TerraGreen

EARTH MATTERS

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World Water Day

Water, Inequality, and the Fight for a Sustainable Future

TERRA YOUTH

Need to Renew the Collective Strength of Humans and Nature

IN CONVERSATION

Suhas Baxi,
Co-founder and Group CEO,
BiofuelCircle

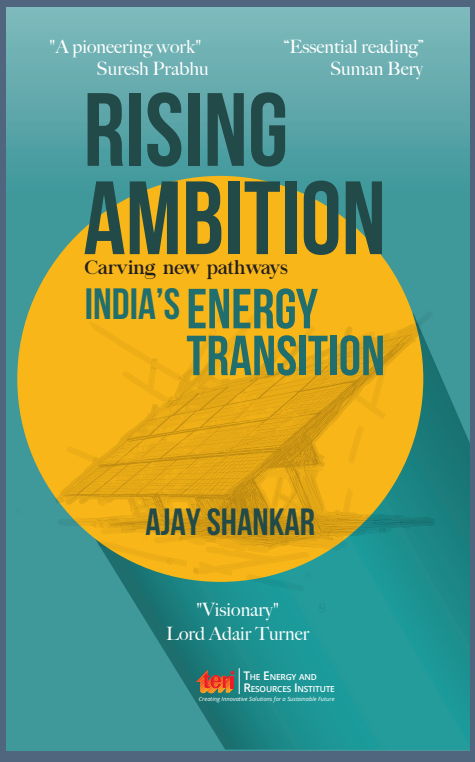
SPECIAL HIGHLIGHTS

Realigning Wildlife Tourism in India

Circularity, Water Stress, and Resilient Building Design



teri



Rising Ambition Carving New Pathways India's Energy Transition

Ajay Shankar
Distinguished Fellow
The Energy and Resources Institute (TERI)

India aims to become net zero by 2070. This book sets out the pathways to net zero with key milestones. It suggests policy choices and ways to minimize the cost of this fundamental transition deriving lessons from the remarkable success that has been achieved in renewables. It makes the case that moving away from fossil fuels would also help India become a developed country with a competitive green economy.

Year: 2025
Size: 5 inch x 8 inch
Pages: 244
ISBN: 978-93-94657-19-9
Price: ₹495.00

"A meticulously documented analysis of India's decarbonization possibilities by one of our most thoughtful and experienced administrative scholars."

Suman Bery
Vice Chair, NITI-Aayog

"Becoming net zero while continuing to grow the economy would be one of India's critical challenges in the future. This is a pioneering work which gives an excellent and comprehensive analysis of the challenges and the best way to succeed."

Suresh Prabhu
Former Union Minister, Government of India

"Rising Ambition is analytically robust but also visionary and a critical guide to how India can both become a rich developed nation and make a major contribution to avoiding the potential catastrophe of global warming."

Lord Adair Turner
Chair Energy Transitions Commission

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EDITORIAL



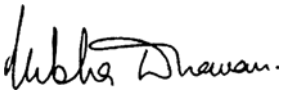
> "Billions continue to face water insecurity in India and worldwide due to climate change, pollution, population growth, and unsustainable use."

Water is fundamental to life, livelihoods, and ecosystems, yet it is increasingly becoming one of the most unequally accessed resources in the world. Observed every year on March 22 since 1993, World Water Day draws global attention to the significance of freshwater and the urgent need for sustainable management of water resources. Worth mentioning here that the World Water Day 2026 emphasized "Water and Gender" under the campaign slogan "Where water flows, equality grows," which highlighted the critical link between water access, gender equality, and sustainable management, aiming to empower women and girls. While water covers nearly 70 per cent of the Earth's surface, billions continue to face water insecurity in India and worldwide due to climate change, pollution, population growth, and unsustainable use. The crisis extends far beyond physical scarcity, revealing deep social and economic inequalities in access to safe water and sanitation.

Variability in the global water cycle is making availability less predictable, while rising demand threatens to outpace supply in the coming decades. The consequences are wide-ranging that affect public health, food security, economic development, and ecosystems, often falling most heavily on women and marginalized communities. World Water Day therefore reminds us that water must be viewed not merely as a natural resource, but as a shared responsibility and a basic right that requires equitable and forward-looking governance.

Set against this context, *TerraGreen's* cover story, "Water, Inequality, and the Fight for a Sustainable Future," examines the multi-dimensional nature of the global water crisis and what it means for sustainability. The article traces how water stress is shaped by pollution, data gaps, climate variability, and governance challenges, while underscoring the strong link between water access and gender equality. It highlights India's unique water situation—marked by growing dependence on groundwater, declining per capita availability, rapid urbanization, and widening demand–supply gaps—and points to the urgency of reforms in pricing, storage, wastewater reuse, and institutional coordination. At the same time, the cover story explores sustainable pathways forward, including advanced irrigation practices, innovative water technologies, nature-based solutions such as watershed management and reforestation, and the indispensable role of community participation. Together, it reinforces a central message: while state action and policy reform are essential, securing a sustainable and equitable water future will ultimately depend on collective, informed, and responsible action at every level.

We hope you will find the content in this issue both thought-provoking and inspiring, reaffirming our collective resolve to safeguard the planet's fragile balance and move steadily towards a sustainable, carbon-neutral future.



Vibha Dhawan
Director-General, TERI



I read with great interest the cover story in the March 2026 issue of *TerraGreen* on green hydrogen. The article clearly explains why sectors such as steel, cement, chemicals, aviation, and shipping remain difficult to decarbonize despite rapid growth in renewable electricity. Its discussion on green hydrogen as a clean fuel, feedstock, and reducing agent makes a compelling case for its role where electrification alone falls short.

Particularly valuable is the attention given to India's context, including renewable expansion, grid challenges, high costs, and the importance of co-located production to improve economics. The reference to the National Green Hydrogen Mission and ongoing pilots in steel, refineries, mobility, and ports grounds the argument in present realities rather than distant promises. While green hydrogen is clearly no quick fix, the article persuasively shows why it deserves focused policy support and patient investment as India works towards its net-zero goals.

Rajveer Vohra
New Delhi

I read the article "Deepening India's Secondary Market for Green Bonds: Opportunities, Challenges and a Strategic Growth Path" with keen interest. The author presents a lucid and timely analysis of why India's green bond market, despite impressive growth in issuances, continues to fall short in mobilizing private capital at scale. The emphasis on secondary market liquidity, price discovery, and investor participation brings attention to aspects that are often overlooked in discussions on sustainable finance. I found the explanation of weak trading activity, the limited emergence of a greenium, and the dominance of buy-and-hold investors particularly insightful. The comparison with mature markets such as Germany and France clearly illustrates what benchmark issuances, active market making, and transparent pricing can achieve. The article persuasively argues that deepening secondary markets is not just a financial reform, but a strategic necessity for financing India's low-carbon transition.

Anil Yadav
Mumbai, Maharashtra

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Ladakh Gets Solar-Powered Ice Hockey Rink in Green Sports Push

The UT of Ladakh is all set to achieve a unique fusion of renewable energy generation and modern sporting infrastructure, with Lt Governor Vinai Kumar Saxena giving approval for the installation of a solar plant atop the famous Ice-Hockey Rink in Leh. The 500 kWp on-grid solar photovoltaic (SPV) plant on the rooftop of the NDS Ice Hockey Rink in Leh will be installed at an estimated cost of INR 2.38 crore. It is a significant step towards promoting renewable energy and sustainable sports infrastructure in Ladakh. The project will be developed under the Special Development Package (SDP) of the Youth Services and Sports Department, UT Ladakh. The project will serve as a model for integrating renewable energy solutions into public infrastructure projects across the Union Territory.

Source: https://www.thestatesman.com/

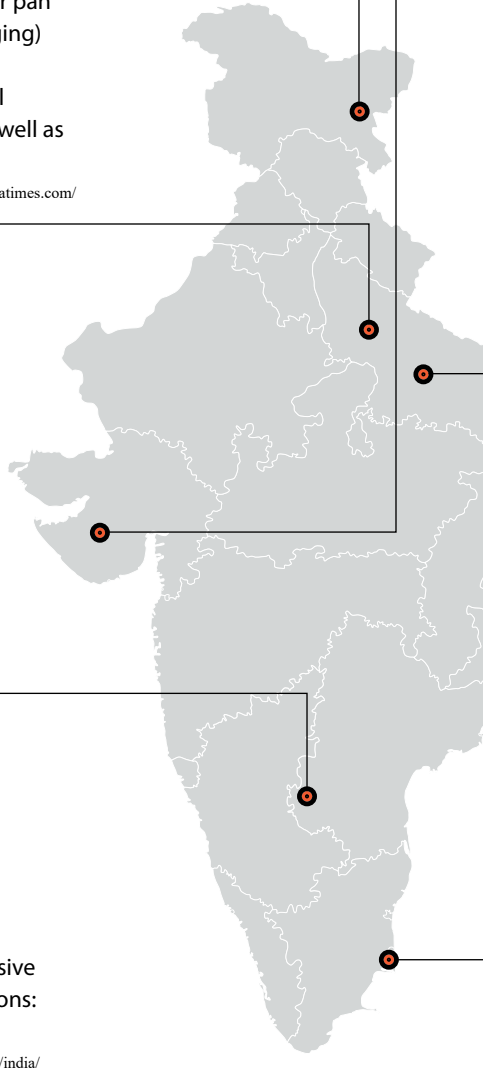
FSSAI Proposes Plastic-Free Packaging for Pan Masala, Gutka

In a significant move targeting single-use plastic in tobacco-related products, the Food Safety and Standards Authority of India (FSSAI) has proposed a complete shift to non-plastic packaging for pan masala, gutka, and similar items. A draft amendment to the Food Safety and Standards (Packaging) Regulations, 2018, released recently, mandates that these products be packed only in paper, paperboard, cellulose or other naturally derived materials. The draft explicitly bars the use of all plastics—including polyethylene, polypropylene, polyester, PVC and multilayer laminates—as well as aluminium foil or metallized layers.

Source: https://timesofindia.indiatimes.com/







BWSSB Becomes India's First Water Board to Receive ISO 50001:2018 Certification

The Bangalore Water Supply and Sewerage Board (BWSSB) has been awarded with the internationally recognized ISO 50001:2018 certification. BWSSB is the first water utility board in India to be awarded with the certification. The certification was officially issued on April 14, 2026 by Bureau Veritas. "The certificate formally recognizes the board's outstanding energy management systems. Specifically, this new certificate honours BWSSB for maintaining its massive bulk water supply pumping stations at an international standards across all three critical locations: TK Halli, Harohalli, and Tataguni," a statement by BWSSB said.

Source: https://www.deccanherald.com/india/



Kandla Port Partners with ICCT to Cut Shipping, Port Emissions

Deendayal Port Authority (DPA) and the International Council on Clean Transportation (ICCT) on April 29, 2026, signed a memorandum of understanding to research and develop strategies aimed at reducing greenhouse gas and air pollution emissions from port and shipping operations at Gujarat's Kandla. Signed in the national capital, the agreement is focused on research, policy development and knowledge-sharing for supporting low-emission, sustainable shipping practices, while combining ICCT's technical expertise with DPA's operational experience. Among the key focus areas of the agreement include: understanding the decarbonization measures that could have greatest emissions impact; identify practical opportunities across ships, fuels, pro-linked trucking as well as in-port equipment; and assess key infrastructure, policy and regulatory changes required to make these measures viable at scale.

Source: https://www.thestatesman.com/

Ministry of Earth Sciences Celebrates Earth Day 2026

The Ministry of Earth Sciences (MoES), Government of India, commemorated Earth Day 2026 on April 22, 2026 at Prithvi Bhavan, New Delhi, centred around the theme "Our Power, Our Planet." The event featured a high-level gathering of scientists, senior officials, and staff who collectively took the Earth Day Pledge, reaffirming their commitment to environmental stewardship. The celebration was graced by Chief Guest Padma Shri Dr Shailesh Nayak, former Secretary of MoES and current Director of the National Institute of Advanced Studies (NIAS). The event was presided over by Dr M Ravichandran, Secretary, MoES.

Source: https://www.pib.gov.in/

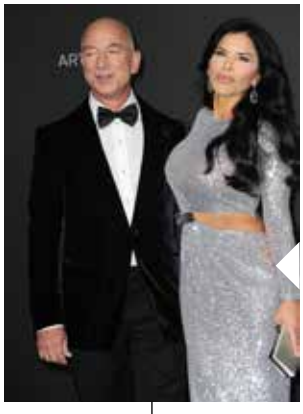




India's first Banana Field Gene Bank launched in Tiruchy

In an effort to support the banana genetic conservation and prevent the loss of valuable genetic resources, the National Research Centre for Banana (NRCB), Tiruchy, launched the 'Banana Field Gene Bank' project recently. Farmers who grow rare banana varieties can register with the NRCB, where scientists will preserve and develop it for multiplication. "This is the first field gene bank for banana in the country," said Dr Trilochan Mohapatra, chairman of the protection of plant varieties and farmers' rights authority (PPV&FRA) and farmers welfare, Government of India, after launching the project. "Due to declining interest in farming, genetic diversity is at risk, which was the reason the Government of India is supporting the establishment of field gene banks for crops such as coconut, banana, and paddy," Mohapatra said.

Source: https://www.newindianexpress.com/

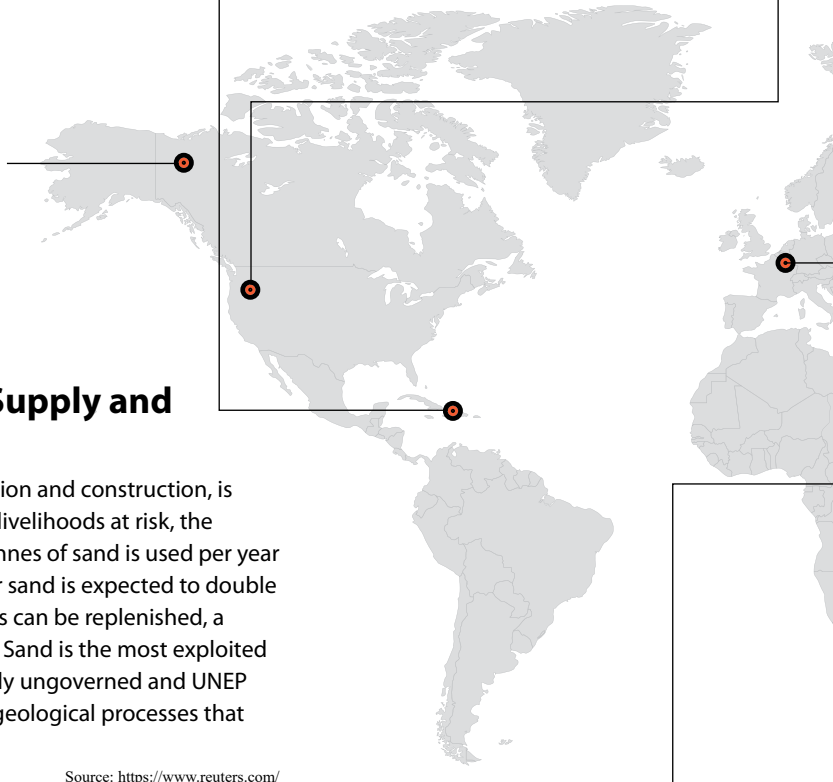


Jeff Bezos and Lauren Sanchez Donate to Develop Plastic-Free Fabrics for Sustainable Fashion

Jeff Bezos and Lauren Sanchez have committed $34 million through the Bezos Earth Fund to accelerate the development of sustainable textiles. The funding focuses on alternatives to conventional materials such as polyester and viscose, which are largely derived from fossil fuels. By supporting research into biodegradable and plastic-free fibres, the initiative aims to reduce the environmental footprint of the fashion industry. What began as a conservation-focused philanthropy is now expanding into material innovation, targeting one of the most resource-intensive sectors of the global economy. The initiative also encourages collaboration between scientists, start-ups, and manufacturers to scale solutions and bring sustainable materials into mainstream global production.

Source: https://timesofindia.indiatimes.com/





Global Sand Demand is Outpacing Supply and Threatening Ecosystems

Growing global demand for sand, driven by rapid urbanization and construction, is exceeding sustainable supply and putting ecosystems and livelihoods at risk, the United Nations said in a report recently. About 50 billion tonnes of sand is used per year for building and a range of other purposes, and demand for sand is expected to double by 2060 under current trajectories—a rate faster than stocks can be replenished, a report by the UN Environment Programme (UNEP) showed. Sand is the most exploited natural resource in the world after water, but its use is largely ungoverned and UNEP said it is being consumed faster than it can be replaced by geological processes that take hundreds of thousands of years.

Source: https://www.reuters.com/

Global Fire Outbreaks Hit Record High As 'Unprecedented' Heat Extremes Loom

Climate change has driven record-breaking outbreaks of fire in Africa, Asia and elsewhere this year, with conditions expected to get worse as the northern hemisphere's summer approaches and El Niño weather patterns kick in, scientists warned recently. Fires from January to April 2026 have already caused unprecedented levels of damage, burning more than 150 million hectares (370.66 million acres) of land, 20 per cent more than the previous record, according to data compiled by World Weather Attribution, a research group that studies the role played by global warming in extreme weather events.

