiple levels from local self-governance to policies at the centre. This can possibly be done through an approach where we go beyond 'balance between environment and economy' to how regenerative solutions that benefit both environment and economy. This may require efforts that are in addition to conventions policy white papers and advocacy. We will have to set up working models with the help of policy makers, especially, the think tanks such as NITI Aayog.

What means of implementation and enabling environment are needed to encourage partnerships involving different stakeholders?

The most crucial enabler for partnerships is a shift in mindset. We must transition from being gatekeepers to being aggregators, co-creators, and facilitators. True partnerships require empathy, active collaboration, and a hands-on approach. Once we embrace this spirit of collective action, the external environment will align—creating a fertile ground for impact. While funding is vital, the real challenge is mobilizing stakeholders who are committed to the cause. When we approach these collaborations as architects, not just

fundraisers, we unlock the potential for exponential change.

Can you provide an example of how your organization has used partnerships to accelerate sustainable development and climate solutions?

One of The Habitats Trust (THT) core value is collaborations. Thus, in everything we do, we collaborate. Today THT has over 120 partners ranging from government agencies, armed forces, sports organizations, non-governmental organizations, researchers, and grassroots individuals. There are thus over 50 examples. However, if I have to name one I will pick our Lakshadweep project. Where we are developing an integrated plan for development of the archipelago. We have partnered with local organization, researchers, Department of Science and Technology, Department of Tourism, Indian Navy, Indian Coast Guard, local communities, and Biomimicry 3.8 (a design firm). If we are able to find a solution, we will be able to multi-solve various challenges such as energy, water, waste management, tourism, livelihoods, economic sustenance of the islands, and more. Thus, offering a comprehensive, regenerative solution that can serve as a model for other island communities facing similar challenges.■

Partnerships: key to sustainable development

Ami Henson, CEO, Weeyacom LLC, in this dialogue with *TerraGreen* establishes how enduring partnerships are a prerequisite for arriving solutions aimed at sustainable development. She is of the opinion, means of implementation and enabling environment are needed to encourage partnerships involving different stakeholders. Weeyacom is a woman-owned firm that empowers clients to make sense of a complex world by co-designing custom approaches to monitoring, evaluation and learning (MEL) that generate more sustainable development and security sector solutions.

What, in your view, defines effective partnership in the context of sustainable development and climate solutions?

Effective partnerships begin with establishing the needs and why: shared purpose and values, a clear understanding of how a systemic approach and cross-sectoral solutions address what changes are needed, and mutual trust, ensuring all stakeholders are aligned towards the common goals. Whether addressing hunger, renewable energy, or climate adaptation, successful partnerships recognize the interconnectedness of these issues and the value of systemic approaches to create lasting, transformative change.

They leverage the unique strengths of diverse actors, including governments, businesses, academia, and civil society,

to address interconnected challenges by identifying and leveraging convening powers of the different partners. Transparent governance, equitable resource sharing, strong relational coordination, and the integration of local knowledge are crucial for ensuring sustainability and scalability. This collaborative foundation ensures that partnerships adapt to changing contexts, delivering results that address the root causes of complex global challenges.

How do you envision integrating climate solutions and sustainability across policies, industries, and sectors?

Climate solutions as well as Sustainable Development Goals inherently involve wicked problems that demand multi-sectoral approaches and coordinated funding mechanisms. We can no longer operate in silos with separate water, health, or energy projects. For example, integration across sectors is essential. Policies must prioritize cross-cutting solutions that align economic growth with environmental resilience, while industries and governments work together to embed sustainability and sustainable development at every level. This requires decision-makers to adopt systems thinking and systems innovation as they design new programmes. Partnerships that bridge public, private, and community interests are critical for addressing interconnected challenges, such as food security, clean energy, and climate adaptation. By integrating diverse perspectives and leveraging shared resources, we can create holistic solutions that are scalable and sustainable.

What means of implementation and enabling environment are needed to encourage partnerships involving different stakeholders?

Successful partnerships thrive in a supportive environment with policies that prioritize collaboration and innovation. Such policies must translate into incorporation of collaboration goals in programme designs and contracts. This includes funding mechanisms like blended finance, capacity-building initiatives for stakeholders, and platforms for real-time data sharing. Tools such as USAID's Five Rs Framework—covering roles, resources, rules, results, and relationships—can not only guide effective implementation but lock in commitment from partners. Leveraging both Theory of Change (TOC) management and Monitoring, Evaluation, and Learning (MEL) frameworks is essential for guiding impactful and adaptive partnerships. Governance systems should balance international expertise with local leadership, ensuring equity and cultural sensitivity. Systemic design that integrates human-centred design and systems thinking enables inclusive decision-making and adaptive strategies. Finally, trust-building through transparent communication and shared accountability fosters long-term partnerships that thrive across diverse contexts.

Can you provide an example of how your organization has used partnerships to accelerate sustainable development and climate solutions?

TERI, PSNC, LMI, Farm Monitor and Weeyacom are partnering on an innovative project leveraging Orange-Flesh Sweet Potatoes (OFSP) to address hunger, poverty, and climate change, with TERI spearheading the effort and LMI initiating and developing the cross-cutting strategy. The initiative integrates the global IT experts of PSNC and Farm Monitor in cutting-edge technologies, which enables optimizing biofertilizers, smart agribusiness IT, and bioeconomy solutions, to maximize OFSP's potential as a functional food and superior second-generation biofeedstock. A feedstock that emanates from potentially the best use and securitization of arable land. And new players will be engaged in the programme, as it sets up the

overall framework for addressing critical needs the UN SDG experts and the Pact for the Future say are so critical. The societal value of this cuts across the sustainable farming community; business and industry's joint profit and sustainability goals; community economic development enabling job-creation through cross-sectoral value chains; nutrition and health implications and parties; climate- and water-sensitive parties; and more.

Weeyacom's role is to support and enhance collaboration among cross-sectoral stakeholders to facilitate goals attainment for individual participants and across the sectors. This systemic approach aligns with SDG 17 by breaking down silos to tackle interconnected challenges holistically. While much work has been done and this is being launched piece by piece, we are still in the funding stage for launching the holistic solution. But the project demonstrates the power of partnerships to deliver scalable and sustainable solutions, addressing critical global needs in food security, climate resilience, and economic development. ■

Partnerships to Accelerate Sustainable Development and Climate Solutions

In this interaction with *TerraGreen*, **Katie McGinty**, Vice President and Chief Sustainability and External Relations Officer, Johnson Controls, gives us her insights on the relevance of leveraged partnerships to accelerate sustainable development and climate solutions. She opines "an effective partnership is rooted in shared purpose, trust, and accountability." She also shares how her organization, Johnson Controls, is making positive contributions towards realization of sustainable development, notably in the Indian context.

What, in your view, defines an effective partnership in the context of sustainable development and climate solutions?

Sustainable goals necessitate a partnership-led or collaborative approach, as these goals are inherently meant to serve achieve the combination of economic, environmental, health, and security goals. Sustainability progress serves the wider community as a whole and is best accelerated by the combination of civil society, global north and south, governments, business, academia all at the table together

An effective partnership is rooted in shared purpose, trust, and accountability. It demands alignment of goals, resource sharing, and a commitment to innovation. At its core, such collaborations bridge diverse expertise—from industries deploying scalable solutions, governments helping to accelerate deployment through policies that encourage and incentivize adoption, to communities ensuring grassroots impact. Transparent communication and measurable outcomes further cement trust and effectiveness. For instance, global initiatives like the UN's Race to Zero bring diverse stakeholders together to align on science-based targets. In India, following the state government directive, several cities in the state of Maharashtra are developing Climate Action Plans (CAPs) to address climate risks, including Mumbai's climate budget, which integrates sustainability into urban planning and development. These examples underscore the importance and potency of collective action—the convergence of ambition, action, and inclusivity.

How do you envision integrating climate solutions and sustainability across policies, industries, and sectors?

For climate action to be effective, there needs to be a holistic approach that involves embedding sustainability as a foundational principle across all

sectors, rather than something that is an after-thought or add on. Policies must incentivize the adoption and implementation of efficiency first—working to reduce emissions and waste as the top priority since such action cuts costs and frees up capital for further climate action and delivers the clean environment that protects health and well-being. After efficiency is maximized, then investment can accelerate renewable energy growth, and sustainable infrastructure more broadly. Building circular economy structures where materials are reused and repurposed in the economy are also powerfully effective in cutting emissions and waste. In this regard, governments play a catalytic role in driving change, by implementing green standards and financing mechanisms and building necessary supportive infrastructure.

Globally, initiatives like the US Inflation Reduction Act, the EU Green Industrial Deal, and the Singapore '80-80-80' Green Building Initiative illustrate how cross-sectoral policies enable systemic shifts. In India, the National Solar Mission has been pivotal in integrating renewable energy across industries. At Johnson Controls, our work exemplifies this—combining cutting-edge technology with policy engagement to scale decarbonization in several sectors from health care to aviation, to real estate. Such models underscore the power of synergizing policy and industry action to drive universal impact. Bringing the power of technology and partnership together enables us to drive results that are good for people and the planet. With a pharma company in India, for example, Johnson Controls has shown that we can reduce energy consumption by 45%, resulting in $1.2M savings, while also significantly cutting carbon emissions. At our own factories we demonstrated that leaning into decarbonization bolsters the bottom line, cutting emissions more than 40% and operating costs by nearly $1M/year. These examples are critical since we can accelerate climate action when we demonstrate that prosperity and taking care of the planet go together rather than representing inherent tradeoffs.

What means of implementation and enabling environments are needed to encourage partnerships involving different stakeholders?

Creating an enabling environment hinges on robust policy frameworks, financial mechanisms, educational and awareness mechanisms, and capacity-building initiatives. Public–private partnerships can amplify resources, while clear governance structures ensure accountability. Equally important is fostering a culture of innovation and collaboration among stakeholders. Platforms like the World Sustainable Development Summit (WSDS) provide a vital forum for dialogue and partnership-building.

Globally, the adoption of carbon financing mechanisms has encouraged businesses to invest in sustainable technologies. In India, green bonds are mobilizing capital for climate-friendly projects. Furthermore, last year's Union Budget made significant provisions for advancing India's sustainability goals, including enhanced budgetary allowances (from INR 128.5 bn to INR 191 bn) for renewable energy, with an emphasis on solar, thermal, and nuclear energy projects.

Johnson Controls, through its partnerships, has demonstrated how collaboration with stakeholders across various sectors and Tier-1 and Tier-2 urban centres can accelerate progress. A key example includes our work with the All-India Institute of Medical Sciences in Gorakhpur, Uttar Pradesh where state-of-the-art and high-efficiency cooling and infection control technologies are deployed. This supports not only in providing quality health care, but also drives progress towards decarbonization for the state.

Can you provide an example of how your organization has leveraged partnerships to accelerate sustainable development and climate solutions?

At Johnson Controls, partnerships are central to our mission of creating smarter, healthier, and more sustainable buildings. A compelling example is our recent collaboration with the Mahindra Group to launch the Net-Zero Buildings Initiative. This is a first-of-its-kind partnership, which integrates cutting-edge technologies, such as AI-driven building management systems, to decarbonize India's commercial, urban residential and public buildings. This initiative comprises a cost-free, all-in-one toolkit and training, with a view to help building and facility owners learn about best practices of sustainable buildings. The toolkit empowers them to understand implementation strategies to assess building parameters, identify and implement conservation measures, and understand building regulations in India, available incentives, technology, financing models, etc.

Together, we are working to create scalable models for net-zero campuses in India and beyond. By aligning with Mahindra's sustainability vision and leveraging our technological expertise, this initiative exemplifies the transformative power of partnerships in achieving Sustainable Development Goals. It underscores our belief that partnership accelerates impactful climate solutions. ■

‘Climate Mitigation Not A Cakewalk’

Multi-Stakeholder Collaboration a Pre-Requisite to Achieve Goals

As India marches on the path of sustainability, guided by Net-Zero 2070 goal, collaboration and streamlined approach is the need of the hour. **Mr Sanjay Seth, CEO, GRIHA Council**, weighs in on effective stakeholder collaborations, international coordination regarding shared climate mitigation targets. He speaks to **Harshita Kaur** on the implications of the future that the world holds courtesy climate change and unsustainable practices.

What in your view defines effective partnership in the context of sustainable development and climate solutions?

Sustainable development and climate mitigation are not a cakewalk. It is a journey that needs to be covered together, ensuring no one is left behind! In these unprecedented times, when everyone is talking about scaling up climate solutions, multi-stakeholder collaboration is a pre-requisite if we want to achieve our national and international goals limiting global warming. In the current climate discourse and conformity to the global SDG 17 (Partnerships for the Goals), it is evident that both top-down and bottom-up approaches are necessary to accelerate climate action at all levels, viz., government, private and public sector, and civil society.

By leveraging the strengths of every stakeholder group, we must explore and share our knowledge, expertise, experiences, innovations and technologies that are directed towards mitigating climate impacts and building a sustainable future. To expedite this, strengthening multilateralism and cooperation between the Global North and the Global South plays a crucial role. Identifying the capacities, gaps and disparities at all levels, various domains must be prioritized to build inclusive and equitable engagement processes. The Agenda 2030 presents an opportunity to address the shortcomings whilst bridging the global North-South divide, thereby, promoting a more balanced approach to implementing global SDGs and climate action.

How do you envision integrating climate solutions and sustainability across policies, industries and sectors?

