TerraGreen

₹70

EARTH MATTERS

Subscriber's copy VOLUME 19 | Issue 2 | May 2026

The Geopolitics of Heatwaves

Energy Shocks and India's Cooling Challenge

SPECIAL HIGHLIGHTS

Role of Critical Minerals in Clean Energy Transition

Nanoparticle Waste Pollution

TERRA YOUTH

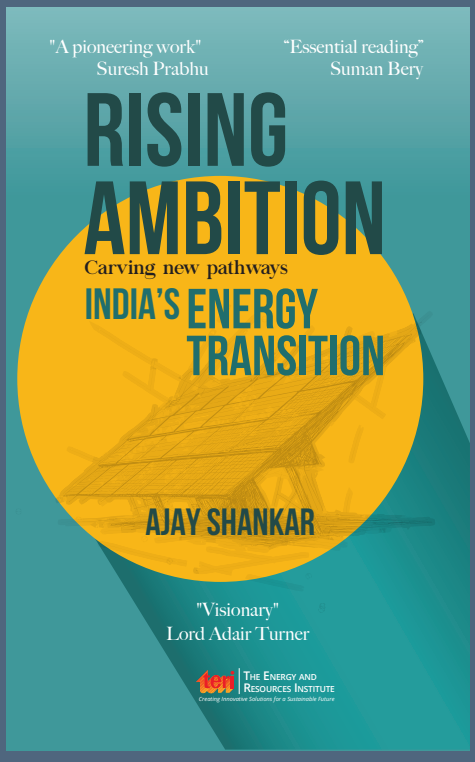
Crisis or Catalyst for Change?



IN CONVERSATION

Kusum Pandey, Mural Artist

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

The Energy and Resources Institute (TERI)
Darbari Seth Block, India Habitat Centre, Lodhi Road,
New Delhi – 110 003, India
: teripress@teri.res.in • : http://bookstore.teriin.org

EDITORIAL



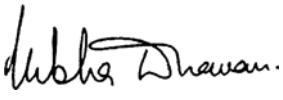
> "The intensifying interplay between climate change and geopolitical instability is reshaping how nations confront the challenge of keeping their populations safe from extreme heat waves."

Extreme heat is no longer a seasonal inconvenience; it is fast emerging as one of the defining challenges of our time. Across India and many parts of the world, heatwaves are becoming more frequent, intense, and prolonged, turning cities into heat islands and placing unprecedented pressure on infrastructure, public health systems, and economies. Increasingly, these climatic events are intersecting with global disruptions, reminding us that environmental risks cannot be viewed in isolation. The intensifying interplay between climate change and geopolitical instability is reshaping how nations confront the challenge of keeping their populations safe from extreme heat waves.

This macro level systemic crisis was starkly visible through the recent surge in global energy uncertainties linked to disruptions in critical supply routes such as the Strait of Hormuz. For countries like India, where rapid urbanization and rising incomes have led to an increasing dependence on energy-intensive cooling systems, these developments expose a deeper structural vulnerability. Record-breaking electricity demand during peak summer months reflects not only the severity of heat stress but also the limits of power-dependent adaptation strategies. At the same time, the uneven distribution of cooling access highlights a growing crisis of heat inequality, where vulnerable communities bear the brunt of both rising temperatures and constrained energy access. These realities call for a fundamental rethinking of urban design, energy use, and climate resilience.

Set against this backdrop, *TerraGreen's* cover story in this issue examines how extreme heat has evolved into a multidimensional challenge that spans climate, energy security, and social equity. The article underscores how global energy disruptions, combined with surging domestic demand, are exposing the limitations of fossil fuel-dependent cooling systems. It argues for an urgent transition towards passive and nature-based cooling strategies such as cool roofs, urban green cover, and climate-responsive architecture that can reduce heat exposure without increasing energy burdens. Drawing attention to India's urban heat island effect and the deepening divide in access to thermal comfort, the cover story stresses the importance of integrating these approaches into policy frameworks through mandatory building codes, urban planning reforms, and community-driven interventions. It also situates cooling within a broader framework of national security, public health, and climate justice, highlighting the need for coordinated, cross-sectoral action.

We hope this issue encourages thoughtful engagement with the challenges and opportunities ahead, and reinforces our collective commitment to building cities that are not only sustainable, but also inclusive, adaptive, and prepared for the uncertainties of a warming planet.