Source: https://www.reuters.com/

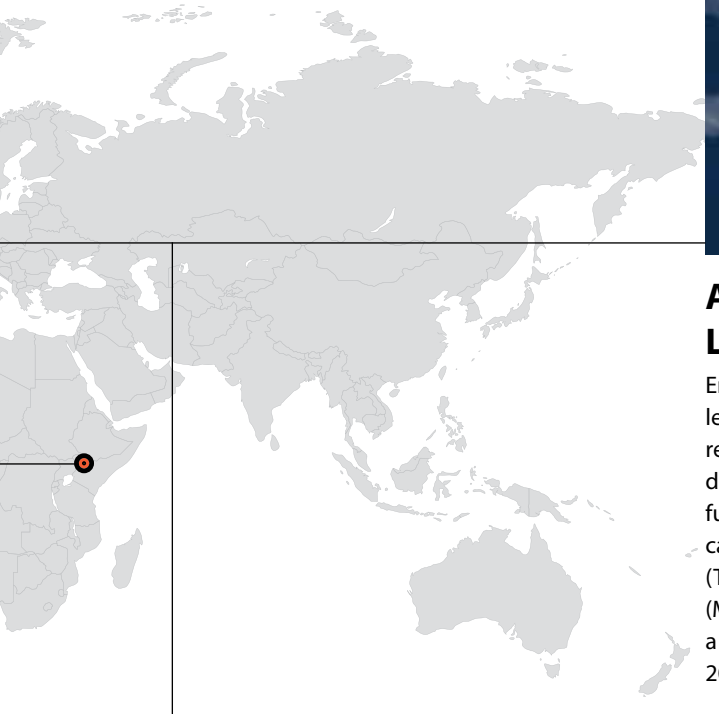




Earth Is Splitting Open beneath the Pacific Northwest, Scientists Say

Scientists have, for the first time, clearly captured a subduction zone in the act of breaking apart. These zones form where one tectonic plate sinks beneath another, and they are responsible for some of the most powerful geological events on Earth. The new findings, published in *Science Advances*, offer a rare look at how these massive systems evolve and raise new questions about earthquake risks in the Pacific Northwest. Subduction zones shape the planet in dramatic ways. They move continents, trigger major earthquakes and volcanic eruptions, and pull old crust deep into Earth's mantle.

Source: https://www.sciencedaily.com/





Airline Emissions in Europe Top Pre-COVID Levels Despite Pledge to Decarbonize

Emissions from flying in Europe have now passed pre-pandemic levels, with Ryanair's carbon footprint 50 per cent higher than in 2019, research has shown. Total aviation emissions continue to increase despite industry pledges to decarbonize and the introduction of more fuel-efficient planes, driven by the massive expansion of low-cost carriers. According to analysis by thinktank Transport & Environment (T&E), Ryanair's CO_2 emissions alone in 2025 reached 16.6 megatonnes (Mt) of CO_2 – around the same amount as the total annual emissions of a small European country such as Croatia. The airline carried just over 200 million passengers in 2025, compared with 140 million in 2019.

Source: https://www.theguardian.com/

Inequality Causing 100,000 Extra Deaths a Year from Heat and Cold in Europe

Economic inequality adds more than 100,000 deaths to the vast toll from heat and cold in Europe each year, research has found. Cutting levels of inequality to match that of Europe's most equal region, Slovenia, as measured by the Gini index, would reduce temperature-related mortality by as much as 30 per cent, equating to 109,866 people, the study found. The findings come after the EU's Copernicus monitoring project ranked recently as the third-hottest April on record globally, with some countries such as Spain recording their hottest April on record. The return of the natural heating phenomenon El Niño—which may shape up to be unusually strong—has raised fears of a brutal European summer in 2026.

Source: https://www.theguardian.com/



How Farmer Institutions Are Making Carbon Finance Work

The Saharanpur Experience

The article by **Prisha Pareek, Aakash Warman**, and **Sayanta Ghosh** explains how farmer institutions in Saharanpur are enabling carbon finance through agroforestry. By aggregating small farmers under Farmer Producer Organizations, the initiative makes carbon credit generation financially viable while building local capacity. With technical support from TERI, the project combines geospatial monitoring, transparent governance, and trusted grassroots leadership to link climate mitigation with sustained income diversification for farmers, offering a scalable, community-driven climate solution.

Carbon finance assigns economic value to reducing or removing greenhouse gas (GHG) emissions. The concept of carbon crediting originated with the Kyoto Protocol (1997), an international agreement that introduced flexible market mechanisms to reduce GHG emissions and enabled emission reductions to be traded or credited across countries and projects. Under subsequent climate policy evolution, the Paris Agreement, adopted in 2015, expanded cooperative approaches to carbon markets by allowing internationally transferred mitigation outcomes and by encouraging market and non-market mechanisms to help countries enhance ambition and cost-effectively achieve their targets.[1,2]

In the Agriculture, Forestry and Other Land Use (AFOLU) sector, activities such as afforestation, reforestation, and agroforestry remove carbon dioxide from the atmosphere by storing it in trees and soils. This removal is quantified using approved methodologies, verified under recognized carbon standards, and converted into carbon credits that represent one tonne of CO_2 equivalent removed or avoided. These credits are then purchased by companies in voluntary or compliance carbon markets, and the resulting revenue is shared with project participants.[3]



[1] United Nations Framework Convention on Climate Change. (1997/2005). Kyoto Protocol to the United Nations Framework Convention on Climate Change. Details available at <https://unfccc.int/process-and-meetings/the-kyoto-protocol>

[2] United Nations Framework Convention on Climate Change. (2015). Paris Agreement Crediting mechanisms. Details available at <https://unfccc.int/process-and-meetings/the-paris-agreement/article-64-mechanism>

[3] Climate Promise. (2025). What are carbon markets and how do they work? United Nations Development Programme. Details available at <https://climatepromise.undp.org/news-and-stories/what-are-carbon-markets-and-how-do-they-work>

Agroforestry, a land-use system where trees are integrated with crops or livestock has a direct link to carbon finance because it combines productive agriculture with carbon sequestration. Trees in agroforestry systems absorb and store carbon in their woody biomass over time while maintaining productive land use, making such systems eligible to generate carbon credits when removals are measured and verified.[3]

For farmers, this framework creates an additional source of income. Traditionally, tree-based farming involved growing trees and selling timber after several years, often with uncertain returns. With carbon finance, farmers can earn from timber and also from the carbon stored in their trees. The mechanism is structured as follows: trees are planted and maintained, carbon sequestration is measured using approved methodologies, carbon credits are issued after independent verification, credits are sold in the market, and revenue flows back to farmers.

Individual land parcels are too small to justify the costs of standalone carbon finance projects. Grouping farmers together into collective projects resolves this cost-benefit gap and makes participation economically viable.

While the framework is conceptually straightforward, implementing it at scale requires technical expertise, structured institutional systems, extensive outreach, and long-term monitoring. In many jurisdictions, these projects are undertaken in collaboration with government departments due to their administrative authority and capacity to mobilize farmers and stakeholders for large-scale implementation.

Sustainable Development Goals and Carbon Finance

A structured agroforestry-based carbon finance initiative contributes directly to SDG 1 (No Poverty), SDG 13 (Climate Action), and SDG 15 (Life on Land). Such project advances SDG 1 by creating an additional and structured income stream for farmers through verified carbon credit generation, thereby diversifying household earnings beyond conventional agricultural and timber markets. It directly contributes to SDG 13 by facilitating measurable GHG removals through large-scale agroforestry plantations under an approved carbon methodology, with long-term monitoring and verification mechanisms. SDG 15 is addressed through the expansion of woody biomass on agricultural landscapes, promotion of species suited to local ecological conditions, and sustained increase in vegetative cover over a 40-year project period.



The Saharanpur Scenario

Large-scale carbon finance projects are inherently complex undertakings, requiring technical expertise, institutional structuring, extensive manpower, and coordinated outreach. Rather than relying on government departments, the Saharanpur project engaged directly with local Farmer Producer Organizations (FPOs). Three FPOs came together to support implementation, a strategic choice, as their deep embeddedness in the agricultural community and understanding of local conditions, farmer concerns, and institutional systems provided a strong foundation for project execution.

By positioning FPOs at the centre of implementation, the project ensured grassroots participation. Farmers were not only involved in planting trees but were engaged in key discussions related to project. Early interactions showed that carbon finance concepts were unfamiliar and technical, with questions ranging from basic participation rationale to more analytical inquiries about climate change mitigation. Through sustained engagement and transparent



communication, these complexities were gradually clarified. The integration of TERI's proposed institutional mechanism with the existing structures of the FPOs ensured alignment with local operational practices. Revenue flow systems, monitoring roles, and governance responsibilities were structured in a way that maintained clarity and accountability.

Geospatial technology played a central role in strengthening the technical foundation of the Saharanpur initiative. High-resolution satellite imageries were used for historical land-use analysis, vegetation assessment, and identification of potential land under Afforestation, Reforestation, and Revegetation (ARR) projects methodology. Continuous vegetation monitoring, canopy density estimation, and statistical validation enhanced measurement accuracy. Geo-tagged field data integrated with spatial analysis ensured transparency, traceability, and long-term monitoring throughout the project lifecycle. Project boundaries were digitally demarcated and converted into geospatial formats such as shapefiles and KML files, storing precise latitude and longitude coordinates. These files supported project registration, validation, and long-term monitoring. Field plots were geo-tagged using GPS-enabled devices, ensuring traceability at every stage.

Before field implementation, a feasibility assessment was undertaken to examine not only where the project could be implemented, but also whether it would be technically and economically viable as a carbon finance initiative. This included land suitability assessment using satellite imagery and geospatial analysis, identification of eligible villages and plots, assessment of recommended agroforestry species suited to local conditions, suitable plantation models, and estimation of expected carbon credit potential. In this sense, feasibility was not limited to locating available land; it also helped determine whether the proposed landscape could support credible carbon accounting, project development, and future revenue generation for farmers.

A distinguishing feature of the Saharanpur initiative was the decision not to outsource technical tasks. Even the preparation of KML files for individual farmer plots, often handled by external consultants, was undertaken by trained FPO members. TERI provided technical guidance and verification, but the operational responsibility remained local. This approach enhanced skill development, strengthened institutional capacity, and fostered a sense of ownership.

Trust emerged as a central factor in the project's success. Because FPO members were local and already trusted within their communities, the initiative benefited from pre-existing credibility. Farmers' confidence in their FPOs gradually extended to the implementing organization. As FPO members visibly led awareness campaigns and technical processes, interest expanded organically. Observing local leadership encouraged more farmers to participate.

Can This Be Replicated?

The Saharanpur project illustrates that carbon finance can be implemented through decentralized, community-led institutional arrangements.
With structured technical support, consistent communication, and integration with existing farmer institutions, complex climate-linked interventions can be operationalized effectively at the grassroots level.
The initiative demonstrates how traditional agroforestry systems can be strengthened through scientific measurement, transparent governance, and market linkage. By combining environmental objectives with income diversification, the project aligns climate mitigation with livelihood enhancement.

The Saharanpur scenario offers a structured and replicable framework for future carbon finance projects. It shows that with the right institutional design and local participation, carbon finance can move beyond theory and become a functioning, measurable, and community-driven climate solution. ■

Prisha Pareek, Aakash Warman, and Sayanta Ghosh, Land Resources Division, The Energy and Resources Institute (TERI).

Malaria Didn't Just Kill Early Humans

It Shaped Who We Became

Long before humans spread across the globe, a deadly disease may have quietly shaped where our ancestors lived—and even how we evolved. New research reveals that malaria didn't just threaten early human survival; it actively pushed populations away from high-risk regions across Africa, fragmenting groups over tens of thousands of years. This separation influenced how different populations met, mixed, and exchanged genes, helping shape the genetic diversity we see today.

A growing body of research suggests that modern humans did not originate from a single location, but instead emerged through interactions among groups spread across different regions of Africa. Traditionally, scientists have explained where these populations lived based mainly on climate. New findings now point to another powerful influence: disease, particularly malaria.

In a study published in *Science Advances*, researchers from the Max Planck Institute of Geoanthropology, the University of Cambridge, and collaborating institutions explored whether malaria caused by *Plasmodium falciparum* affected where humans chose to live between 74,000 and 5,000 years ago. This period was crucial, as it came before humans spread widely beyond Africa and before agriculture significantly changed how malaria was transmitted.

Disease Shaped Where Humans Could Live

The results indicate that malaria, one of the oldest and most persistent infectious diseases affecting humans, played a major role in shaping settlement patterns. Regions with high transmission risk appear to have pushed human populations away, effectively separating groups across the landscape. Over tens of thousands of years, this separation influenced how populations encountered one another, interbred, and exchanged genetic material, contributing to the patterns of human diversity seen today. These findings highlight that disease was not just an obstacle for early humans but a key force shaping the course of human evolution.



Modelling Ancient Malaria Risk

"We used species distribution models of three major mosquito complexes together with paleoclimate models," explains lead author Dr Margherita Colucci of the Max Planck Institute of Geoanthropology and the University of Cambridge. "Combining these with epidemiological data allowed us to estimate malaria transmission risk across sub-Saharan Africa."

The team then compared these malaria risk estimates with a separate reconstruction of the environments early humans were able to inhabit across the same region and time frame. Their analysis revealed that humans consistently avoided, or could not remain in, areas where malaria transmission was especially high.

Long-Term Effects on Human Populations

"The effects of these choices shaped human demography for the last 74,000 years, and likely much earlier," says Professor Andrea Manica of the University of Cambridge, one of the senior authors of the study. "By fragmenting human societies across the landscape, malaria contributed to the population structure we see today. Climate and physical barriers were not the only forces shaping where human populations could live."

Rethinking the Role of Disease in Human History

"This study opens up new frontiers in research on human evolution," adds Professor Eleanor Scerri of the Max Planck Institute of Geoanthropology, also senior author of the study. ■

Source: https://www.sciencedaily.com/



Realigning Wildlife Tourism in India

Success lives beyond the roar, in the silence you hold

India's wildlife tourism is booming, but its current trajectory risks undermining the very ecosystems it depends on. Rising demand, rigid safaricentric models, unchecked resort development, and an obsession with tiger sightings have led to crowding, diluted experiences, and mounting ecological stress. While regulations such as carrying capacity norms are essential, the deeper challenge lies in misaligned expectations and flawed product design. The article calls for a realignment through diversified, lowimpact experiences, stronger bufferzone management, community integration, educationdriven tourism, and tighter accommodation norms. By shifting measures of success from numbers and sightings to learning, ecological health, and community wellbeing, wildlife tourism can grow without eroding the wild. Read the full article by **Manav Khanduja**.





Over the past decade, particularly post COVID-19 pandemic, wildlife tourism in India has witnessed a remarkable surge. Destinations such as Jim Corbett National Park, Ranthambore National Park, and Bandhavgarh National Park have become almost mythical when it comes to public imagination—synonymous with the promise of a tiger emerging through golden grass. Each year, the sector continues to grow in scale, ambition, and consequence. While this popularity has brought attention, revenue, and in some cases, stronger protection frameworks, the sector is at an inflection point where the very ecosystems it seeks to celebrate is threatened.

The Supreme Court of India's enforcement of carrying capacity norms was a critical and necessary intervention, an attempt to place ecological limits on an otherwise expanding industry. Yet, regulation alone cannot reshape intent. The direction of wildlife tourism as it continues to grow suggests a deeper misalignment between expectation and experience, growth and sustainability, presence and pressure.

The Experience Gap: When Demand Outpaces Current Supply

One of the most immediate challenges facing the sector is the paradox of access. With stricter limits on safari vehicles made available per zone and per day, permits for popular reserves sell out months in advance, especially during high season. Many visitors, who often travel long distances, find themselves unable to secure park entries when booking closer to the date.

India's wildlife tourism model remains overwhelmingly dependent on vehicular safaris into core zones across most tiger reserves. When access is restricted, as it must be, the experience remains sustainable, but also creates scarcity, which, instead of being reframed as exclusivity or depth, is often perceived as denial. The result is disappointment, sometimes even disillusionment. But this is not a failure of conservation policy; it is a failure of product design.

Contrast this with landscapes like Satpura National Park, where experiences like canoeing in the backwaters, and guided walking safaris in buffer areas have redefined how guests engage with the forest. These immersive experiences allow visitors to experience it from a different, deeper lens, opposed to a fleeting experience in a gypsy. The lesson is clear: diversification is not simply an add-on, but an essential to offset the demand and create new avenues of exploring the forest.

The Shift from Wilderness to Wedding Destination

Equally concerning is the transformation of accommodation options, and related ecosystems around key parks. In Jim Corbett National Park, easily accessible

by road from Delhi, the proliferation of large-scale resorts, luxury hotels and villas around the gateway town of Ramnagar has shifted the narrative.

New upscale properties, conceived as gateways to the forest, are being developed to accommodate large footfalls and drive demand. Such luxury resorts and chains are increasingly being positioned and marketed as venues for the events economy. Think destination weddings, corporate offsites, and high-volume tourism. The consequences ripple outwards—noise and light pollution, strain on local resources, unregulated construction, and a dilution of the very ethos that defines wildlife travel.

When the forest becomes a backdrop rather than the focal point, the integrity of the experience is compromised.

From Eco-Tourism to Mass Tourism

At its best, wildlife tourism in India has been a powerful tool for conservation and community upliftment. Lodges employing local staff, growing and sourcing local produce, building sustainability into their design and operations and investing in conservation initiatives have created ecosystems where tourism directly benefits those who have grown up around the forest and coexist with wildlife.

However, the rise of mass tourism threatens this balance. High footfall, low engagement models often bypass local communities, centralizing profits while externalizing ecological and social costs. The shift from eco-tourism to volume-driven tourism risks alienating the very stakeholders whose support is critical and proven for conservation success.





The Tiger Fixation

No conversation about Indian wildlife tourism is complete without addressing the star of the show that pulls in the crowds. The Bengal tiger is, undeniably, a conservation success story and a national icon. Yet, the singular focus on tiger sightings creates a narrow and often unrealistic expectation; a safari bereft of a sighting is deemed unsuccessful by many visitors, regardless of other precious and varied encounters with India's rich biodiversity.

With the Supreme Court of India restricting tourism to 20 per cent of park areas and capping vehicle numbers per safari slot, movement is concentrated along limited routes. This results in crowding of vehicles at hotspots and distorted practices, especially when guests and guides feel the need to justify the high cost of the experience.

A more balanced approach would be to retain vehicle limits but expand the areas open to tourism, particularly across buffers and lesser-used zones and routes. When space widens, pressure disperses, both on wildlife and on visitor expectation. Simultaneously, we must consider—if the majority of visitors seek tigers, can sightings be managed more systematically instead of leaving them to chaos and frenzy?

A decade ago, practices like elephant safaris, where the forest department would guide visitors to a confirmed sighting on the backs of elephants, created a certain assurance. Guests felt their patience would be rewarded. This system was rightly phased out for ethical reasons concerning elephant welfare. But in today's context, technology offers new possibilities. The use of AI-driven systems, live vehicle tracking, and real-time communication between guides and park authorities could help manage and guide movement towards probable sightings in a more controlled, less disruptive manner.