Climate solutions are an amalgamation of roles and responsibilities of every stakeholder involved in the process. For instance, aligning with global and national commitments, the Government of India launched various policies and programmes such as the Swachh Bharat Mission, Rooftop Solarization Programme, adoption of green buildings, sustainable transportation, etc., that will be propelled by industry response and end-user adoption.

For making the policies conducive, industries play a significant role by bringing the market shift, thereby enhancing the 'adapt and adopt' patterns at the end-user level.

For instance, to tackle the menace of air pollution, the Government of India introduced the Bharat Stage (BS) Emission Standards for all motor vehicles to regulate vehicular emission standards. After implementing the BS I to BS IV norms, the Government of India implemented the BS VI norms in 2020 skipping the intermediate policy. This has pushed the automobile industry to optimize vehicle designs, invest in research and development for identifying appropriate technologies and reduce costs while ensuring a sustainable supply chain infrastructure and an enhanced uptake by consumers. This exemplifies how policies, industries and end-users together have a crucial role in ensuring implementation and acceleration of climate actions.

What means of implementation and enabling environment are needed to encourage partnerships involving different stakeholders?

Nations worldwide are developing national policies and programmes that are in tandem with the shared global sustainability and climate mitigation targets. For instance, India is a signatory to major global environmental conventions and treaties including the Montreal Protocol on Substances that Deplete the Ozone Layer. Aligning with the global framework, the Government of India launched the India Cooling Action Plan (ICAP) to improve energy efficiency, reduce direct and indirect emissions, enhance refrigerant transitions, and promote energy-efficient technologies. In this case, the industry's response to this initiative will drive market changes through cost-effective and sustainable solutions. Further, the success of this programme relies on spreading awareness and incentivizing adoption via labelling programmes.

Similarly, the misconception that green buildings are expensive is a myth. There is a need to demystify this thought by raising awareness and changing the mindset to make the right choices at the right time. Incorporating green building features early in the design phase can effectively manage expenses, resulting in long-term cost savings. However, if the design and material selection processes are skipped, and plug-ins of materials are subsequently introduced, then these materials will come at an additional cost. At the policy level, state governments and municipal bodies play a crucial role by offering incentives like additional Floor Area Ratio (FAR), tax benefits, and faster approvals to developers and users opting for green buildings.

These are a few examples based on the 'push and pull' model where policy drives innovation, industry facilitates adoption, and consumers embrace change.

Can you provide an example of how you at GRIHA use partnerships to accelerate sustainable development and climate solutions?

Collaborations and partnerships work as enablers in accelerating climate action. We have collaborated with a diverse set of stakeholders that include academic institutions, industry bodies, government entities, etc. By formalizing these partnerships through memoranda of understanding (MoUs), we foster a

shared vision and enable collaborative alliances to achieve more inclusive and sustainable outcomes.

Our partnerships with academic institutions facilitate in the development of novel, innovative and cutting-edge research and solutions. Collaborating with the industry bodies helps us understand the viability and applicability of the research while offering practical, scalable solutions depending on the market demand. The government partners provide crucial policy support and regulatory frameworks. Together, each one of us contributes to create a robust ecosystem that facilitates the implementation of climate solutions.

Furthermore, training and capacity building of industry professionals and the workforce is another essential component in accelerating climate action. By offering customized capacity-building and training programmes, we equip individuals with the required skills and knowledge to drive sustainable practices within their organizations and beyond. Furthermore, it enhances the sector's capacity to transition to sustainability and promote a long-term systemic shift ensuring far-reaching impacts, thereby contributing to the greater vision of building a climate-resilient future.■

Harshita Kaur is Research Associate at TERI.

Reducing Greenhouse Gas Emission in Electric Grid

Pathbreaking New Circuit Breaker Technology Promises to Keep Emissions in Check

A new innovation in circuit breakers used in high tension power grids claims to cut down the Global Warming Potential against the conventional SF6-based switchgears. **Akilur Rehman** explains how the EconiQ™ switchgear, employing the environment-friendly C4-FN gas, promises to reduce carbon footprint while offering the same reliability, performance, scalability, and compactness of the device.

Circuit breaker, a part of system called switchgear in the electric power grid, is used widely for switching high power under live power flow conditions. A safety device, the circuit breaker works akin to the common household electrical switches. The difference lies in the magnitude of power handled by the device, which is some one billion times that of light switches at our homes.

Handling around 420 kilovolt (kV) and 63,000 amperes (A) of power at the time of switching, the core arcing temperatures can reach up to 20,000°C while the overall contact separation speed reaches 120 km/h within a span of tens of milliseconds. To quench this arc and provide electrical insulation at the same time, a gas called sulphur hexafluoride (SF_6) is widely used in high

voltage switchgear due to its unique thermal, insulating and arc quenching properties during switching of high voltage, high current lines.

While SF_6 fulfils critical requirements of electric grid, it is a greenhouse gas 24,300 times more potent than CO_2, that stays in the atmosphere for over 1,000 years. As it brings a significant environmental threat and liability, research efforts had been underway for several decades to replace SF_6.

Breakthrough in Circuit Breaker Technology

To help the power sector tackle this problem, Hitachi Energy has come out with the world's highest volt-age SF_6-free switchgear — the EconiQ™ 550 kV circuit breaker that can be used in gas-insulated switchgear (GIS) or as a standalone 420 kV circuit breaker. Developed with the help of scientific and engineering principles, as well as design rules, the EconiQ™ portfolio delivers on all parameters. The C_4-FN gas used in small percentages within the eco-efficient EconiQ™ mixture enables the equipment to retain its compact size and minimize material usage, which further reduces the overall carbon footprint. By maintaining the reliability, performance, scalability and compactness of conventional SF_6-based products, EconiQ™ ensures a seamless transition for customers.

For instance, each new 550 kV GIS substation using EconiQ™ eliminates the carbon equivalent of 170 fully booked jumbo jets flying from Paris to New York while retaining the size, performance, and relia-bility levels of traditional switchgear. There are, and there will be thousands of such high voltage switch-gears (circuit breakers and substations) that can use this SF_6-free technology for a significant change in reducing carbon footprint in the electric grid.

World's first SF_6-free eco-efficient 420 kilovolt circuit-breaker

How Does EconiQ™ Fare

Replacing SF_6 in high-voltage to reduce the impact of greenhouse gas emissions in the global power industry is important for moving towards carbon-neutrality. A diluted mixture of natural gases with 3.5 per cent of F-gas with a Global Warming Potential (GWP) of 390 is used, essentially eliminating the car-bon footprint of SF_6 (GWP of ~25,000). Diluted mixture is non-toxic, does not accumulate in water, plants, or soil, and decomposes in the atmosphere into natural substances.

- It delivers same technical performance, size and reliability as SF_6 equipment
- Developed and available today
- Lowest carbon footprint in life cycle assessment (low material-use)

EconiQ™ is eco-efficient system for sustainability, where products, services and solutions are proven to deliver exceptional environmental performance. This SF_6-free innovation will go a long way in not only making the energy assets environment-friendly but also helping the energy transition towards net-zero.■

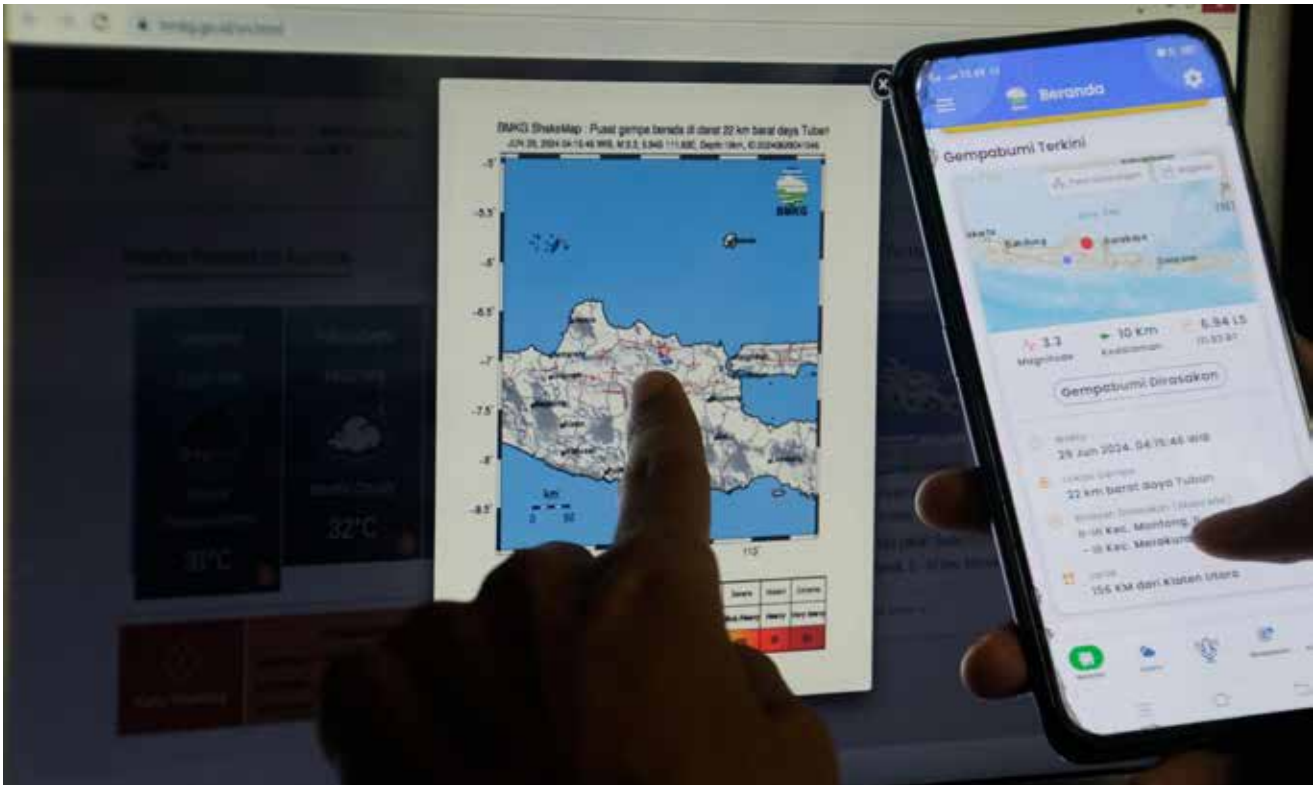
Akilur Rehman is Chief Technology Officer and Market Innovation Lead-South Asia at Hitachi Energy.

AI and Early Warning Systems

Can AI Become a Gamechanger in the Event of a Disaster?

Early warning systems can be life saviour in the event of extreme disasters. With many nations now recognizing the importance of EWS for prevention and mitigation, the technology remains constrained to developed nations due to multiple factors. In this article, **Alice Hill** and **Colin McCormick** report how AI is bringing about a shift in the paradigm of warning systems and bat for equally accessible EWS for developing nations and is a step in the right direction.

Early warning of an incoming disaster — a monster storm, extreme rainfall, or fast-moving wildfire — can save lives and livelihoods by giving people more time to prepare. But for much of the world, early warning remains a distant dream, even as climate change-worsened extremes increasingly ravage the planet. Cost-benefit analyses have repeatedly shown that money invested in mitigating risk from extreme weather can yield big payoffs in reducing damage. According to the UN, just 24 hours of advance notice can reduce damage by 30 per cent, and $800 million invested in early warning systems (EWS) in developing countries could prevent losses of up to $16 billion. Yet currently, thirty per cent of the world's population still lacks access to EWS. In Africa, that percentage doubles. To close the early



warning gap, the UN has launched a goal of 'Early Warning for All' by 2027.

Role of AI in Disasters

The backbone of any effective EWS is accurate weather forecasts. Artificial intelligence can provide faster and, in many instances, more finely tuned forecasts than conventional approaches. In just the last few years, artificial intelligence has become a powerful tool to fast-track forecasts and is rapidly changing the landscape for early warnings.

Consider California's AI-powered wildfire detection system implemented by Cal Fire, the state's main firefighting agency. Using a network of over one thousand high-definition cameras, the system detects and warns firefighters of emerging threats at the earliest signs of smoke. During piloting, California officials reported that the software was able to alert firefighters accurately even before dispatch centres received emergency calls around 40 per cent of the time.

Google is similarly co-developing FireSat with Muon Space, the Earth Fire Alliance, and others. The initiative will utilize a wide array of satellites to monitor the Earth's surface and update imagery for authorities every 20 minutes, far more rapidly than satellite imagery currently available to officials. The AI is trained on infrared sensors that identify heat signatures and feed the detection models, allowing for early detection of fires as small as five-square metres, enabling effective responses.

Collaborative Efforts to Clear the Hurdles

In some cases, the challenge for weather forecasting is providing more local, granular predictions that conventional weather models miss. A good example is the collaboration among Oxford University, the World Food Programme, and the IGAD Climate Prediction and Applications Centre. This team has trained AI models to refine conventional low-resolution forecasts, zooming-in to create highly specific rainfall and flooding forecasts across East Africa. Notably, these models can be run on a laptop, instead of the expensive supercomputers required for conventional forecasts.

To be sure, barriers to effective early warning systems still exist. They include — among other things — a paucity of trained meteorologists in the developing world, a lack of historical data to support AI, funding challenges, limited infrastructure, and energy use during AI training. But given the payoff of early warning in reducing loss of both life and economic damage, AI has already proven to be one of the most promising ways to close the early warning gap. ■

Alice C Hill is David M Rubenstein Senior Fellow for Energy and the Environment Council on Foreign Relations; and Colin McCormick is Chief Innovation Officer at Carbon Direct.