Such an approach may invite debate. It challenges traditional notions of chance in the wilderness. Yet, it also acknowledges a reality: the current model, marked by congestion, heightened expectations and rising costs, and uneven experiences, is not entirely working. The goal remains to reduce the pursuit of the sighting, so that visitors can enjoy the presence of this big cat and other wildlife in a thoughtful way.

Institutional Silos

Underlying these challenges is a structural disconnect between key stakeholders. Tourism departments often prioritize visitor numbers and economic



growth. Forest departments focus on ecological balance and protection. Revenue departments operate within yet another framework. Without alignment, policies can become fragmented. A cohesive, cross-sectoral approach is essential to ensure that growth does not come at the cost of sustainability.

Pathways to Realignment

If the current trajectory reflects imbalance, the path forward must be one of integration between experience, ecology, and economy.

Diversifying the wildlife experience

The future of wildlife tourism lies beyond the safari vehicle. Non-vehicular experiences like walking safaris, cycling trails, canoeing and boat rides, birding expeditions in designated areas and the development of photography hides can significantly expand visitor engagement while reducing pressure on core zones. These activities not only distribute footfall, but also deepen the quality of interaction and offer different avenues for engagement with the same ecosystem.

Buffers, often overlooked, hold immense potential. With thoughtful development like designated trails, interpretation centres and signage, regulated access, and trained guides, they can become vibrant spaces for exploration.

Reframing tourism as education

Wildlife tourism must evolve from passive viewing to active learning. Interpretation of natural ecosystems and wildlife behaviour is key. Skilled naturalists, immersive storytelling and strong communication, and well-designed educational materials can transform a sighting into an understanding. Visitors who leave with knowledge—about ecosystems, conservation challenges, and local cultures—are more likely to become advocates. Understanding leads to the impulse to protect.

This shift requires investment in training, curriculum development, and standardization of guiding practices across parks.

Integrating cultural and rural immersion

Forests do not exist in isolation; they are interwoven with human livelihoods and stories. Experiences that connect visitors with local communities, like village walks, traditional craft workshops, farm and market visits, food festivals focused on regional cuisine and storytelling, can enrich the tourism offering while creating alternative revenue streams for residents. This not only reduces dependency on core safaris but also fosters a more inclusive model of tourism, and can help market the region as a more holistic destination focused on cultural immersion.

Strengthening buffer zone infrastructure

Buffer zones are the bridge between protection and participation. Developing them with intent could look like creating water bodies to encourage wildlife movement and sustenance, and establishing controlled road networks. One of the most effective ways to unlock their potential is through staggered and flexible safari timings, instead of simply looking at them as secondary spaces that exist on the periphery of "real" wildlife experiences. Animals do not recognize boundaries and distinguish between core



and buffer, although their movement and behaviour patterns might differ due to increased presence of humans. Buffers could allow for flexible entry and exit schedules, spreading visitor movement across the day, reducing peak-hour congestion, and creating a more relaxed experience.

A compelling example of this approach can be seen in Tadoba-Andhari Tiger Reserve, where buffer zones have steadily evolved into rich wildlife viewing areas. With improved habitat conditions, and regulated access and management, these spaces now draw attention and revenue, not as alternatives, but as destinations in their own right. In doing so, they have helped ease the mounting pressure on core zones.

Equally important is the idea of multiple entry points and addition of new gates to disperse visitor flow across a wider area. This reduces bottlenecks, minimizes localized stress on specific zones, and extends the economic benefits of tourism to communities beyond the usual clusters through creation of livelihoods. Expanding buffer access through such policies leads to an outward ripple effect, enhancing ecological resilience and visitor experience.

Regulating accommodation with purpose

There is an urgent need to redefine what constitutes a wildlife lodge. Policies must incentivize low-impact, eco-sensitive architecture and operations. They must limit large-scale constructions that prioritize volume over value. Certifications, zoning regulations, and stricter enforcement can help ensure that accommodations remain aligned with conservation goals.



Managing expectations through narrative

Perhaps the most subtle yet powerful shift lies in storytelling. Marketing must move away from guaranteeing tiger sightings to celebrating the unpredictability of the wild. Campaigns, digital platforms, and on-ground communication should emphasize the journey, not just the jackpot. When visitors arrive with curiosity instead of expectation, the forest has space to reveal itself and the broader web of life.

Institutional collaboration

Finally, realignment requires governance that is as interconnected as the ecosystems it seeks to protect. Regular dialogue between tourism boards, forest departments, conservation organizations, and local communities can lead to more cohesive policies. Joint frameworks for planning, monitoring, and revenue sharing can ensure that all stakeholders move in the same direction.

A Different Measure of Success

In the end, the question is not whether wildlife tourism in India will continue to grow. The question is how it will grow, and what it will leave behind. Will it be measured in numbers— by footfall, occupancy, revenue and sightings? Or in something more enduring the measure of its success, be it the health of forests and ecosystems, the dignity of communities, and the depth of understanding it fosters?

To realign wildlife tourism is not to reduce its scale, but to refine its purpose. After all, in the forest, success is not only the roar you hear, but the silence you learn to hold. ■



Manav Khanduja, Co-Founder, Pugdundee Safaris.



From Farm Waste to Fuel

Building India's Biomass Bank Economy

BiofuelCircle is a pioneering digital platform dedicated to creating sustainable biomass supply chains by connecting farmers, rural entrepreneurs, and bioenergy producers. The company's platform enables the efficient collection, aggregation, and utilization of agricultural waste, contributing to India's transition to renewable energy and fostering rural economic growth through its innovative, participatory business model. Here, we are in an exclusive email conversation with **Suhas Baxi, Co-founder and Group CEO, BiofuelCircle** who's building "Biomass Bank" clusters that convert agricultural waste into industrial-grade fuel within a 10-km radius. It is not stubble-burning mitigation but it's a scalable, capital-light model creating self-sustaining economic hubs with direct district-level GDP impact.



India generates an enormous volume of agricultural biomass every year, yet much of it remains underutilized. How do you see this resource fitting into the country's evolving clean energy landscape?

India's agricultural biomass represents a significant yet underutilized resource that can play a meaningful role in the clean energy transition. While it is not a complete substitute for fossil fuels, it has the potential to contribute meaningfully addressing nearly 10–12 per cent of national energy demand in the medium term.

More importantly, biomass is a reliable, locally available energy source that complements other renewables such as solar and wind. By converting agricultural residue into bioenergy, India can reduce dependence on fossil fuel imports, strengthen energy resilience, and address environmental challenges such as stubble burning in a structured manner.

BiofuelCircle has introduced the idea of "Biomass Bank" clusters. Could you briefly explain how this decentralized approach works and what makes it effective in the Indian context?

The Biomass Bank model is a decentralized, cluster-based approach where biomass aggregation, processing, and supply are organized locally around demand centres such as bioenergy plants and industrial users.

Each Biomass Bank operates as a rural micro-enterprise, typically involving an investment of around ₹3 crore and generating annual revenues of ₹3–4 crore. These units aggregate agricultural residue from nearby farms, process it, and ensure a reliable, consistent supply to end users.

What makes this model particularly effective in India is its alignment with the country's agricultural realities fragmented landholdings, seasonal residue availability, and a strong rural workforce. By decentralizing operations, the model reduces logistics costs, improves supply reliability, and creates tangible economic value within local communities.

Agricultural residue is often perceived as waste, sometimes leading to practices such as open-field burning. How can structured biomass markets help change this perception among farmers?

Structured biomass markets fundamentally shift the perception of agricultural residue from waste to a monetizable resource. When farmers have access to reliable procurement



systems, transparent pricing, and assured demand, residue becomes an additional source of income rather than a disposal challenge.

Our experience shows that when the right ecosystem comprising infrastructure, awareness, and market linkages is in place, farmer participation is both willing and enthusiastic. Many farmers value the opportunity to earn incremental income while adopting more sustainable practices.

This shift from waste to value is critical in reducing stubble burning and building a more sustainable and economically viable agricultural ecosystem.

Your platform integrates digital tools such as telematics and GPS-enabled machinery. How are such technologies helping organize and streamline what has traditionally been an unstructured sector?

Technology is central to transforming biomass aggregation from an unstructured activity into a data-driven, organized supply chain.

At BiofuelCircle, we have deployed GIS and GPS-based systems to map farmland, crop patterns, and residue availability. This allows for precise planning of aggregation activities, infrastructure deployment, and harvesting timelines.

In parallel, telematics and satellite-enabled tracking help optimize logistics

by improving route efficiency, reducing empty runs, and ensuring timely pick-ups. Together, these technologies bring transparency, efficiency, and predictability into the system key enablers for scaling biomass supply chains sustainably.

In your view, how can decentralized biomass clusters contribute to building more resilient and localized energy supply chains?

Decentralized biomass clusters strengthen energy resilience by creating localized supply chains that are less dependent on long-distance transportation and centralized infrastructure.

By sourcing biomass locally and supplying it to nearby industrial users or bioenergy plants, these clusters reduce supply disruptions and enhance reliability. They also contribute to diversifying the energy mix, which is essential for reducing dependence on fossil fuel imports.

When integrated with other renewable sources, decentralized bioenergy becomes an important pillar in building a more distributed, resilient, and future-ready energy ecosystem.

BiofuelCircle connects farmers, rural entrepreneurs, and industrial buyers through a digital platform. How does this ecosystem create opportunities for rural livelihoods?

The BiofuelCircle ecosystem is designed to create economic opportunities across multiple layers of the value chain. Farmers benefit by monetizing agricultural residue, creating an additional and reliable income stream. At the same time, Biomass Banks operate as rural micro-enterprises, enabling local entrepreneurship with strong revenue potential and predictable payback timelines.

Beyond this, the ecosystem generates employment across aggregation, logistics, processing, and operations. By connecting stakeholders through a digital marketplace, we enable transparent transactions, efficient coordination, and sustained economic activity across rural regions.



From a policy perspective, what steps could further accelerate the development of efficient biomass supply chains in India?

A critical step would be to formally recognize the biomass supply chain as a distinct and essential segment within the bioenergy ecosystem.

Currently, most policy interventions are directed towards farmers or bioenergy producers, while the supply chain which requires significant investment in aggregation, logistics, processing, and technology remains under-supported.



Accelerating this sector will require incentivizing supply chain infrastructure, improving access to capital, and ensuring long-term policy clarity. Treating biomass supply chains as core energy infrastructure, rather than short-term initiatives, will be key to attracting sustained investment and enabling scale.

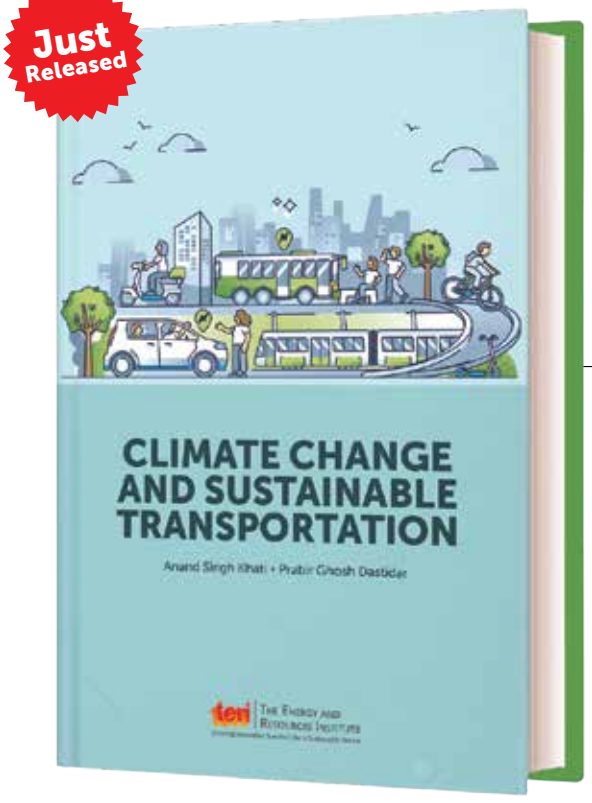
As India advances its clean energy transition, what role do you see decentralized biomass solutions playing in strengthening both sustainability and rural economic growth?

Decentralized biomass solutions will play a dual role in advancing sustainability while driving rural economic growth. Environmentally, they enable the productive utilization of agricultural residue, reduce emissions from stubble burning, and contribute to fossil fuel substitution. Economically, they create new income streams for farmers, foster rural entrepreneurship, and generate local employment.

As these systems scale, their true impact will be reflected in the extent of fuel substitution achieved. When bioenergy begins to replace fossil fuels at scale, it signals not just environmental progress, but the emergence of a robust, inclusive, and economically sustainable clean energy ecosystem. ■

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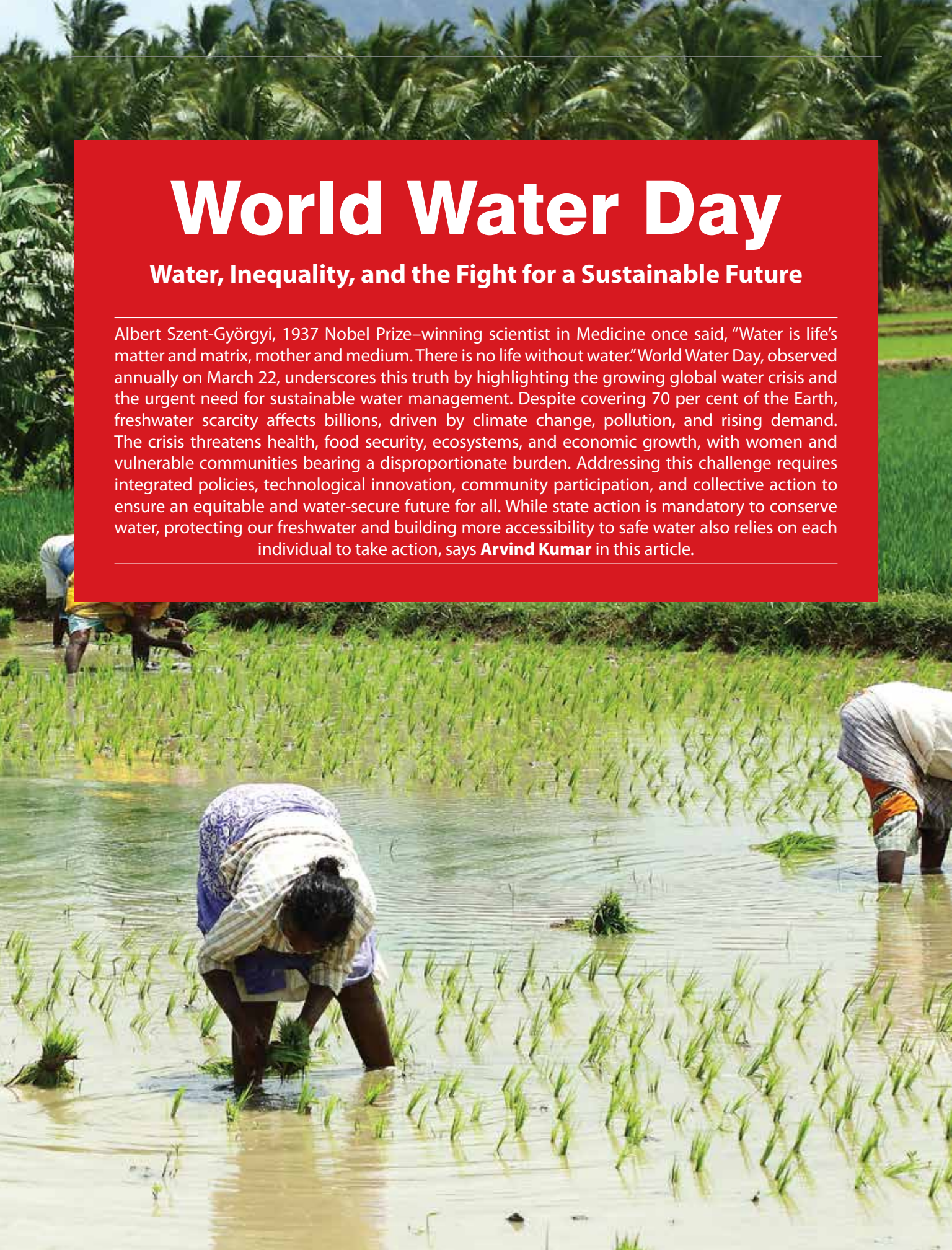
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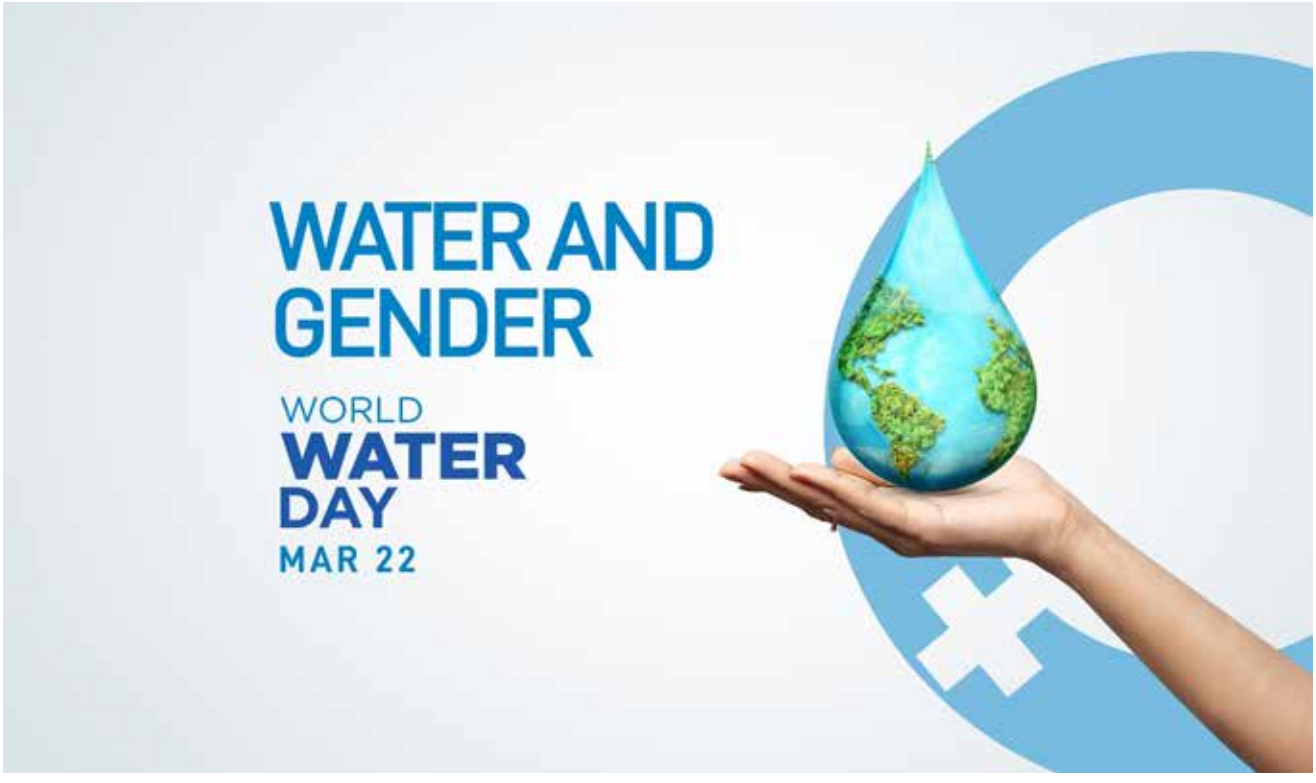




World Water Day

Water, Inequality, and the Fight for a Sustainable Future

Albert Szent-Györgyi, 1937 Nobel Prize–winning scientist in Medicine once said, "Water is life's matter and matrix, mother and medium. There is no life without water." World Water Day, observed annually on March 22, underscores this truth by highlighting the growing global water crisis and the urgent need for sustainable water management. Despite covering 70 per cent of the Earth, freshwater scarcity affects billions, driven by climate change, pollution, and rising demand. The crisis threatens health, food security, ecosystems, and economic growth, with women and vulnerable communities bearing a disproportionate burden. Addressing this challenge requires integrated policies, technological innovation, community participation, and collective action to ensure an equitable and water-secure future for all. While state action is mandatory to conserve water, protecting our freshwater and building more accessibility to safe water also relies on each individual to take action, says **Arvind Kumar** in this article.