From Waste to Worth

Partnerships Addressing Marine Litter

Marine litter and climate change are closely connected as plastics contribute to greenhouse gas emissions and stronger storms worsen littering. A pilot project in Goa, funded by the EU and led by TERI, demonstrates a circular economy approach by involving local fishermen in the collection and upcycling of discarded fishing nets. **Dr Ashwini Panandiker** details how the initiative is offering an innovative solution to reduce marine litter while also providing economic opportunities.

Marine litter and climate change are interconnected global challenges. Plastics discarded into the ocean degrade over time, releasing greenhouse gases such as methane and ethylene, which intensify global warming. Conversely, the effects of climate change, including stronger storms and rising sea levels, exacerbate marine litter by washing debris into waterways. This vicious cycle harms marine biodiversity and reduces the ability of ecosystems like mangroves and coral reefs to sequester carbon effectively, further accelerating climate change.

Collaboration Key to Tackle the Menace

Addressing the complex issues require collaboration across sectors. Governments, industries, researchers, and communities must work together to create sustainable waste management systems. Circular economy models that focus on minimizing waste and maximizing resource reuse, offer promising solutions to reduce both marine litter and greenhouse gas emissions. Partnerships are essential for raising public awareness and ensuring that everyone contributes to protecting marine ecosystems and mitigating climate change. Such collaborations enable scalable and lasting solutions.

TERI and EU's Joint Initiative

One example of such an initiative is a pilot project implemented in Goa by TERI, with funding from the European Union Resource Efficiency Initiative. This project focused on establishing a collection mechanism for discarded fishing nets, emphasizing the importance of partnerships across the value chain. The project was supported by the Directorate of Fisheries and the Goa State Pollution Control Board, and it engaged approximately 215 traditional fishermen from villages such as Siridao, Odxel, and Cacra.

The project aimed to: (i) understand the challenges faced by fishermen in disposing of fishing nets; (ii) raise awareness about the impacts of marine plastic litter; (iii) provide training on upcycling discarded fishing nets into reusable products on a small scale; and (iv) explore opportunities for establishing a collection mechanism and promoting mass recycling. As part of this initiative, hands-on training workshops on upcycling scrap fishing nets were conducted and attended by 56 participants. These workshops resulted in the creation of decorative products from discarded nets, showcasing the potential of turning waste into valuable items.

To close the loop, the project involved all key stakeholders, including fishermen from pilot villages, government bodies like the Directorate of Fisheries, Goa State Pollution Control Board, Goa Waste Management Corporation, aggregators or scrap net dealers, retailers of fishing nets, and industries specializing in recycling discarded fishing nets. A collection drive in the pilot villages resulted in the recovery of approximately 500 kg of discarded fishing nets. The aggregator compensated fishermen for their contributions and purchased the scrap nets, which were then sent to an industrial facility for mass recycling. This process prevented the nets from being discarded in the ocean or incinerated. Awareness campaigns also educated fishermen on proper cleaning and separation of ropes to maximize financial returns.

Key outcomes of the project included: (i) creating a replicable demonstration model for promoting circular economy principles and reducing marine litter; (ii) successfully engaging key stakeholders across the value chain; and (iii) establishing responsible end-of-life management for discarded fishing nets, showcasing the feasibility of circular economy practices.

Way Forward

Building on the lessons learned from this project, the way forward includes several crucial steps. First, there is a need to increase awareness among fisherfolk about the proper disposal of fishing nets. Second, infrastructural improvements such as establishing collection points in small villages, must be prioritized. Existing Material Recovery Facilities (MRFs) at the panchayat level could be utilized for this purpose. Finally, the Directorate of Fisheries could develop and implement policies for the proper disposal of discarded fishing nets and organize periodic collection drives to ensure their effective management.

This pilot project highlighted the importance of partnerships in tackling marine litter. By fostering collaboration and adopting sustainable practices, it is possible to protect marine ecosystems, mitigate climate change, and move closer to achieving a circular economy.■

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Optimizing Waste Management

How BBMP is Monitoring Source Segregation of Waste Effectively

The Unique Household Numbering System in Bengaluru enhances waste management by tracking segregated waste from individual households and improving compliance with segregation guidelines. Successfully implemented in the Dasarahalli zone, the system has led to an increase in segregation levels, optimizing recycling and composting processes, while also fostering accountability and transparency in waste management, **Chandreyee Mitra, Mohammed Idris** and **Jai Kumar Gaurav** write.

The Waste Solutions for Circular Economy Project, aimed at enhancing sustainable waste management, has introduced the Unique Household Numbering System (UHNS) to streamline waste tracking and segregation monitoring. Through UHNS, each household is assigned a unique number, which enables easy tracking of segregated waste from individual households and ensuring better compliance with waste segregation guidelines. This initiative plays a crucial role in achieving the project's objective of a circular economy by emphasizing sustainability on collection of segregated waste.

A Unique Initiative by BBMP

By integrating UHNS into the waste collection workflow, the Bruhat Bengaluru Mahanagara Palike (BBMP) sanitation staff can link the collected waste to specific households. This linkage allows authorities to identify areas with poor segregation practices and take necessary actions. The system not only enhances transparency but also enables effective monitoring and evaluation of waste management practices. Furthermore, UHNS significantly improves operational

efficiency by reducing errors and redundancies in waste collection processes while optimizing collection routes and resource allocation, thereby saving time and resources. The UHNS also serves as a motivator for households to adopt and adhere to segregation guidelines.

The project has successfully implemented the Unique Household Numbering System (UHNS) across all eight wards of the Dasarahalli zone in Bengaluru, demonstrating its effectiveness in enhancing waste management practices. This implementation has led to rise in waste segregation levels, showcasing the potential of UHNS to drive accountability and promote sustainable source segregation practices at the community level. With the help of this project initiative, the segregation level of the 8 wards has increased by 10~15 per cent approximately.

The rise in segregation levels has also resulted in furthermore benefits, such as:

- Better segregation of wet, dry, and hazardous waste at the source
- Optimization of resource recovery processes such as composting and recycling
- Reduced contamination of recyclable materials
- A few challenges occurred during the implementation of UHNS, and they need to be addressed for the successful adoption of the model
- Resource limitation - due to a lack of knowledge about the system of the implementation team (ULB sanitation staff)
- Technological barriers - due to low digital literacy among stakeholders and poor internet connectivity in some areas can hinder the effective use of digital tools

Way Forward: Scope and Achievements

The project hence introduced this system to BBMP sanitation staff during capacity-building sessions. These sessions are designed to provide comprehensive training to the staff, equipping them with the knowledge and skills necessary to implement the Unique Household Numbering System (UHNS). The pilot's success created a scalable framework, paving the way for broader adoption across multiple wards. By empowering ULB sanitation staffs, the initiative may create a sustainable framework, facilitating the Unique Household Numbering System's replication across cities.

The UHNS can be made more effective by considering the following steps:

- ULB sanitation staff should receive more hands-on training to use the system effectively.
- Households that comply with these guidelines can be rewarded. ■

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Thriving Fields

Enhancing Soil Health and Crop Production with Less Inputs

Rising global population, shrinking arable land area pose a major challenge of feeding people. This is further marred by rapidly declining soil quality and reduced crop production. In this article, **Dr Mandira Kochar** and **Dr Vatsala Koul** share a disruptive strategy of inclusion of biological agri-inputs for enhanced crop productivity and soil enrichment in the Indian context while simultaneously reducing impacts on the environment.

Shrinking per capita arable land, surging population, and rising demands are posing a big challenge of the millennium — producing more food to feed the people while safeguarding the environment at the same time. Climate change is increasingly leading to frequent and unexpected environmental fluctuations globally. Productivity and resilience in agriculture are the topmost priorities of Government of India and it plans to focus on climate-resilient agriculture through resilient crop varieties as well as introduce farmers to natural farming. The excessive usage of chemical agri-inputs has led to degraded soil health, reduced soil fertility and deteriorated soil quality globally (1/3rd of world's soil is degraded as per FAO, 2015). This has led to declined productivity and pushed the world into food insecurity for its ever-growing population. Due to cascading issues like climate change and related

environmental concerns, food supply will fall by 12 per cent over the next 25 years, triggering a 30 per cent increase in the prices of food. On one hand, healthy soil can provide balanced nutrients to plants, essential for good crop production but soils are becoming depleted in carbon content, ground water polluted with nitrates, along with increased nitrous oxide and methane emissions into the air. With the natural resource base getting depleted and degraded, major disruptions in food and its production system will, without doubt, force the agricultural system to change.

Natural Microbiomes vs Chemical Fertilizers

The soil rhizosphere is 'home' to several microbiomes containing a functional network of microbes, many of which are responsible for various traits and features exhibited by plants. There are multipronged impacts of bio-prospected, functional microbiomes not only on the soil rhizosphere but they also balance plant nutrition and soil properties over a period of time. Microbes of the rhizosphere microbiome interact in multiple ways to improve plant growth and offer potential to increase crop resilience in climatic fluctuations especially those related to nutrients and water. The impact of microbes on nutrient dynamics, carbon cycling, soil health and stress tolerance of plants contributes to the development of sustainable ecosystems along with positive impacts on the soil microflora and their deployment towards the roots. Hence, functional microbiomes can provide multiple benefits to soil and plant health and the response to changing climates and extreme weather challenges faced by our farmers can also be mitigated largely.

These microbiomes can then be tailored to guide the transition towards a more sustainable and resilient agriculture, decrease farming costs, improve crop yields, inform agricultural policies and help achieve reductions in fertilizer usage. This will further help enhance farmers' additional income.

Indiscriminate Use of Chemical Fertilizers Deteriorating Soil

Highly-subsidized chemical fertilizers are being used indiscriminately on majority of dead or dying Indian soils to provide more nutrients to the growing crops. However, crop production is not increasing due to the soil quality deteriorating rapidly. A shift in subsidy

from fertilizer to nutrients is needed so that there can be a balance of nutrients in the soil that help in tying up carbon to the soil. To ensure sustainable agricultural practices, the Indian government is trying to encourage Zero Budget Natural Farming (ZBNF) with a view to decrease the input costs, improved crop yields, and thereby enhancing sustainability and efficiency of agriculture while supplementing farmers' incomes. The government has introduced various schemes, such as PM-PRANAM, to encourage biofertilizer manufacturers take several initiatives to fast track the adoption of bio-fertilizers into farming practices to bring about a shift from conventional to regenerative/organic farming practices. This involves the usage of mycorrhiza and bacterial bio-fertilizers. Keeping in mind that natural microbial relationships provide added benefits as compared to pure microbial cultures; microbiome-based bio-formulations must be put to use along with chemical agri-inputs due to the extended benefits they provide for crop growth, soil and the environment. All in all, a combination of chemical and biological agri-inputs can provide a win-win situation for all. This is a disruptive strategy which will significantly impact crop production, soil quality and health.

The integration of ecology with microbiological, molecular, and functional approaches allows to propose solutions to make agricultural production more resilient to environmental stresses. It will also enable the development of economical, edaphoclimatically stable bio-formulations to address environmental challenges faced by farmers while conserving the natural microbial biodiversity of soil at the same time.

We are at crossroads with a choice between doing nothing, risking future food security and health, or deciding to act, by radically altering our food production practices from a sustainable and bio-economical perspective. The utilization of soil microbiomes could accommodate the necessary surge in agricultural production, without continuing to degrade our natural resource base.

Natural Agri-Inputs: A Sensible Alternative

Given the rising global demand for food and the current rate of soil nutrient extraction, exacerbated by the increasing use and decreasing worldwide supply, there is a dire need for a sustainable alternative that helps meet various UN SDGs. Mycorrhizal fungi and soil microbiomes can significantly improve the soil quality, while solubilizing and enhancing phosphorus (as well as other essential micronutrients) uptake could be a very effective approach to overcome soil degradation amid nutrient-deficiency crisis. This would also suffice to fix nitrogen in soil and sequester carbon along with enriching the soil microbiota, enhancing crop productivity, water use efficiency, and the biodiversity of the site. Additional benefits include diversifying farmers' risks, reducing their costs, albeit enhancing the food nutrition security of the country. ■

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From Lab to Oil Fields

Xanthan Gum: The Ingredient Driving Drilling Efficiency

In this article, **Paul C Jeyaseelan, Dr K Nanthakumar, Shishram Chahar, Dr Veeranna Channashettar** and **Dr Banwari Lal** describe how Xanthan gum, a polymer used in the oil well drilling process is revolutionizing it. How despite being widely used in the industry, there is no production of Xanthan gum in India, and how lab-developed bio-based polymer can prove to be a game changer and fill the gap.

Xanthan gum polymer is a natural, high molecular weight anionic polysaccharide and an important industrial biopolymer produced during the fermentation process using the bacterium *Xanthomonas campestris*. Due to its unique properties, it is used in a variety of applications such as food and beverages, oil and gas, pharmaceuticals, personal care, and cosmetics.

Xanthan in Action

Among these applications, Xanthan gum-based oil well drilling mud dominates a major market share due to its novel properties and environment friendly nature. Acting as a viscosifier and stabilizer, Xanthan gum has excellent tolerance to a wide range of temperatures, pH levels, and salinity, as it increases the mud's penetration rate and suspension ability for drill cuttings. It can also reduce pressure loss during drilling, stabilize the wellbore, prevent damage to

oil formations, and improve the efficiency of drilling, work-over, and completion processes.

The Global Market

The global Xanthan gum market was valued at $963 million in 2021, at $1,037.41 million in 2022, and is projected to grow at a compound annual growth rate (CAGR) of 7.83 per cent to reach $1,515.19 million by 2027.

The increase in the number of oil reserves in recent years, along with the rising oil and gas exploration and drilling activities worldwide, has contributed to this growth. Indian oil companies, such as ONGC and Oil India, alone import around 4,000 metric tonnes of Xanthan gum (XC polymer) annually from China, Indonesia, and the USA. According to recent market rates, India imports Xanthan gum products worth approximately $15 million every year.

TERI's Breakthrough

In India, there is no production of Xanthan gum products to meet domestic demand. Therefore, TERI intends to develop a bio-based Xanthan gum polymer/viscosifier with the primary goal of producing indigenous drilling polymers under the 'Make in India' programme. TERI's Industrial Biotechnology Area initiated research on bacteria-based Xanthan gum polymer back in 2014. After five years of extensive experimental studies, the TERI Xanthan gum polymer was tested at the Oil India Chemical Lab, Duliajan (Assam), and the ONGC Institute of Drilling Technology, Dehradun (Uttarakhand). It met all the parameters specified for drilling fluids (as per American Petroleum Institute specifications). TERI's Xanthan gum product has been upscaled and validated under field conditions at ONGC oil wells (three wells: KLDKD, KLDLO, and WDBD at ONGC Ahmedabad Asset) under the ATGC scheme of the Department of Biotechnology, Ministry of Science and Technology, Government of India. Due to the superior quality of the developed Xanthan gum-based drilling mud chemicals, TERI successfully demonstrated the product in three oil drilling wells and achieved Technology Readiness Level 8 (TRL). To further commercialize the developed product, TERI filed a patent and created a detailed feasibility report (DFR). ■

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Advancing Sustainable Solutions

Flexible Solar PV Modules: New technology for niche applications

TERI and Power Roll's collaboration in introducing flexible solar PV technology to rural India has shown significant promise through pilot projects in Uttarakhand. **Kapil Muddineni, N S Prasad, Paul Laidler, Dr Mini Govindan** and **Rashmi Murali** reflect on how these flexible modules, which are lightweight, cost-effective, and versatile, have been implemented in various rural applications, including agriculture, education, and animal husbandry.

The Energy and Resources Institute (TERI) and Power Roll have been working on flexible solar PV module applications for the Indian market since 2017.

Initially, market research was conducted on potential end-use applications for flexible solar PV systems. Flexible solar modules are the new generation solar PV modules without glass and aluminium frames.

Flexible Modules: An Edge Above Rigid Framed PV

These modules offer several advantages which include light weight, low installation and logistical cost, portability, and enhanced weather protection, among others.

Flexible modules weigh only about 23 per cent of conventional modules. The third-generation flexible technology could be produced at a very low cost compared to the conventional rigid framed PV and would be in the market at highly competitive prices disrupting the market. The lightweight, flexible and rollable sheets can be easily carried. No specialized equipment or tools are needed to handle modules during transport. The cost of bulk transport by sea, air, rail and roadways would be much lower than the conventional PV modules, either in weight or volume terms. The need for dedicated mounting structures could be eliminated, thus saving the costs. The modules can be mounted on any surface. The modules can be mounted on curved and flat surfaces on any type of roof construction. They can also be used as facades, adding aesthetic value while generating energy. Assembling and disassembling the modules from systems is easy. During extreme weather conditions, the flexible modules could be easily disconnected and stored, thus, minimizing the damage associated with such weather events. Flexible panels withstand higher impact than the rigid glass and framed modules.

Supi village

One Module, Multiple Uses

Since 2018, TERI has been carrying out pilot studies on various applications


Buri Bana village

catering to remote villages in Mukteshwar, Uttarakhand.

Water pumping: In 2020, an off-grid solar water pumping system powered with ten 100 Wp flexible solar PV modules (arranged in the form of a mat) was installed to meet the irrigation requirement for around 50 farmers in Dadima village. The solar PV mat was installed on a roof constructed with stones and metal sheets. Access to affordable water for agricultural use has increased crop yield and improved the income level of farmers (as farmers produced cash crops such as fruits and pulses). This has enabled farmers to invest in a new storage tank with increased capacity, to mitigate seasonal variations in water level from natural spring and daily variability associated with solar PV. The families accessing the water are happy as their hardships of bringing water from far-off places were avoided with continuous supply as the system is performing to their satisfaction.


Nautali village

Community radio station: TERI established a community radio station named 'Kumaon Vani' in March 2010 in the Nainital district of Uttarakhand to bring together communities across several villages in the Kumaon region. Various programmes broadcasted are designed to promote sustainable development among the local farming community. Since its establishment, the radio station has been run by local youth who have received in-depth training in all aspects of radio production and management. A solar PV microgrid powered with five 400 Wp flexible solar modules and lithium-ion batteries was installed in 2022 to provide backup power (in case of outages) and power all equipments such as the radio transmitter, audio systems, and computers, among other things. Modules were directly installed over the metallic sheets over the roof. Uninterrupted power is supplied to the 'Kumaon Vani' station as the solar PV microgrid has been performing well.

Model primary school: A solar PV microgrid powered with four 400 Wp flexible solar modules and lithium-ion batteries was installed at the Government Model Primary School at Buri Bana village in 2022. The solar PV modules were installed on a concrete roof. This system provides electricity for lighting, computers and smart TV. The school principal has given excellent feedback about the system and the students have benefitted.

Animal husbandry: Nautali village did not have access to electricity due to its remote location (with lack of roads) and low population. The Indian Veterinary Research Institute has an animal husbandry facility providing shelter to cows residing in this village. This shelter house was used as a quarantine and treatment for the livestock, hence, they were isolated. The institute was started in 1895 by the British. The shelter house in Nautali village did not have access to the grid supply. In 2022, TERI installed a solar microgrid powered with four 400 Wp flexible modules (installed over the metallic sheets on the roof) and Lithium-ion batteries for catering to this facility in the village. The system has been performing well.

Future of Flexible Solar PV in Rural India

The results from these pilot installations over the past five years provide an immense opportunity to adopt flexible solar PV modules across various market segments in India. With the government's push for local manufacturing and ambitious renewable energy targets to reach net zero, the adoption of this flexible solar PV technology could aid in better adoption of remote applications in rural India.

This work was carried out with the research grant support of Innovate UK, the United Kingdom's innovation agency. ■

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Project REVIVE

A sustainability initiative of JSW MG Motor

Repurposing used EV batteries is crucial towards sustainability and promoting battery circularity. This article by **Kapil Muddineni** and **Neha Jain** highlights the outcomes of work done under JSW MG Motor's initiative 'Project REVIVE' on adopting repurposed batteries for stationary applications.

JSW MG Motor India launched the 'Project REVIVE' initiative in August 2024, along with other innovations at the DriEV.Bharat event. Project REVIVE, is JSW MG's initiative in partnership with TERI, Lohum and BatX, aimed at repurposing EV batteries beyond cars to provide a second life as renewable energy storage systems for sustainable community applications.

Second Life of EV Batteries

The second-life EV batteries market is projected to experience significant growth globally by 2030. As the adoption of electric vehicles in the country increases, the quantum of batteries with potential second-life use will increase. EVs are being promoted globally as a mitigation strategy to reduce emissions. Experts estimate that the global second-life battery capacity will reach about 950 GWh by 2030 (Statista, 2023). Innovative solutions are needed to promote the use of batteries during their second life. Practical evaluation of second-life applications is important to build consumer confidence and promote adoption, leading to the circularity of EV batteries. In this direction, TERI is supporting JSW MG in this initiative as a knowledge partner and conducting trials at TERI's Himalayan Centre by deploying for community applications.

Community Applications

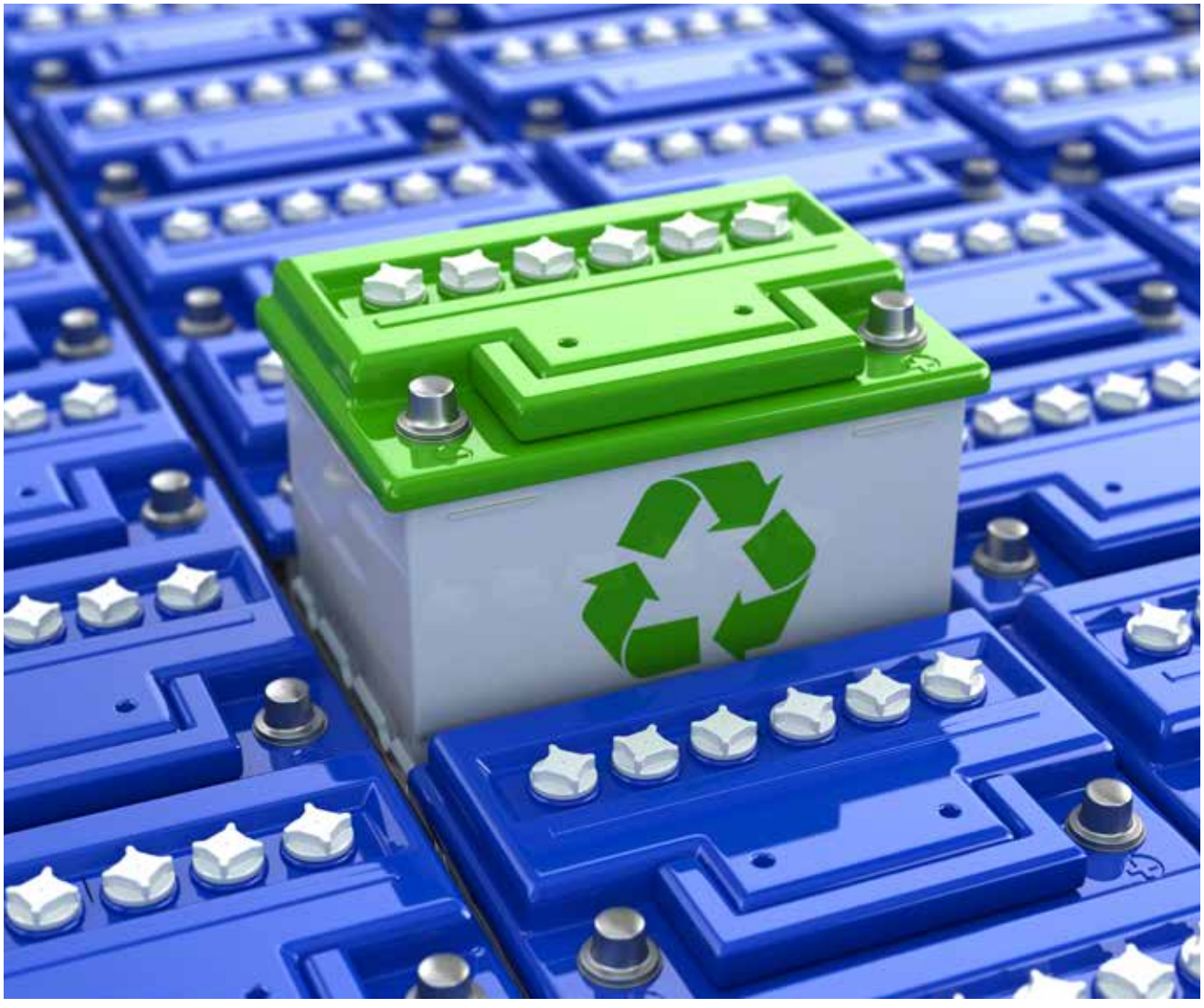
Batteries banks rated at 5 kWh each were installed in a grid-interactive solar PV microgrid configuration. Systems were installed for the following community applications:

JSW MG Motor's DriEV.Bharat Event

School Electrification

Schools in hilly regions face difficulties as the utility grid is unreliable with power outages limiting the delivery of education. The government through its Education Policy is working to provide modern education facilities such as smart TVs, computers, projectors, etc. Access to reliable electricity significantly affects these programmes, during winters. Repurposed EV batteries (in combination with solar PV modules) were deployed in schools in Bana and Gangochor villages. Since deployment, the schools have had sufficient battery backup power to meet their needs. Further, the electricity bills have been reduced.

Community bakery: TRISHA (TERI's Research Initiative at Supi for Himalayan Advancement) was established in 2003 in Supi village in Nainital, Uttarakhand (TERI, 2024). TRISHA is a distinct venture towards sustainable development whose strength lies in ever-greater community engagement. Research and extension at the Centre have largely focused on improving the livelihoods of local farmers. In 2023, TERI set up a bakery run by local women to prepare millet cookies and other products. All the appliances are electric, and cookies are sold to market. Thus, promoting a healthy lifestyle and increasing income to local women. Due to power outages, during certain days of the year, the facility operations are limited. Since the deployment of the second-life EV battery, the facility has not faced any shortfall in electricity and productivity improved.



Farmers Training Centre: Under the ONGC-TERI programme at Mukteshwar, a farmer training centre was initiated. This facility acts as a platform for farmers to learn sustainability practices, produce high-value products and learn from each other experiences. The Centre aims to promote eco-friendly techniques, sustainable livelihoods, homestays, and ecotourism, benefiting 6,000 people in the Nainital and Champawat districts. The facility has food processing equipment, projectors, computers (for staff) and other appliances. A solar PV microgrid with repurposed EV batteries was installed to cater to critical loads of the facility, requiring backup. Since then, the facility has had access to reliable clean energy.

Outcomes

The results from these pilot installations over the past five months reflect the immense opportunity to adopt repurposed EV batteries for community applications. Repurposed batteries could provide clean energy, reliable access to electricity, minimize usage of critical minerals and promote circularity.