World Water Day, held on March 22 every year since 1993, is an annual United Nations Observance focusing on the importance of fresh water and its sustainable management. This day puts the spotlight on the world's freshwater crisis, the systems behind it, and the solutions we often ignore. It is a yearly "status check" on how humanity is doing with the planet's most vital resource. Water is life: people, fauna, and plants alike all depend upon water to survive—its protection impacts us all. The most important resource on the planet, water covers 70 per cent of the globe. It also makes up about 60 per cent of the human body. This is why drinking water plays a key role in keeping our organs and bodily systems functioning smoothly. Water is a major input in the provision of food, from production in the field through all the steps in the value chain. Water is also required to meet personal and household needs, for energy and industrial production, and to maintain important water-dependent ecosystems.

The global water crisis is a multidimensional problem accentuated by climate change, urbanization, and population growth. Even though there is plenty of water, about 2.2 billion people around the world lack access to clean drinking water, and it is estimated that 1.8 billion people reside in areas affected by absolute water scarcity. The current situation is made worse by climate change, population growth, pollution, and insufficient infrastructure. The crisis not only affects human health but also threatens food security, economic development, and the environment.

Variability in the global water cycle is also making it more difficult to predict water availability. Though not considered a global crisis just yet, water scarcity affects every continent. Managing a challenge of this scale and importance requires a global response; especially as global freshwater demand is set to outstrip supply by 40 per cent by 2030.



Challenges that Water Faces

Water pollution is a major challenge. Every day, chemicals and contaminants, including pharmaceuticals, chemicals, heavy metals, and various toxic substances, including lead and mercury, are flushed down drains and sinks. Although treatment plants can remove many contaminants by treating wastewater, much still enters into the environment.

The biggest challenge here is a lack of awareness and lack of data that help us understand how human activities are impacting freshwater ecosystems; in order to protect our freshwater ecosystems, we first need to understand them. From citizens to policymakers to corporations to scientists, access to accurate freshwater data is crucial in order to make the necessary changes.

Water and Gender

'Where water flows equality grows' was the slogan of World Water Day 2026. The theme was "Water and Gender," focusing on safe water and sanitation as human rights and critical enablers of gender equality. The campaign explains that the global water crisis affects everyone, but not equally. Women and girls are disproportionately affected by poor water, sanitation and hygiene services and facilities. In many communities, they are responsible for collecting water for their households, often walking long distances and spending hours each day carrying heavy loads. This can keep girls out of school and limit women's opportunities to work, building businesses, or participating in public life. Water insecurity can also expose women and girls to safety risks when they must travel far from home to find water.



Women are central to the solution. Women manage water in households and communities and play vital roles in agriculture, small businesses, and local water initiatives. Ensuring women have a stronger voice in water governance, better access to financing, and the tools to expand water-related enterprises, can unlock new economic opportunities. To find adequate solutions women and girls must play a central role in designing and implementing services that respond to their specific needs. Promoting gender equality in agricultural water management is not only a matter of rights. It is also an upscaling development opportunity to achieve water and food security for all.

Snapshot of India's Water Situation

India is home to 17 per cent of world's population but has only 4 per cent of world's freshwater resources and managing these disproportionately small resources for





a huge population is a daunting task. Per capita water availability in India dropped from 1,816 cubic metres in 2001 to roughly 1,486 in 2021. By 2050, we will approach the scarcity threshold of 1,000 cubic metres.

The annual utilizable water resources in India are 690 billion cubic metres (BCM) from surface sources and 447 BCM from ground water. In spite of possessing surface water resources, India is highly dependent on groundwater resources. According to the Central Groundwater Board, contribution of ground water is nearly 62 per cent in irrigation, 85 per cent in rural water supply and 45 per cent in urban water supply. Groundwater resources are facing stress from overexploitation due to lack of well-considered water pricing for agricultural use, energy subsidies that promote over-extraction, and sub-optimal matching of crops with the agro-climatic and water zones in states.

The per capita water storage capacity in India is about 209 m^3 which is small in comparison to per capita storage capacities in countries such as Australia (3223 m^3), the USA (2193 m^3), Brazil (2632 m^3), and China (416 m^3). India is facing the challenge to meet its demand through the existing but depleting water resources. To augment scarce water resources, we need to explore unconventional solutions like recycle and reuse of water, rainwater harvesting, etc. Besides, it is possible to store 214 BCM of surplus monsoon runoff in groundwater reservoir.

India's urban population is expected to reach 600 million by 2030, and fulfilling its water needs will be a great challenge. Estimates suggest that the demand-supply gap for the domestic sector will stand at around 50 BCM in 2030, with the demand expected to double by that time.

For India it is Time to Take Action

Water has been recognized as being vital to India's economic growth, well-being of its people, and the sustainability of ecosystems. Over the last few years, the Government of India as well as State Governments have undertaken a range of initiatives focused on groundwater recharge; responsible use of water for agriculture; and use of technologies such as micro-irrigation. Similarly, legislation promoting

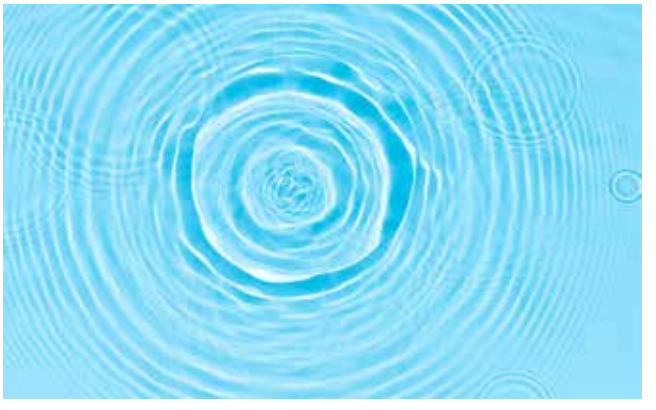
water-efficient energy production or discouraging water pollution by industry have been enacted. More significantly, the Government has consolidated institutional structures under the Ministry of Jal Shakti to bring interrelated water management functions together and drive more effective outcomes.

There is an imminent need to deepen our understanding of the limited available water resources and their usage, and put in place interventions that make water use efficient and sustainable. Pricing water to reflect irrigation costs as well as water scarcity can be an effective model for water conservation in agriculture. Also, water pricing can be powerful tools to control water demand in urban areas as well. With a country generating 140 BCM of wastewater annually, recycling and reuse is imperative to conserve water. The entire country needs to act now and take radical steps to manage and use water more responsibly.

In order to tackle the multi-faceted drivers and impacts of water scarcity, states must adopt a water lens into policy making and planning across sectors. Macro-view and cross-sectoral view of India water problems will help state administrators take a more holistic view of water in their policy making. Without this, the root causes of the water problem (such as from agricultural, industrial, and urban water use), and their multi-dimensional impacts, will not be addressed. Importantly, states must supplement urgent top-down water legislations with a grassroots management approach that involves local community organizations, NGOs, farmer groups, and industry bodies in ideation and implementation of water-related policies and projects.

Sustainable Solutions to the Global Water Crisis

Climate change results in water crisis by altering weather patterns, leading to droughts and floods. As





temperatures rise, evaporation rates increase, further diminishing freshwater reserves and increasing competition for this scarce resource. Understanding these links is essential for implementing sustainable solutions that mitigate the impacts of climate change on water availability.

One of the most effective ways to combat water scarcity is to promote conservation and responsible water use. Public awareness campaigns are vital in educating communities about the importance of water conservation and encouraging sustainable habits.

Advanced Irrigation Techniques

Agriculture accounts for about 70 per cent of global freshwater use. Implementing advanced irrigation techniques such as drip irrigation, rainwater harvesting, and soil moisture monitoring can significantly enhance water efficiency in farming. These methods reduce water waste and increase crop yields, supporting food security while preserving valuable water resources.

Role of Innovative Water Technologies

Innovative water technologies include desalination, water filtration, and purification systems. Desalination entails removing salt and impurities from seawater to produce fresh water. However, it is energy-intensive and costly. Advanced water purification systems have emerged as a means to recycle wastewater for various purposes, including agricultural irrigation and industrial processes. Technologies like membrane bioreactors and solar water purifiers can effectively treat wastewater and reduce reliance on freshwater resources. By investing in these filtration systems, communities can promote water reuse and reduce pollution.



Water Management and Conservation

Natural solutions

Sustainable watershed management plays a critical role in maintaining clean water sources and preventing flooding. By restoring natural habitats and implementing land-use planning, communities can promote natural filtration and maintain the health of the water cycle. This approach not only ensures adequate water supply but also enhances biodiversity and mitigates climate change impacts.

Reforestation initiatives help to restore natural ecosystems that play a vital role in regulating water cycles. Trees absorb rainfall, preventing runoff and soil erosion, and promoting groundwater recharge. Moreover, reforestation aids in mitigating climate change by reducing carbon dioxide levels in the atmosphere. These initiatives are necessary for creating resilient landscapes that support water sustainability.

Sustainable water management to be effective needs local community participation. Engaging residents in decision-making processes fosters a sense of ownership and responsibility towards water resources. Community-led initiatives, such as establishing local water cooperatives and promoting sustainable agriculture practices, empower individuals to contribute to solving the water crisis.

Conclusions

With the global water crisis looming larger than ever, it is crucial to explore sustainable solutions that combat water shortages, pollution, and unequal distribution of scarce water. The global water crisis is a challenging issue that affects millions of people, with consequences for health, food security, and economic development. By adopting sustainable solutions, ranging from conservation practices and innovative technologies to community participation and international cooperation, we can preserve this precious resource. A sustainable and equitable water future is imperative for all. While state action is mandatory to conserve water, protecting our freshwater and building more accessibility to safe water also relies on each individual to take action. Together, we can make a difference. ■

Arvind Kumar, Former Senior Economic Adviser, Government of India.

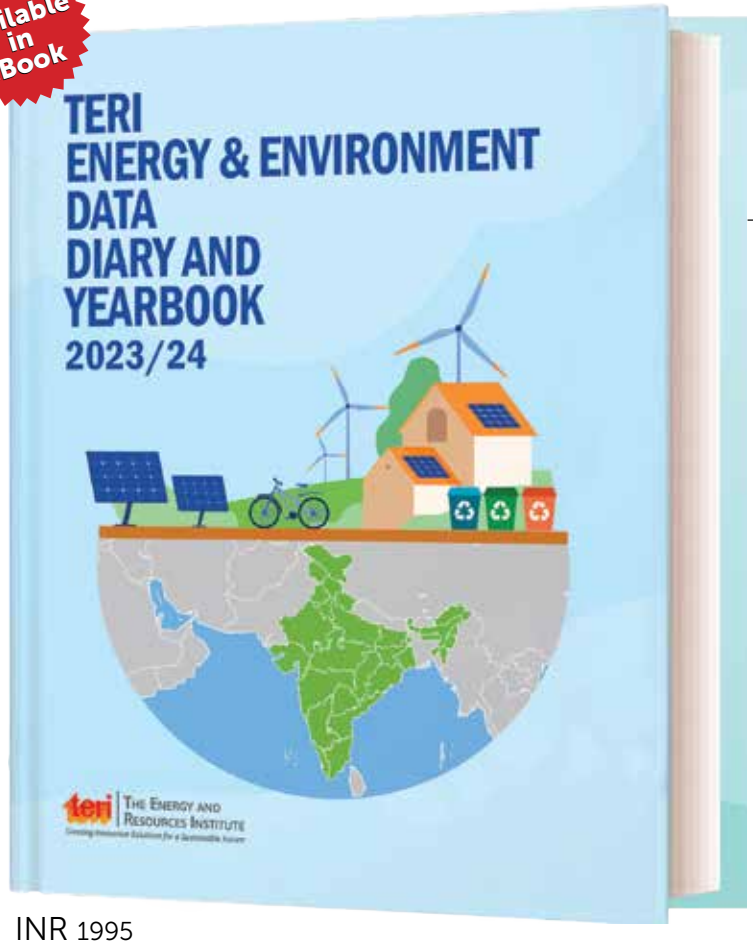
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Fruit to Future

Repositioning India's Oil Palm Sector through Circular Value Integration

In this article, **M S M S Kumar** argues that India's oil palm sector stands at a strategic inflection point, where expanding cultivation under NMEO-OP must now give way to deeper value creation. Moving beyond a linear, oil-centric model, it makes a strong case for circular value integration—leveraging by-products, downstream processing, bioactive recovery, and biorefinery concepts to enhance economic, industrial, and environmental outcomes. The piece highlights opportunities in oleochemicals, nutraceuticals, renewable energy, and carbon markets, supported by policy realignment and cluster-based development. Reframing oil palm as a holistic resource system, the article positions circularity as essential to sustainability, resilience, and long-term competitiveness.

India's oil palm sector has reached a critical turning point. Recent policy momentum under the National Mission on Edible Oils – Oil Palm (NMEO-OP) has successfully accelerated the expansion of cultivation. However, the next phase of sectoral evolution cannot rely on acreage growth alone. Long-term sustainability and competitiveness require a shift from a purely production-focused model to a high-value, circular economy approach. The future of oil palm in India lies not merely in increasing crude palm oil (CPO) output, but in systematically unlocking economic, industrial, and environmental value from every component of the value chain.

Unlike previous analyses that emphasized biomass availability and utilization gaps, this perspective shifts focus towards value realization through downstream integration, circular biorefinery development, and emerging revenue streams—including nutraceuticals and carbon markets. The emphasis is on system-level optimization and economic diversification, moving beyond resource potential to actionable pathways.

The Limits of a Linear Value Chain

Historically, India's oil palm sector has operated within a largely linear framework centred on fresh fruit bunch





(FFB) harvesting, processing and crude oil extraction. This model captures only a fraction of the crop's total economic potential. Substantial biomass and process streams—empty fruit bunches (EFB), mesocarp fibre, palm nut shells, palm oil mill effluent (POME), decanter cake and solid sludge (ETP) are often underutilized or inefficiently managed.

Deepening Downstream Processing

A major opportunity lies in strengthening downstream processing capabilities. Currently, much of India's palm oil value chain stops at crude or minimally refined oil. However, substantial value addition can be achieved through advanced refining and derivative manufacturing.

Palm Kernel Oil (PKO) is naturally rich in lauric acid, a medium-chain fatty

acid prized for its exceptional cleansing, emulsifying, and foaming properties. These qualities have made PKO a valuable raw material across a wide range of industrial and consumer products.

The Versatility of Palm Kernel Oil

Industry Sector	Applications and Derivatives	Key Properties
Personal & Home Care	Soaps, detergents, shampoos, cosmetics, surfactants	Lauric acid-rich; exceptional cleansing, foaming, and emulsifying
Food Processing	Bakery shortenings, ice creams, non-dairy creamers, speciality fats	Favourable melting profile, high oxidative stability
Confectionery	Cocoa Butter Substitutes (CBS) and Equivalents (CBE)	Cost-effective texture and mouthfeel maintenance
Oleochemicals	Fatty acids, alcohols, glycerine, methyl esters	Essential inputs for pharma and polymers

Palm fatty acid distillate (PFAD)—often considered a low-value byproduct—can be utilized as a feedstock for biodiesel, soap manufacturing, and specialized animal nutrition products such as rumen bypass fat. Fractionation of palm oil yields olein, stearin, and mid-fractions, each serving distinct industrial and food applications, including bakery fats, confectionery products, and frying oils.

Despite being one of the world's largest consumers of palm oil, India has limited domestic capacity in oleochemical manufacturing. Oleochemicals—fatty acids, fatty alcohols, glycerine derivatives, and methyl esters—are essential inputs for detergents, personal care products, pharmaceuticals, and polymers. Developing a robust domestic oleochemical sector can significantly enhance value addition, reduce import dependence, and create new industrial opportunities.