When combined with other schemes and initiatives of the government such as PM Surya Ghar Muft Bijli Yojana, circularity for EV batteries can be promoted.

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The Colour of Sustainability

Advancing Climate Solutions Through Eco-Labelled Dyes

This article discusses the environmental challenges posed by the dyeing industry, particularly the harmful effects of synthetic dyes. **Mehak Kaur** and **Dr Mayurika Goel** pen down the rise of eco-labels as a tool for promoting sustainable practices in the fashion industry, with a focus on TERI's pioneering work in developing microbial dyes.

The dyeing industry is notorious for its detrimental impact on both health and the environment. Labelled as the tenth most polluting sector globally, it consumes vast amounts of water, energy, and chemicals. Alarmingly, 20–75 per cent of dyes are discharged as waste effluent, exacerbating environmental degradation. Despite its negative impacts, the global fashion industry has grown rapidly over the past decade, driven by trends such as fast fashion, consumerism, and e-commerce. This expansion has made synthetic dyeing a central part of the

industry, with India emerging as a global leader.

Growing Demand for Sustainable Practices

As awareness of environmental issues grows, many consumers are rethinking their purchasing behaviours and demanding more sustainable practices from businesses. In response, an increasing number of companies are adopting eco-friendly dyes, which are becoming a key focus for sustainability in the textile sector. This shift has given rise to eco-labels — certifications used to market and communicate sustainability efforts to consumers.

Eco-labels are critical tools that empower consumers to make informed decisions and support companies committed to environmental sustainability. These labels not only stimulate market-driven action but also foster the adoption of eco-friendly practices by manufacturers. Furthermore, eco-certification schemes such as Germany's Green Spot, the US Green Seal, and Europe's Digital Product Passport are helping stakeholders make well-informed purchasing decisions by improving transparency about the environmental impacts of products.

Globally, there are around 456 eco-labels across 199 countries, encompassing diverse categories, including products, services, and processes. In India, the government has introduced initiatives like 'Ecomark,' which ensures that eco-friendly products meet specific standards for safety, quality, and performance.

Tackling Greenwashing and Promoting Trust

To prevent greenwashing, the Advertising Standards Council of India (ASCI) has issued guidelines for advertisements making environmental claims, ensuring that businesses' sustainability efforts are truthful, transparent, and verifiable. These measures play an essential role in maintaining consumer trust.

Despite significant progress, some sustainable products, such as natural colourants, extracts, and biorefinery products, remain excluded from eco-label guidelines. Microbial dyes, however, are leading the transition towards eco-friendly textiles. These dyes are celebrated for their potential to replace harmful synthetic dyes and are already making headlines for their role in ushering in a new era of sustainable dyeing. Nevertheless, the production, use, and disposal of these dyes remain unregulated globally, underscoring the need for standardized practices to ensure their sustainability.

The Energy and Resources Institute (TERI) has been at the forefront of promoting sustainability through the development of microbial dyes. TERI's approach follows internationally recognized textile standards like ZDHC (Zero Discharge of Hazardous Chemicals), OEKO-TEX (International Association for Research and Testing in the Field of Textile and Leather Ecology), and GOTS (Global Organic Textile Standard). Their microbial dyes exclude toxic chemicals, steam releases, biocides, and toxic effluents during production.

Furthermore, these microbial dyes possess intrinsic antimicrobial, antioxidant, and anti-inflammatory properties, reducing reliance on synthetic antimicrobial finishes. They offer good colour fastness and are free from toxicity, making them a safer alternative for both workers and consumers.

Developing Eco-Label Criteria for Microbial Dyes

Building on existing models, TERI aims to create eco-label criteria specifically for microbial dyes. These criteria will focus on using sustainable raw materials, minimizing resource consumption, ensuring biodegradability, supporting

fair trade and ethical labour standards, and maintaining transparency through established certifications. TERI's approach seeks to encourage market incentives from governmental authorities, foster innovation and collaboration between industry and research, and bolster consumer trust through credible certifications.

Potential of Eco-Labels in Advancing Sustainable Development

Eco-labels play a pivotal role in connecting diverse stakeholders — researchers, businesses, and consumers — in the shared mission of environmental stewardship and climate resilience. By aligning with various Sustainable Development Goals (SDGs), such as SDG 8 (Decent Work and Economic Growth), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 17 (Partnerships for the Goals), eco-labels drive sustainability, transparency, and accountability in the textile industry.

These labels empower communities dependent on the dyeing industry by promoting the shift from harmful synthetic dyes to sustainable alternatives, thus transforming both industry practices and consumer behaviour. ■

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Empowering Women, Transforming Livelihoods

The Impact of Solar PV Systems in Sewing Clusters of Jharkhand

The environmental benefits of using solar power, coupled with training in system maintenance and financial management, have created a sustainable model that has positively impacted the local community. **Palak Khanna**, **Prashanta Swain** and **Dr Amit Kumar Thakur** report how an initiative by CCL and TERI with an aim to demonstrate the power of renewable energy is transforming livelihoods and empowering women in rural India.

The Solar PV Project in the Chitarpur sewing cluster, Ramgarh, Jharkhand, led by The Energy and Resources Institute (TERI) is a CSR initiative of Central Coal Fields Limited (CCL), Ranchi, is an example of how renewable energy can transform livelihoods, particularly for women-led enterprises in rural India. Prior to the intervention, the women in these sewing businesses faced numerous challenges, primarily revolving around unreliable electricity. Power outages were frequent, forcing these women to work fewer hours and depend on manual labour, severely limiting their productivity. Competing with automated garment manufacturers in urban areas became nearly impossible, trapping them in a cycle of low income and constrained opportunities.

Erratic Power Supply, Limited Opportunities

The project aimed at alleviating these energy challenges by introducing a hybrid solar photovoltaic (PV) system, a clean, reliable, and sustainable energy solution. By doing so, it empowered 150 micro and household-based sewing enterprises, where women play a central

A beneficiary of the solar PV project working with lighting and solar-powered sewing machines, showcasing the transformative impact of renewable energy on women-led livelihoods.

A community sensitization and awareness session led by TERI and Agargati, supported by CCL, empowering women in Chitarpur to adopt solar PV solutions for their sewing enterprises.

role as both workers and business owners. Before the solar PV installations, the lack of consistent power meant these women could only operate for about four to six hours daily, primarily during daylight. As a result, their earnings were limited, and their ability to scale their operations was stifled.

Impact of Solar PV: Extended Working Hours, Increased Income

With the installation of solar PV systems, this changed dramatically. Now, the sewing enterprises can work between 8 and 12 hours a day, doubling their productive time. The women no longer must worry about power outages disrupting their workflow, which has translated into substantial income growth. On average, beneficiaries reported an increase in earnings between ₹1,000 and ₹5,000. For women from economically weaker households, even a modest income growth represents a lifeline, providing the financial independence they need to manage household expenses, save for the future, and gain a stronger voice in decision-making.

One of the beneficiaries with solar PV system and battery

The indirect impacts of the initiative have been equally transformative. Reliable electricity has improved the quality of life for entire families. For example, children in these households now have access to lighting after dark, allowing them to study in the evenings, something that was previously impossible due to power cuts. This has led to improved academic performance and created better educational prospects for the next generation.

Furthermore, the solar PV systems have enabled the women to diversify their work. They now have the ability to experiment with new sewing designs, keeping up with market trends and increasing the demand for their products. This not only enhances their competitive edge but also elevates their skills, opening doors to new business opportunities and sustainable growth. The improved work environment — made possible by better lighting, fans, and motor-operated sewing machines — has reduced physical strain, leading to better health outcomes. Women who once struggled with eye strain from sewing in dim light or endured physical exhaustion from manual stitching now report greater comfort and efficiency at their work. The project's environmental benefits are also significant. By replacing kerosene and fossil fuel-based energy sources with solar power, the initiative has contributed to cleaner air and reduced carbon emissions. This has improved the health of these families by reducing exposure to harmful indoor air pollution.

Improved Quality of Life, Gained More Confidence

Socially, the project has also fostered stronger community bonds and greater financial literacy. As a part of the initiative, TERI organized training programmes to ensure the sustainability of the solar systems. Women, including young women were trained in system maintenance, while women were educated on financial management, empowering them to take charge of their finances and develop a deeper understanding of savings, loans, and investments.

Perhaps one of the most profound indirect impacts is the sense of empowerment and dignity this project has brought to the women in Chitarpur. With financial independence, they now have greater autonomy in their households, a stronger voice in family decisions, and a renewed sense of confidence.

This transformative initiative exemplifies a successful partnership between Central Coal Fields Limited (CCL), Ranchi, The Energy and Resources Institute (TERI), and the NGO Agargati, translating collaborative efforts into on-ground action through community mobilization, sensitization, awareness generation, and the active involvement of local women in adopting sustainable energy solutions. ■

Palak Khanna works as Research Associate at Sustainable Development and Outreach division, TERI; Prashanta Kumar Swain works as Fellow at Social Transformation & CSR division, TERI; Dr Amit Kumar Thakur is Head – CSR and ADIR at TERI.

Responsible IT Asset Disposition

A pathway to corporate sustainability and impact

E-waste is the fastest-growing waste stream globally, posing critical environmental challenges. Improper disposal methods such as landfilling or inefficient recycling lead to toxic emissions, resource depletion, and environmental degradation. This piece of writing authored by **Dr Abhinav Mathur** and **Major General K Narayanan** explicates how this waste, often considered a liability, could be transformed into an asset by adopting simple yet far-reaching sustainable solutions.

In an increasingly digital world, businesses consistently upgrade and replace IT assets to remain competitive. From employee laptops and servers to data storage devices, the global volume of IT asset disposal has reached staggering levels. According to the Global E-Waste Monitor, over 61.3 million metric tonnes of E-waste were generated globally in 2023, which amounts to about 1600 laptops getting discarded per second. The amount of E-waste generated is projected to grow by an estimated 2 million tonnes annually.

These discarded assets need not be treated merely as surplus or waste; they represent a strategic opportunity to meaningful impact sustainability, social responsibility, and data security.

The Sustainability Imperative in IT Asset Management

E-waste is the fastest-growing waste stream globally, posing critical environmental challenges. Improper disposal methods such as landfilling or inefficient recycling lead to toxic emissions, resource depletion, and environmental degradation.

Organizations have a choice: allow their discarded IT assets to exacerbate environmental harm or become champions of the circular economy. Responsible ITAD ensures that the value derived from these assets is maximized without compromising on sustainability through refurbishment, parts cannibalization, or recycling with advanced technologies. Every refurbished laptop reduces the need for new manufacturing, cutting emissions by an estimated 150–220 kg of CO_2 per device.

Studies show that recycling 1 million laptops can save over 3500 tonnes of raw materials, including metals like gold, silver and other rare earth elements!

A study conducted by Attero showed that responsible disposal of 4018 IT assets (IT assets include assets such as laptops, desktops, servers, and printers) results in savings of 520 MT of CO_2e and 24.8 MT of landfill waste which is equivalent of saving ~500 MT of coal from being burned and planting ~21,000 trees. The study was conducted by analyzing the assets provided by a typical medium-sized corporate and utilized the IEA Standard Emission Factors to calculate CO_2e emissions and landfill waste, as detailed in the CO_2e savings table here.

S. No.	Assets	No. of assets	CO_2e MT	Landfill waste MT
1	Laptops	1800	106.92	5.71
2	Desktops PC	897	150.57	7.32
3	Storage devices	42	1.41	0.2
4	LCD displays/monitors	624	136.42	5.37
5	Printers + scanners	170	15.07	1.55
6	Servers	120	54.43	4.37
7	Tablets	352	51.17	0.2
8	Power equipment (UPS, power adapter, power supply)	12	4.3	0.09
Total		4018	520.3	24.8

Data Security: a critical pillar of ITAD

The ITAD process isn't just about sustainability; securing the organizations sensitive information should also be a key cornerstone in your decisions involving ITAD. Every discarded device—whether a laptop, server, or storage medium—carries the risk of sensitive data exposure. The 2022 Data Breach Report revealed that the average cost of a data breach for the impacted corporate was $4.35 million, emphasizing the critical need for secure data erasure.

High-quality ITAD providers implement comprehensive protocols to erase or destroy data storage mediums, ensuring complete security. Collaborating with trusted ITAD providers protects sensitive information and demonstrates a commitment to data privacy, mitigating reputational and financial risks.

A Strategic Opportunity for Reducing Emissions

With corporate ESG goals increasing focused on reducing emissions and improving ESG impact, ITAD offers a unique avenue to further improve ESG scores. ITAD partners that refurbish, cannibalize, and recycle assets under one roof have the best chance to maximize the residual value that can be derived from discarded asset, and they have the best chance to minimize emissions. Advanced recycling processes recover more than 98% of the materials at 99.98% purity levels, while ensuring maximum reuse and minimal waste.

Additionally, transparent environmental and social impact reporting from ITAD providers allows organizations to integrate these impact numbers into their ESG disclosures, showcasing measurable progress towards sustainability commitments.

Social Impact: turning IT assets into instruments of change

The value of IT assets can potentially be made to extend beyond its corporate and economic utility once they are upgraded and can be agents that transform lives. Social responsibility can be integrated into an organization's ITAD vision, and the IT assets can be donated after refurbishment to charities, schools, and social organizations and can be used by their beneficiaries for learning digital skills which are necessary for them to join the mainstream.