High-Value Bioactive Recovery

Another emerging opportunity lies in recovering minor bioactive components from palm oil and its derivatives. Compounds such as tocotrienols (a superior form of vitamin E) and carotenoids (such as beta-carotene) have significant applications in nutraceuticals, pharmaceuticals, and functional foods. With appropriate extraction and purification technologies, these components can transform palm oil from a bulk commodity into a source of high-value health ingredients. This improves economic returns while aligning the sector with growing global demand for natural and functional products.



Circular Biorefinery Model

The most transformative potential, however, lies in adopting a circular economy framework. A circular oil palm system converts all by-products into valuable outputs, creating a closed-loop ecosystem with minimal waste. This shift represents a fundamental transition from waste management to resource optimization.

- **Empty fruit bunches**: Processed into compost or biochar, improving soil health and enhancing carbon sequestration.
- **Mesocarp fibre**: Renewable energy source, livestock feed or soil amendments.
- **Palm nut shells**: Converted to activated carbon for water and air purification.
- **Palm trunks and fronds**: Furniture, flooring, mulch.
- **Decanter cake and solid sludge from ETP**: Feed ingredient and soil conditioner.
- **Boiler ash**: Soil amendment.

POME presents a significant clean energy opportunity. Through anaerobic digestion,1 KL of POME yields 24–26 m^3 of biogas. This biogas can be upgraded to Bio-CNG, reducing methane emissions while powering mill operations or supplying external markets. The nutrient-rich digestate can be used as a fertilizer, closing the nutrient loop within plantations. Integrating rainwater harvesting and precision irrigation further optimizes the "Water Footprint,"



turning environmental challenges into managed assets.

Carbon Monetization Pathways

Circular practices open new avenues for carbon revenue. Methane capture from POME, biochar application in soils, and replacement of fossil fuels with biomass energy can generate verifiable carbon credits. With proper monitoring and accounting systems, mills can participate in voluntary carbon markets, creating an additional income stream while supporting India's net-zero ambitions.

Policy and Institutional Alignment

To accelerate this transition, the existing policy framework must evolve from supporting plantation expansion to actively promoting value addition and circularity. Realizing these opportunities requires strong policy and institutional support. The current framework, effective for plantation expansion, must evolve to incentivize value addition and resource efficiency.

Key recommendations for policy engagement include:

- **Incentive linking**: Tie government support to by-product utilization, energy recovery, and carbon performance.
- **Mandating methane capture systems**: Standardize in new and expanding mills to improve environmental outcomes.
- **Standardization**: Establish national quality standards for EFB pellets and bio-based fertilizers to build market trust.

Cluster-based Industrial Development

Cluster-based development offers a practical pathway. Oil palm-intensive regions—particularly in Andhra Pradesh and Telangana—can be developed as Integrated Palm Bioeconomy Zones. These clusters can facilitate shared infrastructure, reduce logistics costs, and promote industrial symbiosis, where the output of one process becomes the input for another. Public–private partnerships can play a crucial role in establishing demonstration projects that validate techno-economic feasibility.

Phased Roadmap for Transition

A phased roadmap can guide the sector's transition:

- **Short-term (1–3 years)**: Implement proven technologies such as EFB composting, biomass briquetting, and POME-based biogas generation.
- **Medium term (3–6 years)**: Scale up value-added products—Bio-CNG, activated carbon, nutraceutical extracts.
- **Long term (6–10 years)**: Develop advanced biorefinery concepts—pyrolysis, gasification, second-generation biofuels, and bioplastics.

Andhra Pradesh Model for Circular Hub

With nearly 2.5 lakh hectares under oil palm (accounting for ~80% of India's CPO production), Andhra Pradesh is well positioned to become a national model for circular oil palm development. By integrating POME-to-Bio-CNG systems, activated carbon units, structured compost return programmes, oleochemical clusters, rainwater harvesting, and intercropping. Such a success model can then be replicated across other oil palm–growing regions in India.

Conclusion: From Fruit to Future

Ultimately, the future of India's oil palm sector will be determined by its ability to move from a linear oil-centric model to a circular, value-integrated ecosystem. This transition will enhance economic returns, minimize environmental impacts, diversify farmer and mill incomes, and build greater resilience.

"Fruit to Future" is not just a slogan—it is a strategic necessity. By treating oil palm as a comprehensive resource system rather than a single-output crop, India can build a more sustainable, efficient, and self-reliant edible oil sector. This transformation aligns with the ancient ideal of 'kalpavruksha'—where every part of the tree sustains and enriches the system. The time has come to convert waste into wealth and position oil palm as a flagship of India's circular bioeconomy—delivering both economic prosperity and environmental stewardship. ■

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Disclaimer: The views expressed are personal and do not represent those of any organization.

Circularity, Water Stress, and Resilient Building Design

A Systems Perspective for Sustainable Infrastructure Governance

In this article, **Mutaharra Abida Waheed Deva** examines how circular economy principles and climate-resilient building design can address water stress and infrastructure vulnerability. It explores global best practices, emerging research trends and policy frameworks while highlighting the relevance of these approaches in the Indian context and climate-sensitive regions such as Kashmir. The article argues that integrating circular resource management, water-sensitive urban design and resilience planning can significantly enhance sustainability outcomes while reducing systemic risk.

Climate change, water stress and rapid urbanization are reshaping the sustainability challenges facing the built environment. Buildings account for nearly 40 per cent of global energy consumption and energy-related carbon emissions, making them both a major contributor to environmental pressures and a critical area for climate solutions. At the same time, infrastructure systems are increasingly exposed to extreme weather events, water scarcity, and ecological degradation.

For policymakers, infrastructure planners, and corporate boards adopting circular and resilient building strategies represents both a governance imperative and a long-term economic opportunity.

Why Resilience in the Built Environment Matters

The built environment plays a central role in shaping environmental sustainability and climate resilience. According to the Intergovernmental Panel on Climate Change (IPCC) and the United Nations Environment Programme (UNEP), buildings account for approximately 36–40 per cent of global energy consumption and greenhouse gas emissions.



Urban expansion, infrastructure development and population growth are increasing pressure on natural resources particularly water. The World Resources Institute estimates that several regions of the world will face severe water stress by 2030 if current consumption patterns continue.

Water stress occurs when water demand exceeds available supply or when poor quality limits its use. Rapid urbanization, climate variability and inefficient resource management have intensified this challenge in many developing economies including India.

In this context, the integration of circular economy principles, climate-resilient infrastructure design, and sustainable resource management has become essential. These approaches can help reduce environmental pressures while strengthening infrastructure resilience to climate risks.

For corporate boards, infrastructure investors and governance institutions the built environment represents a critical frontier for Environmental, Social, and Governance (ESG) risk management and sustainable development.



Circularity in the Built Environment

Circular economy thinking is transforming the way infrastructure systems are designed and managed. Unlike the traditional linear model of take–make and dispose formula circular systems emphasize resource efficiency, reuse, regeneration and lifecycle optimization.

In the built environment, circularity involves designing buildings that minimize waste, maximize material recovery and operate within natural ecological cycles.

Water circularity strategies

Water circularity has become a key component of sustainable building design.

On-site wastewater treatment and reuse

Grey water and treated wastewater can be reused for non-potable purposes such as toilet flushing, landscaping, and cooling systems. This reduces dependence on freshwater extraction and strengthens water security.

Dual plumbing systems

Separating potable and non-potable water streams allows buildings to maximize water reuse while ensuring safety in drinking water systems.

Rainwater harvesting and groundwater recharge

Intelligent rainwater harvesting systems capture stormwater/flood water and enhance groundwater infiltration. This approach reduces urban flooding while improving local water availability.

Lifecycle material reuse

Circular building design also incorporates modular construction and materials designed for disassembly and reuse thereby extending the life cycle of building components.

Benefits of Circular Building Systems

Circular building systems provide several environmental and economic advantages:

- Reduced freshwater extraction
- Lower embodied carbon in construction materials
- Improved building-level resource self-sufficiency
- Lower lifecycle operational costs
- Enhanced climate resilience

For businesses and investors, these strategies align with ESG performance metrics and sustainable finance frameworks.

Resilience Principles in Building Design and Renovation

Resilience refers to the capacity of infrastructure systems to absorb shocks and be adaptive to change, and recover quickly from disruptions such as natural disasters, climate events or resource shortages.

In the built environment, resilience must integrate engineering design, environmental sustainability and governance mechanisms.

Passive and Adaptive Design

Passive survivability is an important concept in resilient architecture. It refers to the ability of buildings to maintain safe and habitable conditions during disruptions to power, water, or other essential services.

Key design strategies include:

- Building orientation for natural heating and cooling
- High-performance insulation and ventilation systems
- Climate-responsive building envelopes

These strategies reduce energy consumption and improve resilience during extreme weather events.

Integrated Retrofit Approaches

Many existing buildings were constructed without climate resilience considerations. Retrofitting therefore plays a critical role in improving sustainability outcomes.

Modern retrofit programmes combine:

- Structural safety improvements (e.g., earthquake resistance)
- Energy efficiency upgrades
- Water conservation and recycling systems

Integrated retrofits enhance long-term asset performance and climate resilience.

The Water–Energy–Food Nexus in Buildings

Resilient infrastructure planning increasingly adopts a Water–Energy–Food (WEF) nexus perspective recognizing the interconnected nature of resource systems.

Examples include:

- Cooling systems designed to minimize water consumption
- Green roofs that reduce heat while retaining storm water
- Urban agriculture integrated into building systems

These approaches enhance both resource efficiency and urban resilience.

Global Governance Frameworks and Best Practices

Governments and international organizations are increasingly incorporating resilience and circular economy principles into infrastructure governance.

Key frameworks include:

- United Nations Sustainable Development Goals (SDGs)
- Paris Climate Agreement commitments
- UNEP Global Status Report for Buildings and Construction
- World Bank climate-resilient infrastructure programmes

These initiatives emphasize risk-informed planning, sustainable materials, and water-efficient infrastructure systems.

Green Building Rating Systems

Several rating systems now integrate sustainability and resilience principles, including:

- GRIHA (India)
- LEED (United States)
- BREEAM (United Kingdom)

These frameworks guide building developers and infrastructure investors towards resource-efficient and climate-resilient construction practices.

The Indian Policy Context

India has increasingly incorporated sustainability and climate resilience into national development policies.

Key initiatives include:

- National Action Plan on Climate Change (NAPCC)
- State Action Plans on Climate Change (SAPCCs)
- National Mission on Sustainable Habitat
- National Water Mission

India's building sector is also influenced by regulatory frameworks such as:

- Energy Conservation Building Code (ECBC)
- National Building Code (NBC)
- Indian Green Building Council (IGBC) standards
- GRIHA certification system

These frameworks aim to improve energy efficiency, water management, and climate resilience in infrastructure development.

Kashmir: A Climate-Sensitive Regional Perspective

The Kashmir region represents a particularly sensitive ecological zone. Its mountainous terrain, fragile ecosystems and complex hydrological systems make it highly vulnerable to climate impacts.

Recent years have witnessed:

- Increased flood risks
- Changing precipitation patterns
- Water stress in urban areas
- Land degradation in catchment zones
- Winter snow deficit
- Rainfall deficit

Historic floods in the region have demonstrated the need for climate-informed urban planning and resilient infrastructure systems.

Integrated Planning Requirements

Addressing these challenges requires a multi-dimensional approach that integrates:

Hydrological design

Buildings must incorporate systems for water management and groundwater recharge.

Structural resilience

Infrastructure must be designed to withstand seismic activity, floods, and landslides.

Community engagement

Participatory planning ensures that local knowledge and environmental realities inform infrastructure decisions.

Emerging Research Gaps and Opportunities

Despite growing global attention circular economy implementation remains limited.

Circularity gap

According to the Circularity Gap Report, the share of recycled materials in the global economy remains low despite increasing discussion of circular economy principles.

Economic potential

Research suggests that circular economy adoption could generate trillions of dollars in economic value globally by 2030. This will create many employment opportunities and reducing environmental impacts.

Resource consumption challenges

Material extraction remains a major driver of greenhouse gas emissions, biodiversity loss, and water stress.

Measurement challenges

Scholars emphasize the need for robust circularity indicators to measure progress effectively and guide policy decisions.

Investment patterns

While investment in circular business models is increasing particularly in recycling and resale; however, high-impact innovations such as design for reuse and remanufacturing still receive limited financial support.

Governance and the Role of Corporate Boards

For corporate boards and Independent Directors, climate resilience and circular resource management are increasingly



part of fiduciary oversight and risk management.

Infrastructure investments face growing exposure to:

- Climate-related financial risks
- Regulatory changes
- Water scarcity
- Resource volatility

Boards must therefore integrate ESG principles into strategic planning and capital allocation decisions.

Adopting circular and resilient building systems can help organizations:

- Reduce operational risk
- Improve long-term asset value
- Meet sustainability reporting requirements
- Strengthen stakeholder confidence

Conclusion: A Systems Path Forward

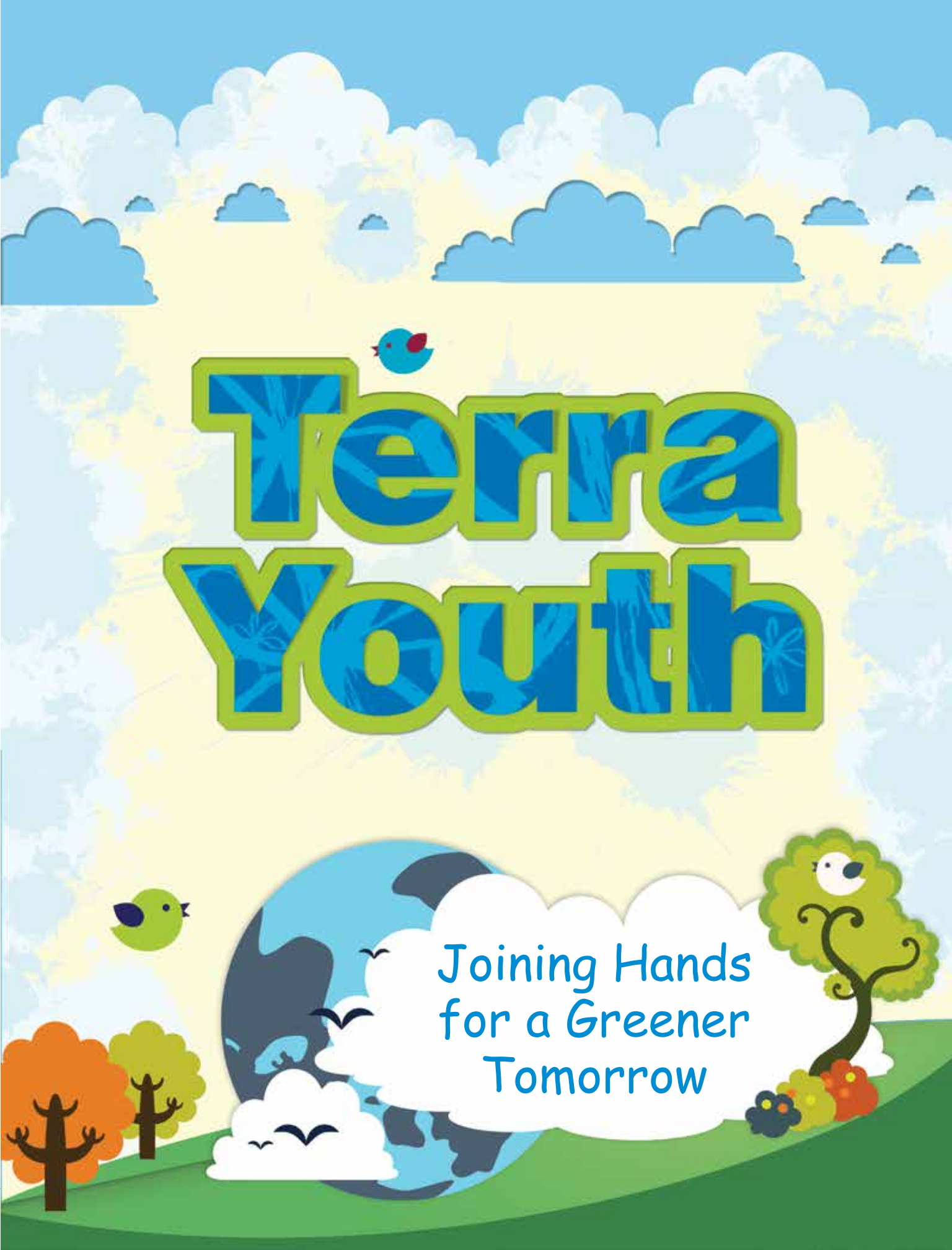
Addressing climate change and water stress requires a fundamental transformation in how infrastructure systems are designed and managed.

Circular economy principles and resilience-based building design offer a pathway towards sustainable, adaptive, and resource-efficient built environments.

For countries such as India and climate-sensitive regions like Kashmir combining global best practices, national policy frameworks and local knowledge systems is what is needed. This combination can create infrastructure that is both environmentally sustainable and economically resilient.

The future of sustainable development depends on adopting a systems approach that integrates climate adaptation, water security, circular resource management, and responsible governance. Such an approach can ensure that the built environment evolves from being a major source of environmental pressure to becoming a key driver of sustainability and resilience in the 21st century. ■

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Terra Youth
Joining Hands for a Greener Tomorrow

Accelerating Unease between Nature and Humans

Need to Renew the Collective Strength

Drawing from personal memories and everyday practices, **Sankalpa Satapathy** reflects on a time when humans shared an instinctive relationship with nature, particularly within Indian cultural traditions. It shows how philosophy, religion, folklore, and daily rituals once recognized the interconnectedness of all living beings. Set against this is the contemporary urban reality, where fastpaced living, consumerism, and the commodification of nature have led to growing alienation. This widening rupture has serious consequences—from ecological damage and climate change to displacement and social conflict. The piece argues that uncritical ideas of "development" threaten humanity itself and calls for urgent policy action and a renewed ethical responsibility towards the natural world.