For example:

- **Students** gain access to digital learning tools, bridging the education gap in underserved communities.
- **Small businesses** utilize technology to expand operations and access new markets.
- **Farmers** benefit from real-time data on weather, pricing, and agricultural practices.

Corporate and their ITAD partners can donate refurbished IT assets to NGOs that can use it for their operations or further provide these to their beneficiaries. For example, refurbished devices can enable students to access online education and can allow non-profits to enhance their operations, creating ripples of positive change across communities.

Such initiatives can reflect leadership with a conscience, fostering goodwill among employees and stakeholders while amplifying the organization's CSR impact.

Factors while Deciding ITAD Partners in India—a study

A survey was conducted to study the factors that corporates consider while deciding ITAD partners. This study was conducted with 90 respondents across India who provided a list of their IT assets that they needed to get disposed. Several ITAD partners were invited to this study and were engaged to provide their commercial proposals corresponding to the received RFPs after deliberating with the corporates. The data corresponding to the factors that lead to the selection of partners by corporates was then studied and interviews were conducted to understand the key factors in driving the decision.

Factors corporates consider to decide ITAD partners in India

S.No.	Factors	Survey findings
1	Securing organizational data	20% of respondents were aware of data related risks and wanted a solution for data sanitization. Several of these aware respondents wanted physical destruction of their media.
2	Regulatory compliance	Only 25% of the respondents, largely MNCs were aware of the regulatory compliance requirements. However, a few of the respondents while aware needed to be educated about the specific requirements. For example, a few of the respondents insisted for a certificate of recycling while giving their IT Assets to refurbishers in which case only a form 6 would have sufficed.
3	Vendor selection criteria	Almost no respondent was aware about R2 certifications for recyclers and refurbishers and therefore did not check for this from their respective vendors. Owing to this a lot of IT assets get into the informal sector which is not desirable given India's focus on environment and sustainability.
4	Cost	Almost 95% of the respondents use cost as the key criteria for selection of their ITAD partner. This was true even in cases where their awareness about ITAD and the implications of improper partner selection was clearly understood.
5	Turnaround time	All large organizations had a detailed process and approval hierarchy for disposal of IT assets and worked on a 3–4 weeks' timeframe for their ITAD disposal, in contrast smaller organizations expected their ITAD partners to complete the entire process within one week.
6	Reporting and transparency	Only 10% of the respondents were interested in tracking the subsequent journey of their retired assets and were specifically keen on the impact that their disposition was having on the environment.
7	Stakeholders involved	Almost in all cases the finance teams and procurement teams were involved in making the decision of selecting an ITAD partner. We found only a few cases only in larger organizations in which the chief sustainability officer or the CSR team was involved in the process.
8	Impact measurement	Only 5–10% of the respondents mostly MNCs were keen to understand the environmental and social impact of their IT asset disposition.

Choosing the Right ITAD Partner

An effective ITAD strategy hinges on partnering with a provider that offers:

1.	**Integrated solutions**	Integrated refurbishment, parts cannibalization, and recycling to maximize efficiency
2.	**Sustainability expertise**	Zero-waste environmentally responsible recycling and refurbishment processes
3.	**Data security compliance**	Best-in-class certified tools for data erasure or destruction
4.	**Proven results**	Track record of success and recognized certifications across all ITAD processes – refurbishing – cannibalization – recycling
5.	**Recycling efficiency**	Maximum resource recovery capability, ensuring that most materials from the discarded assets are effectively reused.
6.	**Social impact options**	Donation programmes for refurbished assets to NGOs and charities

The Call to Action for CIOs, CTOs, and CEOs

As leaders shape an organization's future, decisions about IT asset disposition have far-reaching implications. By adopting a forward-thinking ITAD strategy, we can:

1.	**Lead in sustainability and circularity**	Position your organization as a pioneer in environmentally responsible practices and improve ESG metrics while ensuring circularity of rare critical materials
2.	**Enhance social impact**	Use discarded IT assets to create opportunities for those in need
3.	**Mitigate risks**	Safeguard sensitive information and comply with global data protection standards

The Call to Action for Corporates

ITAD needs to be seen as more than just an operational necessity—it has the potential to be a strategic enabler of sustainability, social responsibility, and risk mitigation. By transforming ITAD into a purposeful activity, organizations can align their technology strategy with their sustainability goals, secure sensitive data, and amplify their societal contributions.

IT assets hold the power to redefine an organization's legacy—not just in the digital space but in the world at large. Let's unlock this potential together, creating a future where technology drives positive change for the planet and its people. ■

Dr Abhinav Mathur is Advisor, Board, Attero, Former Advisor to Vice Chairman, NITI Aayog; Major General K Narayanan is the Programme Director, Law and Security Chairman, 11 Groups on Circular Economy, NITI Aayog.

Energy-efficient techniques for realizing sustainability

Major topics covered

- Smart Energy Systems
- Impact of Electronic Equipment on Energy Use and Carbon Footprint
- Standard Energy Use and Carbon Footprint Metrics
- Smart Buildings
- Sustainable Practices for Green Health Care Services
- Knowledge and Behaviour for a Smart Planet
- Worldwide Case Studies for Green Practices

ISBN: 9789394657113 • Price: ₹1195.00

This book stresses the need for us to judiciously, sustainably, and smartly harness and use energy techniques in order to effectively combat climate change. The book also gives an in-depth discussion on utilization of artificial intelligence and information technology to realize energy efficiency in various sectors of economy including such as transportation, buildings, infrastructure, health care, and other services.

Text is supplemented by case studies that depict ground-level reality to facilitate comprehension of the subject matter. The appendices serve as an extended learning of the concepts discussed in the chapters. The publication would serve as a valuable reference for both scholars and researchers engaged in the domain, in addition to, being a guide to industry and the academic world.

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Converging Growth and Sustainability

Building Upon Strategic Partnerships for Climate Resilience

This piece of writing by **Arun Awasthy** well illustrates that technology and infrastructure alone cannot address climate challenges; people must be at the center of every solution, every partnership. Grassroots efforts have the power to transform vulnerabilities into strengths, building resilience while addressing local needs. These initiatives not only protect against climate impacts but also create livelihoods, turning environmental challenges into opportunities for economic empowerment.

As India begins its journey into the second quarter of the 21st century, it faces a dual challenge: staying on course and sustaining its rapid economic growth and simultaneously addressing the escalating impacts of climate change. From erratic weather patterns disrupting agriculture to urban heat islands affecting millions, the climate crisis is no longer a distant phenomenon but an urgent reality shaping our present. For a nation with diverse climates, cultures, and an economy that is still developing, it becomes a dual challenge to not just develop a steadfast social economy but to also prioritize climate consciousness, imbibing it into the very structure of the nation's development as it moves forward.

As India aspires to transform into a $35-trillion economy by 2047, its urban centres will be the engines of this growth. While tier 1 cities have

been the dominant voice in dictating India's urban development so far, in the second quarter of the 21st century, smaller cities are expected to set pace, further bringing about a more spread out wave of development across the tiers. Additionally, according to projections, India's urban population is expected to grow significantly from about 410 million in 2014 to around 630 million by 2030. This reflects a substantial increase in urbanization, with more than 50 per cent of India's population anticipated to reside in cities by that year. With this in view, the urban expansion that India is set to witness will inevitably increase demands for housing, infrastructure, and services, amplifying vulnerabilities to climate risks.

Understanding the Role of Cities in Addressing India's Climate Vulnerabilities

India is one of the most climate-vulnerable countries in the world, with cities often being at the cause and effect ends of this spectrum. In India, cities alone contribute to 30 per cent of the national greenhouse gas (GHG) emissions while still grappling with geographical and socio-economic challenges such as pollution, extreme weather, and resource scarcity. However, despite the existing challenges, we have cities such as Ahmedabad, Chennai, Bengaluru, and Mumbai which have actively stepped up and through dedicated climate action plans made significant strides in bringing about a green conscious development model.

Though these are specific examples emanating from India, the scale of the problem demands more than just isolated actions and examples; it requires a paradigm shift in how we plan, build, and sustain our urban ecosystems and tie in our initiatives to integrate into a cohesive framework that can deliver long-term resilience, and collaboration and partnerships lie at the heart of this approach.

The Solution: Collective Action and Smart Strategies

Addressing these challenges requires partnerships that harness the strengths of diverse stakeholders, which include the government, private enterprises, civil society, and local communities. For India, this approach must focus on actionable, research-backed strategies that are both scalable, nuanced (to be able to incisively solve the diverse problems that we face), efficient and swift (to implement), and inclusive.

One promising avenue lies in adapting successful global models which could be adapted to suit the Indian context. Implementing localized versions that prioritize its most pressing challenges, such as urban public infrastructure, air quality, water management, and energy efficiency, etc., ensures that the best practices are being modularized to ensure equal and inclusive progress. For example, cities could adopt region-specific approaches with support from a national climate fund to standardize resources and technical expertise. This approach would ensure that even smaller municipalities, often excluded from broader programmes, benefit from structured climate planning. Public–private partnerships (PPPs) will also play a key role in driving this change. By leveraging green bonds and

other innovative financing tools, urban infrastructure projects can attract private investment while maintaining a focus on sustainability.

Keeping Buildings at the Core of India's Climate Mitigation Strategy

While large-scale partnerships are essential for addressing climate challenges at the city and state levels, they must also be mirrored in the microcosm of the built environment. Buildings, which account for nearly 40 per cent of global energy-related carbon emissions, represent one of the most significant opportunities for sustainable transformation. In India, efforts are already underway to incorporate green building certifications and energy-efficient technologies. However, for such practices to become mainstream, they must be supported by collaborative, localized efforts at every level, especially when it comes to decarbonizing high-impact sectors like heating, ventilation, and air-conditioning (HVAC) systems and renewable energy.

By leveraging the power of partnerships across private enterprises, government, and local communities, India can drive the adoption of advanced, locally developed technologies tailored to its climate and economic needs. For example, integrating renewable energy sources (RE) alongside high-efficiency HVAC systems in commercial buildings can significantly reduce energy consumption and carbon emissions. This collaboration between technology developers, urban planners, and energy providers can enable the widespread adoption of innovative solutions such as energy storage and smart grids, ultimately reducing dependency on fossil fuels. Going beyond this, a critical function of public–private partnerships (PPP) also lies in the development of a mechanism that prioritizes the delivery of the right strategy, greater speed and efficiency and scale of implementation.

Empowering Communities and Creating Jobs

Technology and infrastructure alone cannot address climate challenges; people must be at the centre of every solution, every partnership. Grassroots efforts have the power to transform vulnerabilities into strengths, building resilience while addressing local needs. These initiatives not only protect against climate impacts but also create livelihoods, turning environmental challenges into opportunities for economic empowerment.

India's sustainability journey must also focus on capacity building. Programmes that train the next generation of urban planners, engineers, and policymakers in sustainable practices will ensure that the solutions we implement today continue to evolve, and remain effective tomorrow. This is where partnerships with academia and industry become essential, fostering a culture of innovation and resilience.

Way Forward

The future of India lies in its ability to balance growth with responsibility. By fostering partnerships that bridge gaps between policy and action, technology and tradition, and global goals and local needs, we can build cities that are not just resilient but also equitable and vibrant.

India has the chance to lead by example, demonstrating how developing economies can realize their economic and developmental aspirations with sustainability leading this (given the mounting evidence that it is now a business imperative, and not merely an 'add on'). This requires bold vision, collaborative effort, and a steadfast commitment to creating a future that prioritizes both people and the planet.

As we move forward, the message is clear: the climate crisis demands action, but it also offers an unprecedented opportunity to redefine progress. Together, through partnerships and innovation, we can transform challenges into stepping stones for a sustainable and equitable future. ■

Arun Awasthy is President and Managing Director, Johnson Controls India.

Indian Cities are Baking

Here's How to Dial Down the Heat

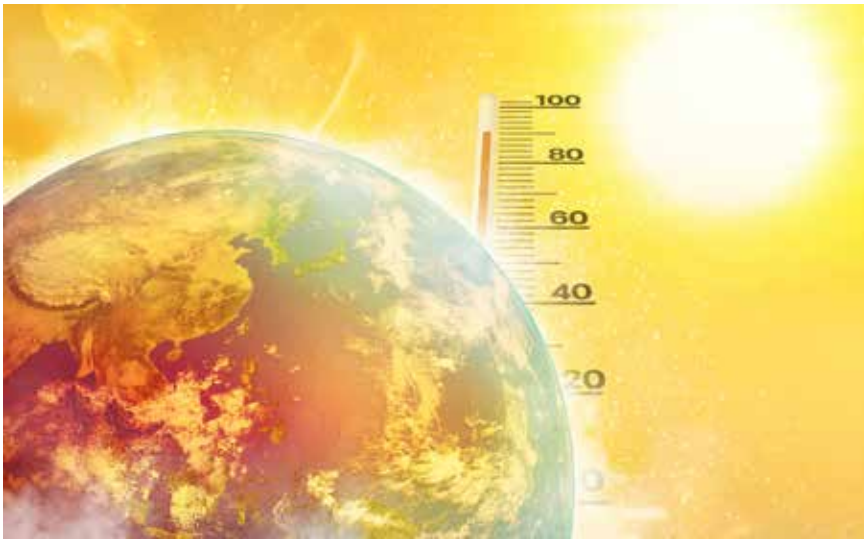
Article by **Dr Balakrishna Pisupati** makes us acquainted with the urgency of developing cooling solutions to stand against the global heat. This requirement will become more pronounced in urban areas as population of this segment is highly likely to increase by a significant margin in the near future. The author has emphasized, to get this done, enhancing capacity among urban planners, developers, and disaster management authorities is essential.

The world is heating up, and India is feeling the burn. According to the World Meteorological Organization, 2024 was the hottest recorded year, with global surface temperatures averaging 1.55°C above pre-industrial levels. The greenhouse gas (GHG) emissions that are causing this global heat crisis have still not reached their maximum. These extreme temperatures affected billions of people worldwide. In India, the authorities reported over 40,000 heatstroke cases across 17 states.

Some 360 million Indians are expected to face extreme heat-related stress by 2050. So, countries need to start insulating their citizens and economies against extreme heat. India, with support from the United Nations Environment Programme (UNEP)-led Cool Coalition, is starting to do just that.

Under the Heat Action Plan 2022, the Indian Meteorological Department and the National Disaster Management Authority (NDMA) directed 23 states to implement the plan and provided guidelines to enhance extreme heat resilience. Many sub-national governments have their own heat action plans.

Meanwhile, under the India Cooling Action Plan, India aims to reduce cooling demand by up to 25 per cent, refrigerant demand by 25–30 per cent and cooling energy requirements by up to 40 per cent by 2038. The plan also prioritizes other solutions, such as passive cooling, building design, fans and coolers, new technologies, and behavioural change.



These steps, many of which were recommended as global measures in UNEP's *Global Cooling Watch* report in 2024, are important not just to protect people and livelihoods, they are important to avoid a vicious cycle of increasing cooling demand burning through more power and further driving climate change. Such measures need to be formalized and included in climate pledges under the Paris Agreement, known as Nationally Determined Contributions, which are due to be updated by February 2025 latest.

Combatting Urban Heat

City dwellers are severely impacted by the growing heat, suffering from the urban heat island effect (UHIE), whereby grey infrastructure and a lack of greenery traps heat and emits it a night, meaning that temperatures stay higher than in the countryside.

Most heat action plans in India lack a standardized scientific approach to mapping and assessing urban heat which

is essential to enable more accurate risk assessment and support to effective heat mitigation strategies. The UNEP's projects are helping to fill this gap by supporting sub-national governments through UHIE assessments and passive cooling recommendations. A National Methodology for UHIE assessment has been developed by UNEP with CEPT University, which collects and overlaps data on land and surface temperature, land-use cover, building form, surface materials and nature of green cover. It's integration into the NDMA heatwave guidelines is in process.

In Tamil Nadu, UNEP and CEPT University have tested this methodology and identified hotspots across urban areas and provided recommendations for the 11 fastest-growing cities in the state including Chennai, Madurai and Thoothukudi. These mapping efforts, coupled with long-term technical assistance from UNEP, are helping Tamil Nadu's cities to take effective heat mitigation measures that can be scaled for the long-term through reconfigured urban master plans and construction norms.

Chennai has witnessed significant urban sprawl over decades, leading to increased temperatures—the result of less vegetation, higher built-up density, and a surge in anthropogenic heat emissions. Between 2013 and 2023, the mean night-time temperatures rose by 0.63°C. Over 64 per cent of the city now falls within high-temperature zones. Here UNEP, in partnership with CEPT University and the World Bank is using hotspot mapping and modelling to inform updates to the Chennai Master Plan.

Strategies for Cool Cities

Of course, there is more to beating the heat than assessments. UNEP and partners have identified a host of actions that will make a massive difference.

Building green infrastructure and restoring natural heat sinks, such as urban forests and water bodies, have

been shown to reduce temperatures. Permeable surfaces, cool roofs and even simple fixes such as using light-coloured paints on walls reduce heat retention. Integrating climate-sensitive designs, optimized floor spaces and enhanced sky-view factors can make buildings cooler and more energy efficient.

Promoting shading, insulation, double-glazing and fans can massively enhance thermal comfort while bringing down emissions. Adopting energy-efficient and optimized air-conditioning systems, and implementing district cooling systems, can keep both people and planet cool.

For example, in Tamil Nadu, UNEP is developing passive cooling guidelines that the Tamil Nadu government can integrate into local regulations and social housing procurement. UNEP is also working with the state government to better direct investments in nature and climate adaptation to respond to the heat crisis—a crisis that last year led the state to declare a heat disaster. UNEP is also engaging and supporting real estate developers and financiers of housing in the state to reorientate investments towards passive cooling—unlocking value from enhanced thermal comfort and reduced cooling loads.

Support to Get it Right

To implement the right strategies and measures, Indian state and city agencies require support to plan and implement long-term resilience measures. There are challenges that hinder progress, including limited access to reliable data and comprehensive UHIE analyses, no national framework to assess urban heat, insufficient capacity in cities for evidence-based policymaking and urban heat planning, a lack of dedicated financing for city-led interventions and often poor coordination across city departments.

Current heat action plans primarily emphasize short-term heat mitigation and emergency response; they must also integrate long-term urban planning strategies to incorporate sustainable, passive cooling solutions, and lower urban temperatures. A coordinated effort between disaster management authorities and urban planning departments is essential. Cities need expanded monitoring systems for temperature and humidity, along with technical and financial assistance for upgraded UHIE assessments following UNEP-CEPT's methodology. Urban planners should prioritize updates to master plans and local area plans in identified hotspots.

To get all this done, enhancing capacity among urban planners, developers, and disaster management authorities is essential. India needs dedicated heat officers, updated building by-laws to include passive cooling features, and financing programmes for greenfield and retrofit buildings and integrating long-term heat resilience into state and city heat plans.

Initiatives like UNEP's India Cooling Programme, which prioritize extreme heat resilience through sustainable solutions, offer scalable models. Additionally, establishing national platforms and hubs can provide consistent support to cities.

Extreme heat is a persistent challenge that requires coordinated global and local action. With scalable solutions, stronger policies and enhanced collaboration, Indian cities, which are on the frontline of the challenge, can show the world how it is done. ■

Dr Balakrishna Pisupati is engaged with UNEP India as Head.

Stakeholder Engagement

Key for Effective Climate Action

Dr Henning Wuester via this article makes us comprehend some of the aspects pertinent to effective climate action. Climate action that is adequate to meet global climate objectives requires fundamental changes across society. For these changes to be successful and sustained, stakeholders from all sectors must be engaged in the process. Effective engagement needs to be underpinned by transparency and data. Transparency is essential in informing decisions, building trust, and ensuring that actions taken achieve intended results.

Climate transparency refers to the gathering, evaluation, and reporting of data and information. It is the basis for planning climate action, ensuring that realistic, yet ambitious targets are set, and then designing effective policies to implement them. Transparency is also vital for tracking climate progress by monitoring policy implementation, assessing whether outcomes are on track, and determining if adjustments are necessary.

By providing an evidence base, transparency helps stakeholders understand complex climate issues and ensures that policies are based on solid data, which ultimately supports better decision-making.

Engaging stakeholders in all phases of climate action—planning, implementation, and evaluation—is essential. Stakeholders from key sectors, including the private sector, need to be part of the solution. Involving affected groups from the start not only raises awareness but also helps create a deeper understanding of the issues at hand. This

inclusive approach ensures that policies are designed with all perspectives in mind, making them more effective and sustainable in the long term.

Moreover, the data collected from stakeholders provides an invaluable resource for refining and improving these policies. As stakeholders share their insights and concerns, the gathered data can inform adjustments and improve the overall process.

While climate action brings many benefits, it often also presents challenges and disadvantages. These potential downsides must be addressed to ensure that the transition is acceptable. Transparency provides the evidence needed to weigh the benefits against the limitations, helping to mitigate potential harm.

This is particularly important when one or more communities could be adversely affected by the change. Transitions to a green economy must be just, ensuring no one is left behind. Transparency is a critical part of such a transition. A just transition is based on an inclusive process where all relevant stakeholders are involved in dialogue, helping to manage challenges and advance progress.

When stakeholders have access to clear, open data, they are more likely to trust the process, collaborate effectively, and feel a sense of ownership over the actions being taken. This collaborative approach reduces conflict and makes the implementation of climate policies smoother and more efficient.

ICAT has published a suite of guides and methodologies to support countries as they implement their climate mitigation and adaptation goals. Two are particularly relevant to stakeholder participation: The Stakeholder Participation Guide and the Just Transitions Monitoring Guide.

The Stakeholder Participation Guide provides a step by step, practical approach to engaging with stakeholders. It addresses the key elements of stakeholder engagement, including their identification, establishing multi-stakeholder bodies, designing and conducting consultations, and establishing grievance redress mechanisms. Its intended users are among others policy makers, and stakeholders themselves. For stakeholders, the guide empowers them to participate more effectively in, and influence, the design, implementation and assessment of policies and actions to ensure that their concerns and interests are addressed.

ICAT's Just Transitions Monitoring Guide provides a step-by-step approach to support the development of a monitoring framework that will enable governments to track the status of a just transition. It was designed for government agencies and ministries such as those responsible for development, climate planning, data management and finance, including national, subnational, regional or local jurisdictions. It builds on experience with implementing the approach through dedicated ICAT country projects in Nigeria and South Africa and is currently being applied through an ICAT project in Brazil.

Data and transparency are at the core of effective climate action. Stakeholder engagement, grounded in transparent data and information sharing, enhances policy effectiveness by raising awareness, improving understanding, and facilitating collaboration. The combined efforts of stakeholders, guided by clear, evidence-based assessments, are crucial for achieving sustainable climate goals and ensuring a just transition for all.

Examples of Successful Stakeholder Engagement

Eswatini

In Eswatini, the ICAT project included a series of workshops with interested parties, who provided invaluable feedback for developing an adaptation measurement, reporting and verification system. They formed a technical working group, and also developed the monitoring and evaluation system for the water and health sectors. In this way, collaborating partners gained a better understanding of the complex interactions between the country's health and water sectors, and stakeholders were empowered to voice their concerns and commitment from the outset.

***Photo credit**: Sally Parsley. International Centre for Eye Health, London School of Hygiene & Tropical Medicine*

Bolivia

In Bolivia, the ICAT project included extensive stakeholder collaboration through workshops and bilateral meetings. From the project start, a sectoral working group of key actors in the energy sector provided data, discussed, recommended, and validated results. In this way, affected government ministries and other agencies were able to provide input into the proposed measurement, reporting and verification framework for the country's energy sector to project greenhouse gas (GHG) emissions, assess the impact of relevant policies and measures, and develop appropriate indicators to report on progress. Stakeholders were also able to give feedback on proposed institutional arrangements and the related regulations.

***Photo credit**: 2010CIAT/NeilPalmer*

***Photo credit**: Cristhian Guzmán on Unsplash*

Kenya

The main objective of the ICAT project in Kenya is to build a data information framework for the crop subsector that is used to inform GHG emissions trends, agricultural development policy and decision making in Kenya, and track NDC implementation progress. This is being done through extensive information sharing among stakeholders, including a workshop to co-design the architecture of a data management system; and training workshops for 100 technical stakeholders across five regions of Kenya.■

Dr Henning Wuester is Director of the Initiative for Climate Action Transparency (ICAT).

Sustainable Aviation Fuel

Opportunities for India

In this piece, **Robert Boyd** ideates on decarbonization of the aviation sector. Sustainable aviation fuel is the foremost step in this endeavour and forms the topic of discussion. The author establishes that decarbonizing the aviation sector requires a comprehensive approach consisting of multiple measures, including fleet replacement, advanced technology, sustainable fuels, operational improvements, and market-based measures.

Climate change is one of the most critical challenges faced by humanity today, which requires action from all stakeholders including governments, civil society, businesses, private sector, financiers, and investors. The aviation sector is among the first global sectors to have committed to taking climate action. In 2021, the global aerospace industry committed to net-zero CO_2 emissions by 2025 and in 2022 governments adopted a long-term global aspirational goal (LTAG) to achieve net-zero carbon emissions from international aviation by 2050 at ICAO 41st Assembly. This is the first time a global sector has made such a commitment and demonstrates unity and leadership. Today, the aviation sector accounts for around 2.5 per cent of global CO_2 emissions. However, this share will grow without decarbonization initiatives, given the rapidly increasing demands for air travel and expected emission reduction from other sectors. The importance of aviation makes the decoupling of passenger growth and emissions vital. Aviation is one of the hardest to abate sectors and without intervention, emissions from the sector are expected

to reach 1.8–2 Gt CO_2 by 2050.

Decarbonizing the aviation sector requires a comprehensive approach consisting of multiple measures, including fleet replacement, advanced technology, sustainable fuels, operational improvements, and market-based measures. Fleet replacement offers the most immediate emissions improvement with a best in class new aircraft delivering around a 20 per cent efficiency improvement over the one it is replacing. However, in several parts of the world, including India, much of the new fleet deliveries is adding to capacity to meet additional demand. Importantly, Boeing's Cascade Climate Impact Model and other studies show that Sustainable Aviation Fuel (SAF) is the biggest lever commercial aviation has to reduce emissions over the next 30 years. Estimates suggest that transitioning to the use of SAF that is renewable, lower-carbon alternative from the conventional jet fuel can reduce the life cycle carbon emissions by up to 84 per cent, with the potential to reduce even more in the future. And SAF has an advantage to be certified and easily used as a drop-in fuel. Furthermore, SAF can be an economically promising option for a country like India which has a large landmass and variety of feedstock options available.