As Ma kept a bowl of fresh water on the parapet, an army of birds descended onto it. The blustering chirping chaos was so loud that morning walkers on the street paused to look at the mayhem that was occurring at our house. My mother stood there happily cooing "my poor little babies…you must have been so thirsty…it is insanely hot". Then she spread some rice grains on the side for them to continue fighting over. The cow along with her beautiful black calf of a few months stood patiently outside the gate waiting for her turn. My mother ran into the house and brought back a bucket containing the starch water that is drained after the rice is cooked in Indian households mixed with salt and jaggery for taste. I watched with wonder as the thick purplish grey tongue of the cow kept lashing out to lick each and every drop of the delicacy. Ma urged me to feed the extra rotis that she made the previous night for the calf. I stood petrified, my arms outstretched with the rotis dangling from the pinch of my fingernails as the calf hesitantly nibbled at and then gobbled them. I let out a blood curdling scream thinking my hand would be chewed in the process. Ma shot me a look of utter disappointment as she kept scratching the calf's head and neck. In the meantime, the dogs had started barking for attention. My father brought the biscuits, milk and bread to feed them.



The circus was far from over. As my parents pottered around the house arguing over which vegetables will have to be bought and in what quantities, a sharp meow was heard. The queen stirred from her sleep, stretched herself, yawned showing her fangs and finally catwalked straight between my mother's legs to deliver the urgency of the situation. She was expecting and certainly her royal highness could not be kept waiting. Ma dropped everything and poured her milk. There was not a moment's delay because she would not stop crying loudly and following Ma around all the while getting in between her legs. Ma had stumbled a few times and had been scratched for which she had to take the tetanus before learning her lesson.



Finally, peace reigned. As my mother sat down to catch her breath, specks perched on her nose, the newspaper in one hand and a steaming cup of tea in the other, I remarked "you have your own animal farm here". She peeked at me through her glasses and smiled. "Aren't we all animals and as social and thinking animals, isn't our responsibility bit higher?", she countered. Being a Sanskrit scholar, she was alluding to the concept of a singular essence that unites all living beings, characterized by its completeness and unity in the cosmos. According to both Purana and Vedanta, it embodies the spirit that animates all life, representing the eternal essence common to every being.[1] The Prana that animates every living being on this earth is common to all of us. All creatures on this earth are connected with each other. This inseparability has inspired the religion and culture of India. We have the elephant headed Ganesha and monkey God Hanuman. Animals are vehicles for our anthromorphic Gods (fiery Goddess Durga riding the lion). Flora are integral to our rituals like worshipping the tulsi, peepal and banyan. *Hitopadesha*, *Jataka* and the *Panchatantra* are some of the more famous classics replete with animal characters which beautifully depict the connection between humans and nature. James Cameroon directed *Avatar* (2009) depicts this connection between humans and nature beautifully on the silver screen.

This connection continued in the almost ritualistic nature in Indian kitchens where extra rotis and food was made along with the daily amount for the animals in the neighbourhood. I remember the lazy summer vacation mornings at my Dida's (maternal grandmother) sprawling verandah tearing up the rotis (the ones I experimented with in terms of weirdest of shapes) and feeding the cows and birds. It is a morning ritual still followed by many in the rural parts of India. As I grew nostalgic about the "good, old days," the famous "aao aao" scene from the movie *Dilwale Dulhaniya Le Jayenge* where Amrish Puri feeds the pigeons as he bonds with Shahrukh Khan flashed before my eyes.

However, with high-rise buildings and the fast paced life that we lead now, our interaction with nature is limited to the throwing of biscuits to the dogs and watering the plants sticking out of plastic pots hanging precariously from our balconies. While travelling we are glued to our phones and would rather derive voyeuristic pleasure from the antics of tamed and trained animals on the social media than look at the real life fights of the dirty pups and calves in our neighbourhoods. The older generation can identify the various kinds of flora and fauna in the neighbourhood. How many of us can? According to Ranjan Panda, Convenor at Combat Climate Change Network, youngsters do not name rivers as sources of water; instead they refer to taps and bottles. It is indicative of a systemic dissociation of humans from nature. The deep connection has been replaced with the highest level of commodification of nature where nature exists only to serve the needs and wants of humans, of course only for those who are able to afford it.

Long gone are the days when we

[1] Details available at <https://www.wisdomlib.org/concept/one-atman>



would run out of our classes to try to touch the rainbow after a spell of rain in the summer. Or fill our lungs deeply and not try to breath out, trying to capture the lingering musky petrichor after the first rain hit the parched earth. Or gleefully look at the birds shake the water from their tiny wings as they bathed in the puddle created by the water hose in the gardens. It was very common for us as kids to play with random animals on the street on our way home from school. Now, I avoid them like the plague because of an unknown fear which stems from the chasm of non-communication with nature's beings that has developed over the years.

I no longer have time to stare in awe at the Ashoka tree glistening at night because of the hordes of fireflies sitting on it. I do not notice the patterns in which flock of birds fly in the sky. The enigmatic allure of ghostly lights over swamps and marshes (Aleya in Bengali, Chir Batti in the Rann of Kutch and will-o'-the-wisp in English) hold no sway over me. I have rationalized the science behind them and demystified the secrets. In no way, I am hinting that rationalizing is wrong but when the rationality is used primarily for ceaseless profit making then there is a problem to reckon.

As humans try to find their worth in materialistic pleasures, nature is scrutinized through the eyes of a trader where the only thing that matters is profit, at any cost. The relentless exploitation of the natural resources has pushed scores of living species to endangerment and extinction. The warming earth has led to increase in sea levels which has already swallowed coastlines and is threatening to inundate bigger cities like Kolkata, Bangkok among others by 2100.[2] Intense heat waves and incessant rains have become the new normal. The people of Jharia, Jharkhand continue to bear the consequences of century-old underground coal fire,[3] all in the name of development. Even as writers like Amitava Ghosh warn of the responsibility that lies with us towards our future generations, capitalist and imperialist tendencies have overridden stark reminders. For instance, the recently concluded COP30 in Brazil avoided any explicit reference to phasing out fossil fuels which have been the main drivers of climate change.[4] Adding to the insult, is the gloating of Donald Trump who vindicated his stance on climate change being a hoax after billionaire philanthropist Bill Gates said a warming world would not end civilization.[5]

In the words of Mahatma Gandhi, "Earth provides enough to satisfy every man's needs, but not every man's greed." The "progress" of humankind at the cost of nature is hurtling the entire civilization towards a catastrophe from which we may not be able to recover. As per the *2021 Groundswell Report* by the World Bank, nearly 40 million people in South Asia, 86 million in Sub-Saharan Africa, and 49 million in East Asia and the Pacific are projected to become internal climate migrants by 2050. Unbearable strain on resources will ramp up the already existing harsh anti-immigration policies which will culminate in violence and war as is already happening in many parts of the world. We have to wake up from the comfortable slumber of willful ignorance that the capitalistic gains have lulled us into. Fossil fuel lobbyists who have harped on the language of development and gains and climate change deniers have to be countered vehemently. There is no time left for gentle negotiations. We have to come together to force governments to make radical policy changes so that the future of life on this earth as we know it may be preserved. In our selfish pursuit of private individual gains, we have lost out on the collective strength of humans and nature. In case, the divorce between nature and humans comes through, nature will reinvent herself but we, humans will pay a deadly price for our disloyalty. ■

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[2] Details available at <https://www.livemint.com/science/kolkata-among-9-cities-at-risk-of-getting-flooded-by-2100-heres-why-11738500395455.html>

[3] Details available at <https://timesofindia.indiatimes.com/etimes/trending/the-100-year-old-fire-which-is-burning-jharkhand-from-under-the-ground/articleshow/113876611.cms>

[4] Details available at <https://scroll.in/article/1088763/cop30-the-good-the-bad-the-unforgivable-and-why-you-should-care-about-the-un-climate-change-meet>

[5] Details available at <https://www.hindustantimes.com/world-news/donald-trump-claims-victory-on-climate-change-after-bill-gates-pivot-101761778568872.html>

Community-Led Rainwater Conservation Transforms Villages in AP

Villages such as Murugummi, Marella, and Thangella in Prakasam district of Andhra Pradesh have emerged as models of water resilience through community-led rainwater conservation initiatives implemented under the Jal Sanchay Jan Bhagidari campaign of the Ministry of Jal Shakti, Government of India. The initiative has significantly improved groundwater availability, strengthened livelihoods, and reduced distress migration in the region.

Earlier, these villages faced acute water scarcity due to erratic rainfall, declining groundwater levels, and frequent borewell failures, adversely affecting agriculture and livelihoods. The situation began to change with active community mobilization through Gram Sabhas, door-to-door awareness campaigns, Kalajathas, workshops, and field demonstrations. Farmers, women, youth, and local institutions collectively adopted practices such as water budgeting, crop planning, and groundwater sharing, fostering a strong sense of ownership.

Adopting a ridge-to-valley approach, the villages implemented a range of rainwater harvesting and conservation measures to capture, store, and recharge rainwater. Key interventions include percolation tanks, farm ponds, staggered trenches, rooftop rainwater harvesting systems, and the rejuvenation of community ponds.

Key Achievements

- **Murugummi**: Construction of 71 water conservation structures with a cumulative storage capacity of approximately 8.11 lakh cubic metres, providing protective irrigation to 264.5 hectares of agricultural land.
- **Marella**: Development of 53 water conservation structures with a cumulative storage capacity of about 10.04 lakh cubic metres, enhancing agricultural sustainability across 220.5 hectares. Additionally, the renovation of community ponds and tanks contributed nearly 5.95 lakh cubic metres of additional storage capacity.
- **Thangella**: Construction of 71 water conservation structures with a cumulative storage capacity of around 5.89 lakh cubic metres, providing irrigation support to 185.3 hectares. The revival of traditional water bodies further augmented storage capacity by approximately 3.98 lakh cubic metres.



Impact

- **Improved Groundwater Levels**: Benefiting approximately 5,900 people by enhancing access to water for domestic and agricultural purposes.
- **Enhanced Agricultural Productivity**: Expansion of protective irrigation has strengthened livelihoods for a majority of farming households.
- **Increase in Milk Production**: Improved water availability has supported dairy activities, providing supplementary income to rural families.
- **Restoration of Soil Moisture**: Enhanced land health has enabled more stable and resilient cropping patterns.
- **Reduction in Distress Migration**: Improved livelihood opportunities have enabled families to sustain themselves locally.

Recognition

Murugummi village was conferred the Second-Best Village Panchayat Award at the 6th National Water Awards, 2024, while Marella was selected among the top 30 villages and Thangella was nominated for national recognition, underscoring the effectiveness of community-led water conservation efforts.

The transformation of these villages demonstrates the effectiveness of the Jal Sanchay Jan Bhagidari approach in fostering community ownership of water resources. The initiative highlights a replicable model for sustainable water management and reinforces the importance of people's participation in achieving long-term water security. ■

Source: https://www.pib.gov.in/

Balancing Growth and Green Goals

Rethinking Consumerism in India

As the world marked Earth Day on April 22, 2026, under the theme "Our Power, Our Planet," attention turned to the choices shaping our shared future. In India, that power rests not only with policymakers and industries but also with millions of consumers whose decisions drive patterns of growth and environmental impact. As aspirations rise, the challenge is to ensure that progress remains aligned with the health of our planet. Read this article by **Shri Prakash** and **Sonal Singh**.

India is the world's fourth-largest economy and is projected to become the third largest by 2030 with a GDP of $7.3 trillion. Economic liberalization in the 1990s spurred consumerism, with private consumption now contributing over 60 per cent to GDP.[1] A major force behind this shift is the rising middle class. Currently, 31 per cent of households earn between ₹5–30 lakh annually,[2] a figure expected to exceed 60 per cent by 2047.

While the goal of becoming a "Viksit Bharat" (developed nation) by 2047 is ambitious, it raises concerns: Can India pursue rapid economic growth while staying within its planetary boundaries? Vulnerable groups like children, women, and the poor are already at greater risk from extreme weather events, with each year being warmer than the last since 2015.

The Environmental Costs of Consumption-Led Growth

India's growth story has been propelled with private consumption contributing over 60 per cent to GDP in FY25, often seen as a route to improving living standards. But this model has environmental consequences with infrastructure expansion, deforestation, and large-scale resource extraction justified as "development," despite degrading ecosystems. India ranks as the third most polluted country[3] in the 2023 *World Air Quality Report*. As overall consumption grows rapidly, so do the environmental risks.

In today's globalized economy, environmental degradation is no longer confined within national borders. Consumption is driven by complex global supply chain with products consumed in one country often causing resource depletion and pollution elsewhere. The emerging modern consumer behaviour marked by reliance on disposable goods, shorter product lifespans, and constant upgrades has worsened the problem. Electronics sector offers a striking example of such consumption trends. India's electronics market, worth USD 155 billion in FY23,[4] is booming due to e-commerce, rising incomes, and easy credit. But aggressive marketing and constant upgrades encourage wasteful consumption of finite resources and generating waste.



India is already the world's third-largest generator of e-waste,[5] producing 3.2 million metric tonnes annually. Per capita generation is lower than the global average but has risen by 70 per cent between 2019 and 2024.[6] Without intervention, this will only accelerate. At the same time, India must create 8 million jobs for the next 10–12 years[7] to achieve the vision of Viksit Bharat by 2047. Much of this will come from MSMEs, which contribute 30 per cent to GDP[8] but also pollute heavily, accounting for up to 15 per cent of industrial emissions and 3–4 per cent of CO2 emissions.[9] Therefore,

1 Details available at https://economictimes.indiatimes.com/news/economy/indicators/private-consumption-share-in-indias-gdp-at-two-decade-high-finance-ministry/articleshow/122126505.cms?from=mdr

2 Details available at https://price360.in/Executive_Summary_Middle_Class.pdf

3 Details available at https://www.downtoearth.org.in/pollution/india-was-third-most-polluted-country-globally-in-2023-right-behind-top-ranking-bangladesh-and-pakistan-95134

4 Details available at https://www.pib.gov.in/PressNoteDetails.aspx?NoteId=153203&ModuleId=3&reg=3&lang=1#:~:text=India's%20electronics%20sector%20has%20experienced,%2C%20now%20manufacturing%2099%25%20domestically.

5 Details available at https://ewastemonitor.info/gem-2020/

6 Details available at https://www.downtoearth.org.in/waste/indias-e-waste-surges-by-73-in-5-years

7 Details available at https://www.thehindu.com/business/Economy/india-to-generate-8-million-jobs-per-year-for-next-10-12-years-chief-economic-advisor-anantha-nageswaran/article69473443.ece

8 Details available at https://www.pib.gov.in/PressReleasePage.aspx?PRID=2142170&reg=3&lang=2

9 Details available at https://www.teriin.org/sites/default/files/files/Financing-Low-Carbon-Tranistion-for-India-MSME-Sector.pdf



India's development pathway must be environmentally sensitive to ensure sustainable livelihoods and climate goals, including India's 2070 net-zero target.

From Conflict to Confluence: Aligning Growth with Sustainability

Economic progress does not have to be in conflict with environmental protection. India has made progress by meeting two of its Nationally Determined Contribution (NDC) way ahead of its target year 2030, but deeper change is needed. Achieving an "Aspirational India" will require harmonizing growth with ecology by revisiting policies, sustainable consumption practices, and reshaping producer priorities to align with circular economy.

India's cultural traditions offer inspiration. Practices rooted in frugality, mindful consumption, and harmony with nature—from food habits to festivals—can guide modern practices. For example, traditional Indian plant-based diet has been identified by WWF as a model of sustainability. Further, nudging consumers to adopt greener habits also works. For example, the Bureau of Energy Efficiency's star rating system has encouraged adoption of energy-efficient appliances.

Producers, too, have a central role. Across agriculture, industry, and services, businesses must adopt green technologies and reduce emissions throughout their value chains. The energy sector alone accounts for 75 per cent of emissions, followed by agriculture at 13 per cent. Incorporating Environmental, Social, and Governance (ESG) standards into business operations is an important step which not only guides companies towards sustainability but also attracts responsible investment.

Conducive regulatory ecosystem is another critical aspect. Policy intervention across energy, finance, manufacturing, and mobility needs to incentivize green practices. India's Mission LiFE (Lifestyle for Environment) is one such initiative, engaging consumers, producers, and policymakers. Policies like Extended Producer Responsibility (EPR), Right to Repair, and circular economy principles are gaining ground, but need stronger enforcement.

The Way Forward

India faces a dual challenge of sustaining inclusive growth while combating climate change and environmental degradation. Unlike developed economies that industrialized by overexploiting natural resources, India must chart a new path of sustainable development in the face of increasing climate risks. Mahatma Gandhi's, words remain relevant: *"The world has enough for everyone's need, but not enough for everyone's greed."*

Action is required at both individual and systemic levels. Consumers must be educated to make sustainable choices, while governments and businesses must enable and reward such behaviour. Tools such as green credits, ESG ratings, and supportive regulations can shift priorities from short-term profit to long-term resilience. Care must also be taken to avoid greenwashing.

India stands at a crossroads. Its growth story inspires, but the environmental cost of unchecked consumerism cannot be ignored because it could undermine both environmental sustainability and long-term prosperity. To become a developed economy by 2047, India must chart out its unique path—one that balances economic aspirations with ecological responsibility, positioning itself as a global leader in inclusive and green development. ■

Mr Shri Prakash, Distinguished Fellow, Transport & Urban Governance division, TERI and Ms Sonal Singh, Research Associate, Transport & Urban Governance division, TERI.



Scientists Say This Algae Could Remove Microplastics from Drinking Water

Researchers at the University of Missouri are developing a new way to remove tiny plastic pollutants from water using specially engineered algae. Susie Dai, a researcher at Mizzou, recently created a modified strain of algae designed to capture harmful microplastics from contaminated water. Her long-term goal is not only to clean waterways but also to recycle the collected plastic into safer bioplastic materials, including composite plastic films. "Microplastics are pollutants found almost everywhere in the environment, such as in ponds, lakes, rivers, wastewater and the fish that we consume," Dai, a professor in the College of Engineering and principal investigator at the Bond Life Sciences Center, said. "Currently, most wastewater treatment plants can only remove large particles of plastic, but microplastics are so small that they slip through and end up in drinking water, polluting the environment and harming ecosystems."