India has abundant feedstock such as (i) agriculture crop residues, (ii) maize/ sugar production (iii) used cooking oil, (iv) municipal solid waste, among others. In 2021, the World Economic Forum produced a report estimating that India could produce up to 24 million tonnes of SAF annually. This was also reinforced by the Minister, MoPNG in 2023. India set initial indicative SAF-blending target for international flights as 1 per cent SAF blending in 2027 and 2 per cent SAF blending in 2028. Various feedstock assessment studies conducted for India suggest that India has enough potential to meet its SAF blend target requirements and may even have possibility of surplus SAF production. A recent report suggests that various mandates and targets will likely drive the global demand for SAF to about 18 Mt by 2030 and about 185 Mt by 2040. It is an opportunity for India to export SAF surplus and meet the global SAF demand. Besides this, there are other co-benefits of SAF production. The use of agricultural crop residue towards SAF production would help increase farmers' income and address problems such as local air pollution. Similarly, use of municipal solid waste toward SAF production could resolve local waste management issues among others. WEF report had summarized all benefits of SAF production in India such as reduced carbon emissions, macroeconomic benefits like creation of new green jobs, enhanced energy security and local benefits like health benefits by alleviating air pollution helping to meet Sustainable Development Goals.

While India has significant potential to produce and export SAF, the current production volumes are relatively small. Even globally SAF production today is a small fraction of the global jet fuel market. SAF production volumes reached 1 Mt in 2024 doubling from 0.5 Mt produced in 2023. According to IATA, this meets around 0.50 per cent of the aviation industry's fuel requirements. In November 2023 at the International Civil Aviation Organization (ICAO)'s third Conference on Aviation and Alternative Fuels a vision was agreed to reduce CO_2 emissions in international aviation by 5 per cent by 2030 through the use of SAF, LCAF, and other aviation cleaner energies in 2023. This highlights the need for more effective policy in order for SAF to scale at the necessary rate over the next 5 years.

Some of the key challenges for SAF in India include:

1. **Lack of stable feedstock supply chain:** SAF can be produced from a variety of feedstocks. However, it is difficult to collect feedstock and transport feedstock to be processed for SAF production. It is therefore important to establish a steady and viable supply chain which provides for adequate distribution and storage facilities to enable continuous SAF feedstock availability for SAF production. Specialized SAF production would create a more robust supply chain.
2. **High-capital investments required:** High costs are associated with SAF production technology as production process are complex requiring specialized equipment. The cost of setting up an SAF production plant requires substantial investments.

'Rules of Thumb' for SAF developed by ICAO's CAEP experts suggest: large-scale SAF plants require around $1 bn. In order to take full advantage of India's feedstock potential, state-of-the-art production capabilities are required along with significant investments in research and development, new infrastructure, and production capacity. Stakeholder interactions in India suggest there are about 7–10 plants at various stages of production in India and would be fully operational by 2027. Taking examples from other sectors like solar, it can be said that it is likely that costs could fall significantly as technologies mature and the SAF industry reaches economies of scale.

3. **SAF technical evaluation process:** There are 11 technology pathways approved to produce SAF while another 11 are under evaluation. These pathways utilize various feedstocks and processes to produce SAF that can be blended with conventional jet fuel or used as a standalone fuel. These technological pathways have been approved by the American Society for Testing and Materials (ASTM) certification. The process to obtain certification is technical, complex, and time-consuming as SAF must fulfil strict criteria to ensure it is technically fit for purpose. From India, CSIR-IIP submitted single reactor HEFA technology pathway in 2021 which is under evaluation.

Way Forward

Developing a conducive SAF ecosystem will require supportive policies and significant investments in the SAF value chain and SAF production capacity. While there is a proposed blending mandate from the government, a comprehensive mix of policies such as incentives for SAF production; de-risking capital investments and demand-side policies is required to enable SAF ecosystem. India has experience in the development of new technologies like solar which can be leveraged upon to establish a conducive domestic SAF ecosystem. The Global Biofuel Alliance (GBA), launched in 2023, has India as its host country and offers an opportunity for India to demonstrate leadership in enabling SAF ecosystem by addressing challenges related to feedstock availability, streamlining supply chain, encouraging investment in SAF production, and developing facilitative policy frameworks at the global level. At a more granular level in India, it is important to get all the right stakeholders from the aviation, energy, policy, and finance sectors together to deliberate and highlight issues and challenges with respect to scaling SAF. Establishing a domestic SAF industry in India is both possible and offers opportunity including GDP growth, job creation, energy security and supporting long-term resilience for the aviation sector. Leveraging global experience, while collaborating with local public and private stakeholders is the pathways for establishing and scaling a SAF industry in India.

Web Resources

https://www.icao.int/environmental-protection/Documents/Assembly/Resolution_A41-21_Climate_change.pdf

https://ourworldindata.org/global-aviation-emissions

https://www.iata.org/contentassets/1d7b998cda0a46a1ab31d4ee3cce5eaf/chart-aviation-carbon-emissions-to-be-abated-by-2050.pdf

https://app.cascade.boeing.com/

https://www3.weforum.org/docs/WEF_Clean_Skies_for_Tomorrow_India_Report_2021.pdf

https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1925417

https://pib.gov.in/PressReleasePage.aspx?PRID=1979705

https://www2.deloitte.com/in/en/pages/about-deloitte/articles/sustainable-aviation-fuel-report.html

https://www3.weforum.org/docs/WEF_Clean_Skies_for_Tomorrow_India_Report_2021.pdf

https://www.iata.org/en/pressroom/2024-releases/2024-12-10-03

https://sustainabilitymag.com/articles/inside-the-disappointingly-slow-year-for-saf-production

https://www.icao.int/Meetings/CAAF3/Documents/ICAO%20Global%20Framework%20on%20Aviation%20Cleaner%20Energies_24Nov2023.pdf

https://www.icao.int/environmental-protection/Pages/SAF_RULESOFTHUMB.aspx

https://www.icao.int/environmental-protection/GFAAF/Pages/conversion-processes.aspx ■

Robert Boyd is the Regional Head for Asia Pacific, Global Sustainability Policy & Partnerships at Boeing.

Partnerships

The Catalyst for India's Carbon Neutrality Journey

This opinion piece by **Srivatsan Iyer** details both status and scope of India's hopeful journey towards carbon neutrality. However, carbon neutrality is not a journey that India will make alone. Partnerships—between the Government of India, private enterprises, financial institutions, and international organizations—are the answer to achieving this balance of robust economic growth while ensuring the success of the ambitious climate. The author makes us understand the potential partnerships and collaborative action holds to fill the technology and resource gaps targets. Collaboration is the key. Collaboration of governments, industries, academia, and communities must be fostered in order to build a resilient and sustainable future.

India is steadily marching towards achieving carbon neutrality as it looks to balance economic growth imperatives with climate goals. Being the world's most populous country and the world's third-largest emitter of greenhouse gases (GHG), India stands at a crossroad. Climate priorities that India has adopted are stated in the Nationally Determined Contributions (NDCs) of the Paris Agreement, making clear the sheer scale of the transformation needed. However, carbon neutrality is not a journey that India will make alone. Partnerships—between the Government of India, private enterprises, financial institutions, and international organizations—are the answer to achieving this balance of robust economic growth while ensuring the success of the ambitious climate targets.

Climate extremes in terms of increased temperatures, extended droughts, severe hurricanes, frequent cloudburst events, etc., destroy communities and infrastructure, and are likely a state of affairs that could define a new normal for the world. The 2018 Kerala floods is one example, which displaced 5.4 million people and caused damage of more than $3.5 billion. This is why immediate action to address adaptation and climate change resilience is critical in the near term.

Between 2019 and 2023, the World Bank's Resilient Kerala Programme

infused $525 million in support, to attract an additional $1.13 billion from development partners. This collaboration invested in-systemic changes and reforms in water resource management, urban planning, climate budgeting, and agriculture, while also addressing public health challenges exacerbated by climate change. Expanding such models throughout India would be instrumental in scaling up adaptation and resilience and reducing vulnerabilities.

India's journey in renewable energy is already among the fastest globally. The goal of the government to increase the non-fossil fuel generation capacity to 50 per cent by 2030 has spurred innovations and investments. Though achieving 500 gigawatt (GW) of renewable energy capacity by 2030 is a massive task, the technologies available to decarbonize the grid are already available and being deployed globally. The challenge here is to mobilize capital and resources to enable this scale-up. Private sector partnerships and foreign direct investments in solar and wind power projects have already proven their potential. The emergence of green finance instruments, including green bonds and sustainability-linked loans are current examples of sources of finance to meet such commitments and accelerate the scale-up of renewable energy and optimize the efficiency of renewable installations. Additional partnerships in research and development can trigger breakthroughs in energy storage and grid integration, two critical components for a renewable-powered economy.

The bigger challenge today is to decarbonize hard-to-abate sectors such as steel, cement, chemicals, and heavy-duty mobility, which account for ~50 per cent of emissions, that cannot be easily solved by current solutions such as renewable energy—they require innovative and transformative solutions. Here lies the potential for partnerships and collaborative action to fill the technology and resource gaps.

Take the example of green hydrogen, a crucial component of India's decarbonisation strategy. Green hydrogen has the promise to do exactly that. But it needs a lot of investment in capital-intensive areas, new technologies, and supportive infrastructure. The Government of India's ₹17,490 crore outlay for the Green Hydrogen Mission is a case in point in public–private partnerships.

Collaboration is the key, from creating joint ventures for the production of hydrogen to establishing infrastructure for Green Hydrogen Hubs. Partnerships with countries already at the forefront of green hydrogen technologies, such as Germany and Japan, could facilitate India's ability to surmount technological hurdles. Domestic partnerships could mobilize the private sector towards scaling up production and align efforts with India's *'Aatmanirbhar Bharat'* vision. Moreover, targeted financial support, such as the ₹400 crore earmarked for developing Green Hydrogen Hubs by the government, is an example of government support for enabling this transition.

Carbon-neutrality: A Shared Responsibility

Carbon neutrality will be both India's national imperative and a global responsibility. The stakes are high—for the country and for the planet. This goal can only be achieved by harnessing partnerships across a broad group of stakeholders. Collaboration of governments, industries, academia, and communities must be fostered in order to build a resilient and sustainable future. The success of missions like the National Solar Mission and the National Mission for Enhanced Energy Efficiency relies heavily on the participation of private players.

By pooling resources, expertise, and intent, we can create a self-sustaining cycle of innovation, growth, and environmental stewardship. India has already demonstrated its capacity for growth in renewable energy. But to truly accelerate our transition to a sustainable future, the entire ecosystem must act in unison. Through partnerships, we can solidify our trajectory towards a clean energy transition and inspire a worldwide shift towards a greener, more sustainable future.

The message is clear—no single entity can tackle the climate crisis alone. Only through shared purpose and collective action can humanity turn the vision of a sustainable future into reality. ■

Srivatsan Iyer is the Global CEO of Hero Future Energies.

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Goa, India
Website: https://www.bits-pilani.ac.in/goa/icsee2025/

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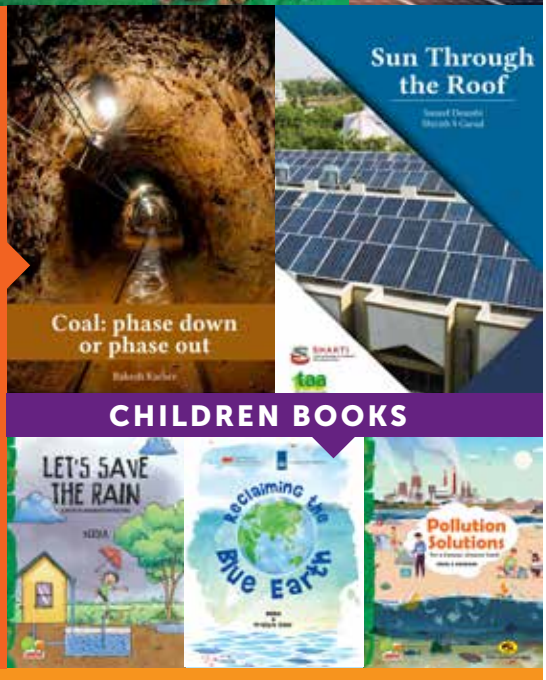

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TERRAGREEN (WSDS SPECIAL ISSUE)

The world is off track. According to the latest progress report on the Sustainable Development Goals (SDGs), of the 169 targets, only 14% are on track, while 20% are not even monitored. Alarmingly, 14% of targets show regression, including those related to hunger, education, employment, and the environment. The first global stocktake underscores the gravity of these challenges. Achieving ambitious temperature goals requires a 43% reduction in emissions by 2030, yet current nationally determined contributions are projected to achieve only a 2% cut. These gaps reveal not only shortfalls in implementation but also deficiencies in the data needed to guide progress.

Acceleration in sustainable development and climate solutions is clearly needed, and partnerships are key to this effort. The challenges facing the world are multifaceted and interconnected, demanding collective action. Partnerships are essential for accelerating progress, fostering shared responsibility, enabling collaborative efforts, and driving innovative solutions. By pooling resources and expertise, partnerships can deliver tangible outcomes to address complex global issues.

The 24th edition of the annual flagship multistakeholder event of The Energy and Resources Institute (TERI), the World Sustainable Development Summit (WSDS), to be held on 5–7 March 2025 in New Delhi. The Summit deliberations will focus on the umbrella theme: 'Partnerships for Accelerating Sustainable Development and Climate Solutions'.

This special edition of TerraGreen covers a wide range of contributions from partners and experts on climate action, green growth, energy transitions, sustainable agriculture, sustainable infrastructure, youth stewardship, market instruments, gender, innovations, and sustainable consumption.

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