Source: https://www.sciencedaily.com/

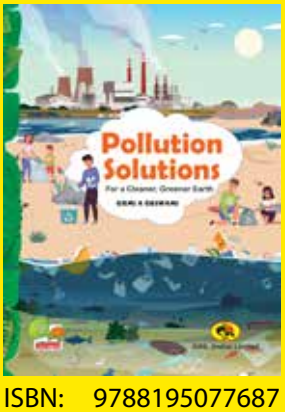
Hidden Ocean Heat Is Creeping towards Antarctica's Fragile Ice Shelves

A major new study drawing on decades of ocean data has found clear evidence that heat from the deep ocean is shifting towards Antarctica. This change poses a growing threat to the continent's delicate ice shelves, which line its coast and help stabilize the ice sheet. Researchers led by the University of Cambridge, working with colleagues from the University of California, analysed long-term measurements collected by research ships and robotic ocean instruments. Their findings show that a large body of relatively warm water, known as 'circumpolar deep water,' has expanded and gradually moved closer to the Antarctic continental shelf over the past two decades. Until now, scientists lacked enough continuous data to confirm this warming trend. Ice shelves act as barriers that hold back Antarctica's inland glaciers and ice sheets. Together, these frozen reserves contain enough water to raise global sea levels by about 58 metres.

Source: https://www.sciencedaily.com/



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POLLUTION SOLUTIONS
FOR A CLEANER, GREENER EARTH

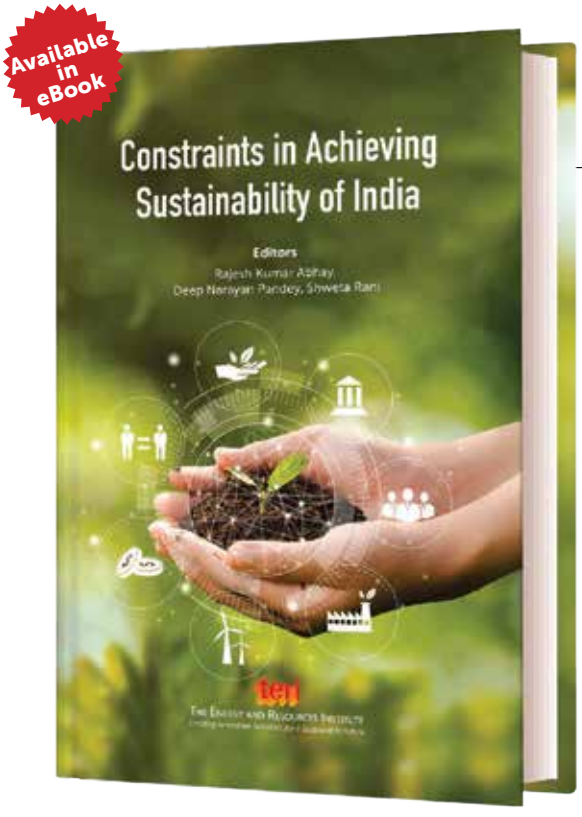
Urmi A Goswami

We are living in a fast changing world. Pollution of natural resources, such as air, water, and land is one of the biggest banes of our times. Under such precarious circumstances, it is needed that the young generation is not only made aware about the different kinds of pollution but also about the solutions. This is what this book *Pollution Solutions – For a Cleaner, Greener Earth* is all about.

Filled with eye-opening facts, informative illustrations, and multiple activities, this book is the perfect guide to help the young generation become environmental crusaders.

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- Assessment of Basic Infrastructure Development and Associated Issues in India

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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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War, Energy Shock, and the Climate Cost

How the Iran–US conflict is compounding global climate and energy risks

The US–Israel war on Iran is triggering a cascading global crisis that extends far beyond geopolitics, eroding climate action at a critical moment. Disruptions in the Strait of Hormuz have destabilized oil and LNG markets, driven up emissions, and slowed the clean energy transition. The conflict is generating massive carbon emissions through military operations and damaged infrastructure, while pollution, oil spills, and ecological harm threaten fragile regions. For climate-vulnerable areas such as South Asia, the war intensifies energy insecurity, accelerates glacier loss, and further shrinks the rapidly vanishing global carbon budget, says **Shamim Haque Mondal** in this article.

The United States–Israel war on Iran has turned a regional security crisis into a systemic climate shock, colliding with a moment when scientists warn that the remaining carbon budget for limiting global warming to 1.5°C is vanishing fast. Energy markets, already strained by years of volatility, have been thrown into what the International Energy Agency now calls the worst energy crisis in history, with consequences that reach from household kitchens to the Himalayan glaciers that sustain South Asia's rivers.

Hormuz: From Oil Chokepoint to Climate Flashpoint

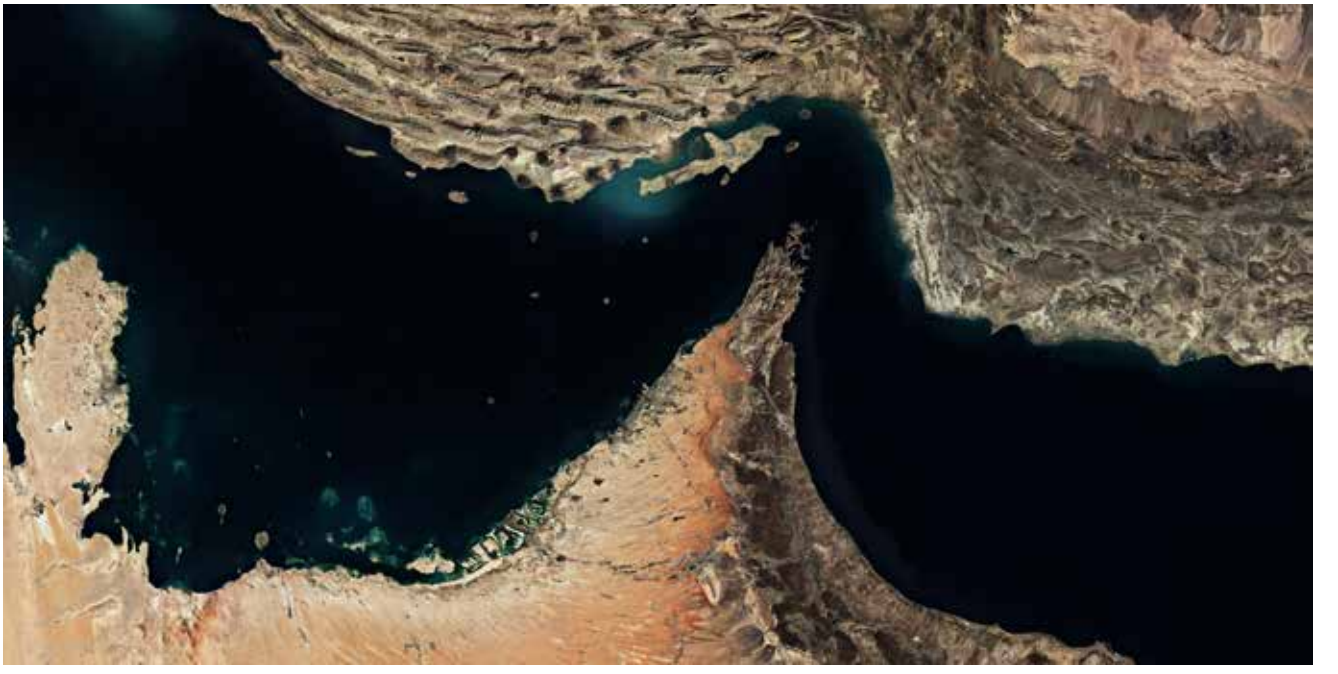
When the USA and Israel launched "Operation Epic Fury," Iranian retaliation quickly closed the Strait of Hormuz, the narrow waterway through which roughly one-fifth of the world's total petroleum liquids consumption and about a quarter of global sea-borne oil trade normally flows. The strait also carries close to 20 per cent of global liquefied natural gas (LNG) trade, making it the single most critical fossil-fuel chokepoint on the planet. Brent crude, which spiked by 10–13%[1] in the early days of the conflict, has remained high as tankers pile up on either side of Hormuz and key producers in Iraq, Kuwait, and the UAE reduce production due to storage shortages and tanker inability to sail.



A War with a Year's Worth of Emissions

The direct climate impact of this war is already staggering. An analysis by researchers at the Climate and Community Institute, using satellite data, fuel use estimates, and damage assessments, shows that the first 14

[1] Details available at <https://www.statista.com/chart/35914/destination-maritime-crude-oil-strait-of-hormuz/?srsltid=AfmBOopbz6QFrT99CMDSX-bueRSJjVoSJ7_sT1JhtbF6dbFIld4EL8yI>



days of US–Israeli strikes and Iranian retaliation produced about 5 million tonnes of carbon dioxide equivalent (CO_2e). That is more than Iceland's annual emissions and greater than the yearly footprint of each of the world's 84 lowest-emitting countries.

Most of these emissions did not come from jets alone but from wrecked buildings and burning fuel. Roughly 20,000 buildings in Iran were reported damaged in just the first fortnight of strikes, with the rubble and future reconstruction associated with about 2.4 million tonnes of CO_2e—nearly half of the initial war footprint. Another 1.9 million tonnes came from 2.5–5.9 million barrels of oil destroyed in spectacular fires at fuel depots and energy facilities, while the fuel burned by aircraft, naval vessels, and ground vehicles in combat added over half a million tonnes more.

These figures make the Iran war part of a grim new dataset on the climate cost of modern conflict. The ongoing Israel–Gaza war has been estimated to produce around 33 million tonnes of CO_2e, a footprint comparable to the annual emissions of Jordan, with reconstruction dominating the total. Russia's full-scale invasion of Ukraine has generated about 311 million tonnes of CO_2e in its first four years—roughly equivalent to the yearly emissions of France—through a mix of direct fuel use, landscape fires, and the embedded emissions of rebuilding shattered infrastructure.[2]

Research by the Transnational Institute and the Conflict and Environment Observatory (CEOBS) suggests that routine military activity—before accounting for wartime destruction—may be responsible for about 5.5 per cent of global greenhouse gas emissions. If the world's militaries were a country, they would rank as the fourth largest emitter on Earth, yet there is still no binding requirement under the Paris Agreement for states to fully report or reduce their military emissions.

The 5 million tonnes of CO_2e emitted in the first couple of weeks of the war in Iran must be understood against a rapidly shrinking carbon budget.[3] Updated assessments indicate that from the start of 2025, only about 130 billion tonnes of CO_2 remain for a 50 per cent chance of holding warming to 1.5°C, implying that at current emissions of around 40 billion tonnes per year, this budget could be exhausted in just a little over three years.

Toxic Skies, Poisoned Seas

Beyond carbon, this war is unleashing a cascade of local and regional environmental harms. CEOBS and Gulf-based researchers have documented serious pollution incidents at major refineries and ports, including Ras Tanura in Saudi Arabia and Fujairah in the UAE, where drone strikes and missile interceptions ignited fuel storage tanks and sent towering plumes of smoke into the atmosphere. These fires release dense clouds of particulate matter, nitrogen oxides, sulphur dioxide, and

[2] Details available at <https://ccpi.org/guest-article-ccpi-x-military-emissions-gap-how-military-emissions-impact-global-warming/>

[3] Details available at <https://www.theguardian.com/world/2026/mar/21/middle-east-iran-conflict-environment-climate>

volatile organic compounds, worsening respiratory illnesses and depositing toxic residues on cropland and urban neighbourhoods downwind.

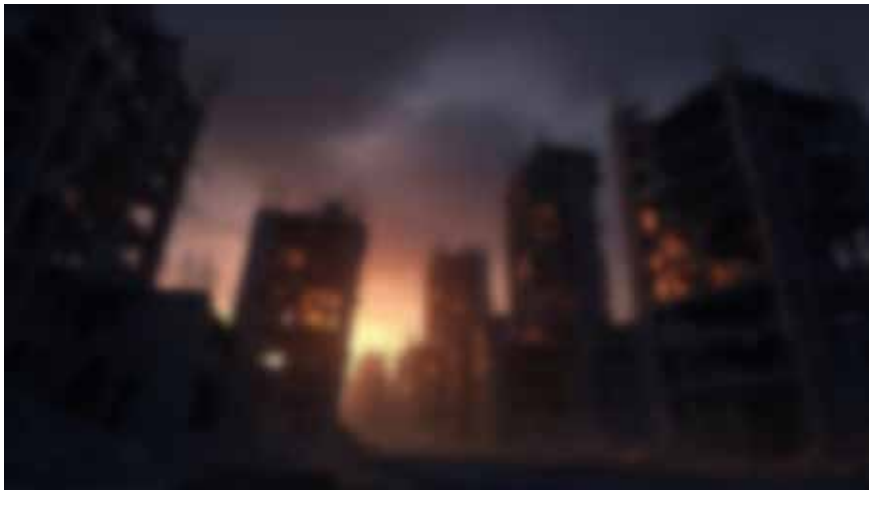
The Persian Gulf itself is at risk of becoming a sacrificial zone. Attacks on tankers and terminal infrastructure increase the likelihood of oil spills in one of the world's most ecologically stressed semi-enclosed seas, where limited water exchange means pollutants linger for years. Gulf Research Center analysts warn that war-related damage to desalination plants, coastal industrial sites, and coral ecosystems will have long-term consequences for marine biodiversity and for the millions who rely on desalinated seawater for drinking and irrigation. Many Iranian missile systems use very harmful fuels such as unsymmetrical dimethyl hydrazine (UDMH) and dangerous chemicals like inhibited red fuming nitric acid.

War, Inflation, and a Stalled Energy Transition

At the very moment when the world needs to cut fossil fuel use rapidly, the Iran war is pushing governments towards short-term energy security fixes that risk locking in higher emissions for decades. The International Energy Agency has warned that the Hormuz blockade and the loss of Middle Eastern capacity constitute the most severe energy crisis since the 1973 oil embargo, with the added twist that LNG flows and petrochemical feedstocks are disrupted at the same time. Some governments have responded by extending the lifespan of coal plants, expediting new oil and gas projects, or relaxing climate policies in the name of maintaining energy supply. This scramble is not only about keeping factories running in Europe or North America. The war has also snarled supply chains for critical materials and components needed for renewable energy, including polysilicon and rare earth elements, slowing the deployment of solar and wind projects in the very regions that most need cheap, clean power. Every month of delay in scaling renewables means another month in which grids rely on burning oil and gas, adding millions of tonnes of avoidable CO_2 to the atmosphere while deepening dependence on the very fuels at the heart of the conflict.

Fallout for South Asia and the Third Pole

The convergence of geopolitical conflict, energy insecurity, and climate stress is particularly ominous for South Asia, which is already identified as one of the most climate-vulnerable regions in the world. The region's food and water security depend heavily on the Hindu Kush–Himalaya, often called the "Third Pole" because it stores more ice than anywhere on Earth outside the Arctic and Antarctic and feeds major rivers such as the Indus, Ganges, and Brahmaputra. New studies from ICIMOD and other research groups show that glaciers in the Hindu Kush–Himalaya are melting faster than before, with ice loss doubling since around 2000 and up to 80 per cent of the current glacier volume at risk of disappearing by 2100 if emissions remain high.[4] Even at 2°C of global warming, recent modelling suggests that only about a quarter of the region's glacier mass may remain, threatening long-term river flows and increasing the risk of glacial lake outburst floods for hundreds of millions of people downstream.



Choosing Between War and a Livable Climate

The climate costs of conflict are now measurable in millions of tonnes of CO_2, lost years of carbon budget, poisoned seas, and destabilized glacier systems that anchor Asia's water security. For nuclear-armed South Asia, locked in its cycles of rivalry, the lesson is stark. Security in the 21st century will not come from dominating energy chokepoints or weaponizing water and oil but from collective restraint, rapid decarbonization, and cooperation to protect shared ecosystems—from the Strait of Hormuz to the Hindu Kush–Himalaya. Wars can continue to fuel what might be called a climate "epic fury," or states can recognize that peace has become a precondition for a livable planet; the choice will shape not only geopolitics but the very habitability of the Earth for generations to come. ■

Dr Shamim Haque Mondal, Physics Division, State Forensic Science Laboratory, Kolkata.

[4] Details available at <https://www.welthungerhilfe.org/global-food-journal/rubrics/climate-resources/glacier-melt-in-the-himalayas-endangers-south-asia>

Dr Ram Bux Singh

A Renewable Energy Pioneer with an Enduring Legacy

The 21st century has brought humanity face to face with some of its greatest challenges—climate change, environmental degradation, rising fuel costs, and growing concerns over energy security. Nations across the world are investing heavily in renewable energy (RE) technologies and searching for sustainable alternatives to fossil fuels. Yet, decades before RE became a global movement, **Dr Ram Bux Singh** had already envisioned a future rooted in clean, decentralized, and sustainable energy systems. Keep reading to learn more…

Widely regarded as one of India's foremost pioneers in biogas and renewable energy (RE) technology, Dr Ram Bux Singh dedicated his life to scientific innovation, rural empowerment, and environmental sustainability. His groundbreaking work transformed the understanding of biogas from a localized experiment into a globally recognized RE solution. Through his relentless research, international collaborations, and grassroots-level implementation, Dr Singh created a legacy that remains profoundly relevant even today.

Born in 1925 in Sitapur (Uttar Pradesh), Dr Singh's life and achievements continue to be a matter of immense pride for both Sitapur and Lucknow. While Sitapur was his birthplace, Lucknow became his *karmabhoomi*, where he spent more than five decades conducting pioneering research and promoting RE solutions.

The Beginning of a Revolutionary Journey

Dr Singh's pioneering journey in renewable energy began with a historic achievement that would forever alter the trajectory of rural energy development in India. On September 9, 1957, in the village of Ramnagar in Sitapur district, he established and inaugurated India's first successful gobar gas (biogas) plant—one of its kind, demonstrating its uniqueness. The inauguration was attended by Shri Govind Narain, ICS, then Chief Secretary of the Government of Uttar Pradesh, underscoring the significance of the achievement. Dr Singh demonstrated how organic waste could be converted into clean fuel and nutrient-rich manure, addressing rural energy, agriculture, sanitation, and environmental concerns simultaneously.

This was not merely a scientific breakthrough; it was a visionary model for sustainable rural development. Dr Singh recognized that India's villages possessed abundant natural and organic resources that could be harnessed scientifically to achieve energy self-reliance. Long before concepts such as the circular economy, waste-to-energy systems, and sustainable agriculture became internationally popular, he had already put them into practice.

Ahead of His Time

One of the most remarkable aspects of Dr Singh's work was his extraordinary foresight. During the global energy crisis of the 1970s, when oil shortages and rising fuel prices created economic uncertainty worldwide, he strongly advocated biogas as a clean, decentralized, and indigenous energy solution. At a time when most countries



Dr. RAM BUX SINGH (Great Inventor : Bio-gas)
(13 Aug 1925 - 18 Sep 2016)

were heavily dependent on fossil fuels, Dr Singh emphasized the importance of renewable biological resources and localized energy systems. His broader vision of renewable energy also included sustained advocacy and awareness regarding other non-conventional energy sources such as solar and wind energy, long before they became central to mainstream energy discussions in India. Dr Singh's collaboration with Preben Maegaard the Danish renewable energy pioneer, author, and co-founder of the Nordic Folkecenter for Renewable Energy—is historically significant. Their

joint work at the Danish Centre for Renewable Energy involved the design and installation of community-scale wind energy systems, which served as early models of sustainable rural electrification.

Today, as governments and industries worldwide seek alternatives to conventional fuels, his ideas appear astonishingly modern and visionary. Current initiatives promoting compressed biogas, organic waste management, and decentralized renewable energy systems reflect principles that Dr Singh championed decades ago.

International Recognition and Global Influence

Although deeply rooted in rural India, Dr Singh's influence extended far beyond national boundaries. His expertise and research gained international acclaim, making him one of the world's most respected authorities on biogas technology. Over the course of his career, he contributed to RE development in more than 15 countries, including the United States, Denmark, Iran, Canada, Mexico, and Costa Rica.

As a consultant for the United Nations, Dr Singh played an instrumental role in designing and supervising the construction of several biogas plants across the globe. His practical knowledge and scientific insights helped governments and organizations understand the immense potential of biogas technology in addressing energy and environmental challenges.

A particularly remarkable milestone came in June 1972, when Dr Singh established the first gobar gas plant in the USA. The inauguration was attended by Senator Mike Gravel from Alaska and attracted significant international attention. His pioneering efforts earned him recognition as the "Father of Methane Development" in the USA.

International publications such as *Mother Earth News*, *The Whole Earth Catalog*, and *Architectural Design* featured his pioneering work in renewable energy.

His work resonated strongly with environmentalists, scientists, and policymakers who recognized biogas technology as a sustainable solution capable of addressing multiple global challenges simultaneously.

Innovations in Biogas Technology

Dr Singh's contributions extended far beyond the establishment of biogas



plants. His scientific curiosity and practical approach led to numerous innovations in biogas technology, waste processing, and renewable fuel systems.

During his association with the Gas Council in London, United Kingdom, he developed innovative gobar gas burners and stoves designed to improve efficiency and usability. He also closely studied the construction of over 200 low-cost biogas digesters and waste processors aimed at converting plant and animal waste into methane and organic manure.

What distinguished Dr Singh's work was his emphasis on affordability and scalability. He believed RE technologies should not remain confined to laboratories or elite institutions; instead, they should be accessible to ordinary people, especially rural communities. His low-cost models and practical designs made biogas technology viable for villages and small-scale farmers.

Dr Singh also served for 16 years as Officer-in-Charge of Asia's first Gobar Gas Research Station in Ajitmal, district Auraiya, Uttar Pradesh, under the Planning, Research and Action Division (PRAD) of the State Planning Institute, Uttar Pradesh (India). Under his leadership, the research station became an important centre for RE research and grassroots implementation. His work there further strengthened India's position as a pioneer in rural biogas technology.



Scholar, Author, and Educator

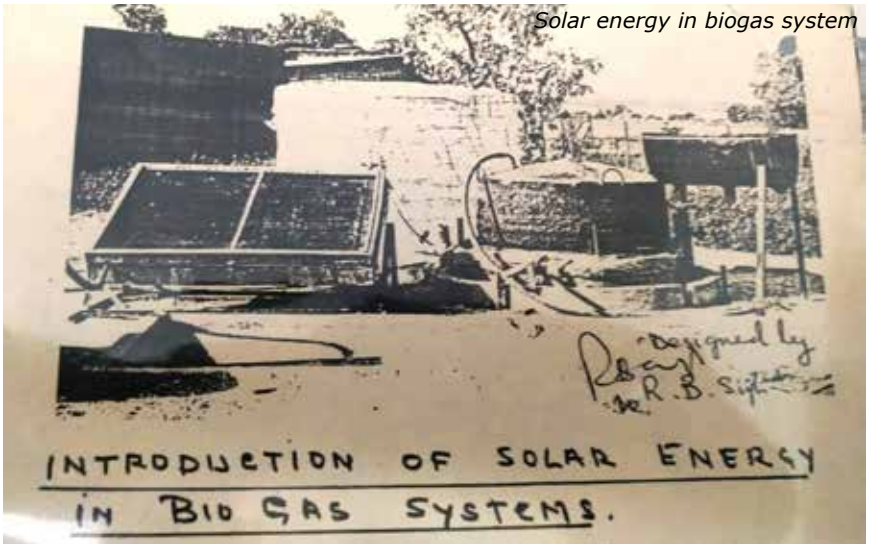
Apart from being a scientist and innovator, Dr Singh was also a prolific author and educator. He authored eight books on biogas technology, many of which became widely read references in India and abroad. His most celebrated work, *Biogas Plant: Generating Methane from Organic Wastes*, is widely regarded as a foundational text in the field. Owing to its detailed technical coverage and practical orientation, the book has been described by several authors and practitioners as the "bible" of biogas technology and is preserved in the collection of the United States Library of Congress.

Through his writings, Dr Singh simplified complex scientific concepts and made RE knowledge accessible to students, engineers, researchers, and rural practitioners. His books played a major role in spreading awareness about the scientific, economic, and environmental benefits of biogas technology.

Honours, Recognition, and Enduring Legacy

Dr Singh's extraordinary contributions received recognition from numerous national and international institutions. His pioneering efforts were formally appreciated through letters issued by the Prime Minister's Office and the President's Secretariat in India. His work was also discussed in proceedings of the United States Senate Select Committee on Small Business in 1973, reflecting the international significance of his research.

Prestigious Indian scientific and national institutions, including, the National Archives of India, Doordarshan, the Indian Agricultural Research Institute (IARI) and the Sardar Swaran Singh National Institute of Bio-Energy, acknowledged and documented Dr Singh's pioneering contributions to biogas technology and sustainable energy research.



Solar energy in biogas system

In recognition of his lifelong dedication to non-conventional energy research, Pacific Western University in California awarded him honorary degrees, including a Doctor of Technological Philosophy.

Even after his passing, Dr Singh's legacy continues to receive national recognition. In November 2024, the Philatelic Advisory Committee in New Delhi approved a proposal to issue a commemorative postage stamp in his honour during his birth centenary year (August 13, 2025 to August 12, 2026). Another major recognition came in September 2023, when the National Archives of India acquired and digitized a priceless collection documenting Dr Singh's life and work. These historic records are now accessible worldwide through the Abhilekh Patal portal, ensuring that future generations can learn from and be inspired by his achievements.

Another significant national recognition came in 2026 when the scientific contributions of Dr Ram Bux Singh were formally included in the National Council of Educational Research and Training (NCERT) Class 9 Science textbook. The textbook describes him as "popularly known as the Father of Modern Biogas," introducing millions of students across India to his pioneering work in renewable energy and sustainable rural development.

A Legacy More Relevant Than Ever

The enduring relevance of Dr Ram Bux Singh's work lies in the fact that many of the challenges he addressed decades ago remain central concerns today. Energy insecurity, environmental degradation, pollution, climate change, and sustainable agriculture continue to dominate global discussions. His vision of decentralized clean energy, organic waste management, and rural sustainability strongly aligns with present-day global discussions on climate action and the United Nations Sustainable Development Goals (SDGs).

Dr Singh understood that true sustainability required solutions that were not only technologically sound but also socially inclusive, economically viable, and environmentally responsible. His work empowered rural communities, promoted self-reliance, reduced dependence on fossil fuels, improved sanitation, and encouraged sustainable farming practices. ■

The article is based on the information and inputs provided by Shri Rajendra Singh, son of the late Dr Ram Bux Singh.

Sensorium Park

A Journey of Life, Memory, and Senses

Nestled within the serene pine forests of Uttarakhand, India, Sensorium Park is a contemplative blend of historical preservation and ecological sensitivity. The site, once a neglected and overgrown British-era cemetery dating back to the mid-1850s, has been thoughtfully transformed by Compartment S4 into a meaningful public space for reflection and sensory discovery. Envisioned by the Uttarakhand Government as an accessible public site, the project was approached by the design team with a more nuanced perspective—one that honours the land's layered and often undocumented history while safeguarding its fragile ecosystem. Rather than imposing itself on the landscape, Sensorium Park embraces poetic restraint, allowing history, nature, and human presence to coexist gently and harmoniously. More than a restoration project, Sensorium Park stands as a reminder that reclaiming the past can also create opportunities for dialogue, introspection, and renewed meaning for the future. Keep reading to learn more…

Sensorium Park is a contemplative blend of historical preservation and ecological sensitivity. Once a dingy, seemingly unsafe space, the site was originally marked by overgrowth and neglect, its history hidden beneath layers of time. Nestled within the serene pine forests of Uttarakhand, this British-era cemetery from the mid-1850s has been reimagined as a public sanctuary for reflection and sensory exploration. The Uttarakhand Government's brief aimed to transform this forgotten space into an accessible site for all. However, *Compartment S4* took a more nuanced approach, honouring the site's ecological and historical significance through minimal yet impactful interventions that





breathed new life into the neglected glory of the cemetery, transforming it into a meaningful public space.

Upon excavation, graves were uncovered, revealing an unspoken history possibly tied to the First World War, though no clear records or archives exist to identify the individuals buried there. This absence of documentation adds to the park's reverence, making its preservation all the more vital. The design intervention is intentionally minimal, allowing the park's natural beauty and layered history to remain at the forefront. Soft interventions, such as small pathways, were carefully introduced with an environmentally sensitive approach—to avoid overpowering or overwhelming the existing ecology and to ensure to leave minimal footprint within the fragile forest ecosystem causing no disturbance to the existing flora and fauna, while still offering a powerful, contemplative experience for visitors.

These burial grounds often mirrored the architectural and cultural sensibilities of the British elite. The intervention was guided by a thoughtful design approach, rooted in the idea of a journey—both physical and metaphysical—that one undertakes while visiting the place. The aim was not merely to restore the site but to reinterpret its narrative, offering visitors an experience that honours its historical significance while engaging them in a sensory exploration of life, memory, and nature.

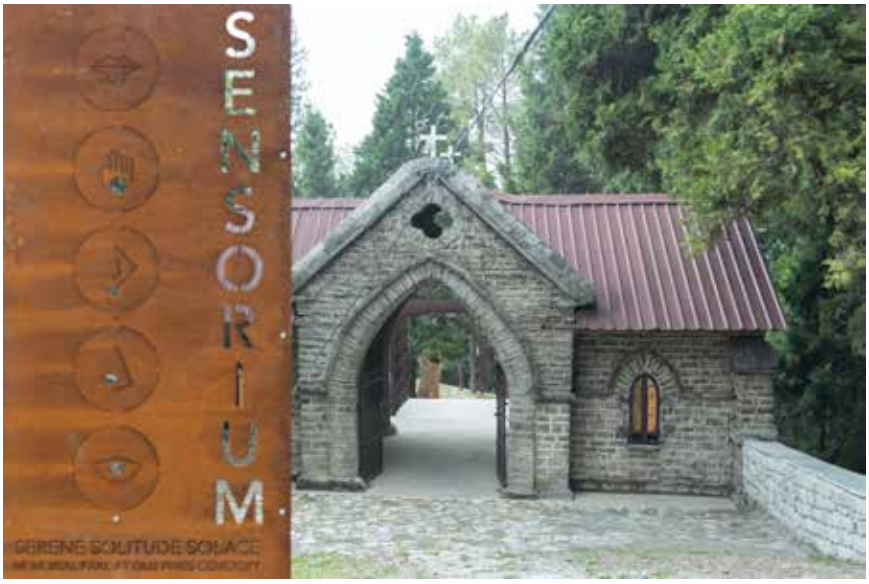
Today, Sensorium Park transcends its origins, offering not just a historical narrative but also a space where the living can connect with the departed. Yet, its transformation prompts critical questions: How should we navigate the legacy of colonial cemeteries? Can their purpose as symbols of empire be reconciled with their modern-day reinterpretation as inclusive public spaces? And, perhaps most intriguingly, does reimagining these sites dilute their historical identity, or does it breathe new life into forgotten narratives?

Over time, neglect and overgrowth shrouded its beauty, risking the loss of its historical narrative. How do we balance the emotional and historical weight of a site with its reimagining for contemporary relevance? At Sensorium, the design thoughtfully integrates history and modernity, with the winding stone path serving as the narrative thread that ties the entire plot together. The pathway itself is not linear, but rather meanders organically through the forest— encouraging exploration, allowing visitors to lose themselves in the landscape, and discover each intervention as a quiet, unexpected moment along the way. At the entrance, the restoration of the original gate using stone, complemented by a contemporary metal structure that frames and highlights it, exemplifies a sensitive

balance between preserving the past and introducing contemporary relevance.

This immersive sensory experience embodies the park's deeper purpose: to celebrate not just the memories of those lost, but the gift of life itself. The design of the cemetery is deeply rooted in its sensorial philosophy, encouraging visitors to connect with the space through a series of thoughtfully placed installations that engage the five senses. As visitors wander the park, their visual senses are drawn to a mirror-clad cabin, seamlessly blending with the surrounding forest and offering an illusionary, reflective experience. The air is filled with the harmonious melodies of a human-sized bamboo wind chime, its sounds merging with the gentle rustling of leaves, creating a serene auditory atmosphere. The scent of fragrant deodar wood planks evokes the forest's vitality, while the taste is subtly activated in a dedicated garden of edible fruit and berry trees. As visitors trace their path, their hands touch the textured stone and bark along the trail, grounding them in the natural environment.

The park's design integrates materials like stone, wood, Corten steel, and acrylic. The journey culminates in a colourful installation, a powerful metaphor for the circle of life. Visitors are invited to meditate on the interconnectedness of life and death, seated in a natural culvert sculpted into stone. This final moment encapsulates the park's essence: a space of the departed to become a place of solace, remembrance, and sensory exploration. The signages, crafted different materials like Corten steel, etched wood, acrylic, etc., subtly guiding visitors without disrupting and visually blocking the surrounding landscape. While each installation offers a distinct sensory experience, encountering them collectively forms a holistic journey that engages all senses.





With these design interventions, the park moves beyond mere physicality, offering an immersive, metaphysical journey where visitors navigate not only the landscape but also the intangible realms of memory, presence, and the flow of time. By embracing this approach, the design blends cultural sensitivity, minimalism, and environmental sustainability, respecting the sentiment attached to this site of memory. The park does not announce its presence but instead creates a space for quiet contemplation, allowing the metaphysical to emerge through its restrained design. Here, the programme takes precedence, with the design seamlessly following, ensuring harmony with the site's history, community, and natural landscape.

Its transformation raises enduring questions about how we choose to preserve and reinterpret the past. As we walk through its winding trails, surrounded by the whispers of history and the vibrancy of life, we are reminded that the act of restoration is as much about asking questions as it is about finding answers. ■



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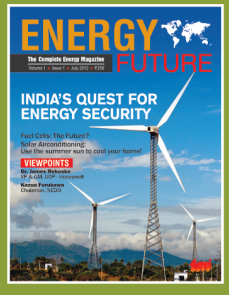
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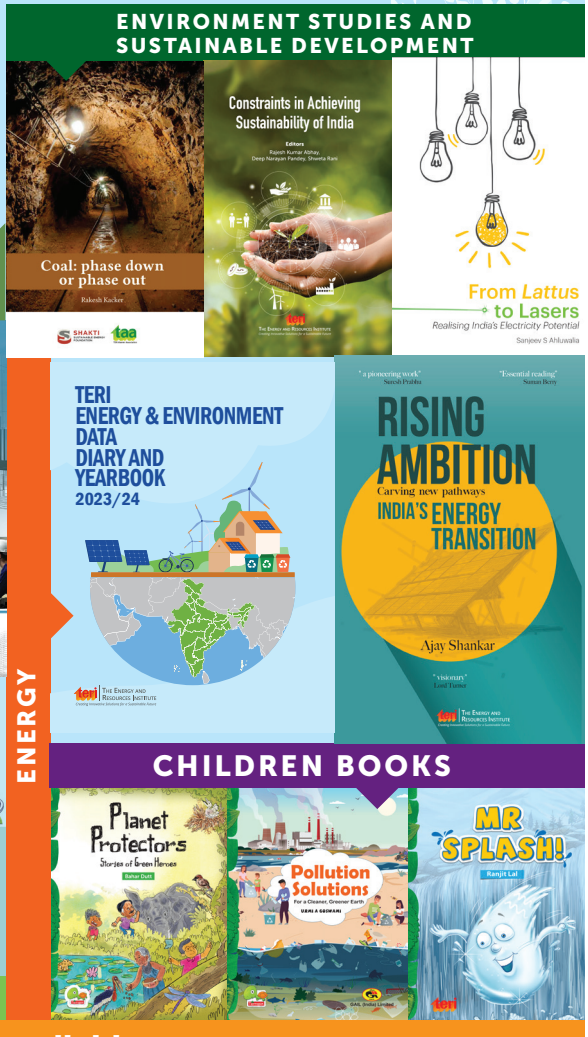
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