Vibha Dhawan
Director-General, TERI



I read with great interest the cover story in the April 2026 issue of *TerraGreen* on the global water crisis. The article offers a comprehensive yet accessible overview of the complex challenges surrounding freshwater scarcity, linking climate change, population growth, pollution, and infrastructure gaps to the mounting pressures on this vital resource. Particularly striking is its emphasis on the multidimensional nature of the crisis, extending beyond water availability to its implications for health, food security, ecosystems, and economic stability. Equally important is the focus on inequality, especially the disproportionate burden borne by women and vulnerable communities. The discussion on India's water situation—groundwater stress, declining per capita availability, and the widening demand–supply gap—grounds the issue firmly in national realities. The article's call for integrated policies, technological innovation, community participation, and behavioural change is both timely and persuasive. By underscoring that sustainable water management requires collective responsibility alongside state action, it reinforces the urgency of building a more equitable and water-secure future.

A K Sharma
New Delhi

The feature article published in the April 2026 issue of *TerraGreen* on wildlife tourism in India is a good one indeed. The article offers a thoughtful and timely critique of the sector's current trajectory, highlighting how rising demand, rigid safari-centric models, and unregulated expansion risk undermining the very ecosystems that attract visitors. Its examination of the "experience gap" and the growing disconnect between visitor expectations and ecological realities is particularly compelling. Equally insightful is the discussion on the shift from eco-tourism to volume-driven mass tourism, and the consequences of an overemphasis on tiger sightings. By drawing attention to issues such as pressure on core zones, resort proliferation, and the marginalization of local communities, the article situates wildlife tourism within a broader socio-ecological context. The call for diversification of experiences, stronger buffer zone management, community integration, and education-driven tourism offers a constructive and forward-looking roadmap. By urging a redefinition of success, from numbers and sightings to ecological health and meaningful engagement, the article makes a persuasive case for a more sustainable and balanced model of wildlife tourism.

Pramod Das
Kolkata, West Bengal

Published by Dr Vibha Dhawan on behalf of The Energy and Resources Institute, Darbari Seth Block, IHC Complex, Lodhi Road, New Delhi – 110 003. Editor-in-chief Dr Vibha Dhawan

© The Energy and Resources Institute. All rights reserved.



Editor-in-Chief
Vibha Dhawan

Editorial Board
K Ramanathan
S K Sarkar
Suneel Pandey

Publishing Head
Anupama Jauhry

Editorial Team
Abhas Mukherjee
Bhavya Bareja

Designer
Santosh Gautam

Production
Aman Sachdeva

Marketing, Sales & Distribution
Sanjeev Sharma

Head office
TERI
Darbari Seth Block, IHC Complex
Lodhi Road, New Delhi – 110 003
Tel. +91 (11) 2468 2100 or 7110 2100
Fax +91 (11) 2468 2144 or 2468 2145

Regional centres
Southern Regional Centre
4th Main, 2nd Cross, Domlur II Stage,
Bangalore–560 071
Tel: (+91 80) 2535 6590-94 (4 lines)
Email: terisrc@teri.res.in

North-Eastern Regional Centre
Chachal, Mahapurush Madhabdev Path,
Hengrabari, Guwahati- 781 036
Tel: (+91 361) 350 0766
Email: terine@teri.res.in

Western Regional Centre
House No. 233/GH-2, Vasudha Housing Colony,
Alto-St Cruz, Tiswadi, Goa-403 202
Tel: (+91 832) 245 9306, 245 9328
Email: teriwrc@teri.res.in

Western Regional Centre
Office No. 318, Raheja Arcade,
Sector-11, CBD-Belapur,
Navi Mumbai - 400 614
Maharashtra
Tel: (+91 22) 2758 0021, 4024 1615
Email: terimumbai@teri.res.in

TERI Himalayan Centre
Latey Bunga, Mukteshwar,
Nainital - 263 132, Uttarakhand
Tel: +91 99901 28101
Email: praveen.sharma@teri.res.in

Contents

VOLUME 19 • ISSUE 2 • MAY 2026

4 NEWS

12 FEATURE

Role of Critical Minerals in Clean Energy Transition

18 IN CONVERSATION

Kusum Pandey, Mural Artist

22 COVER STORY

The Geopolitics of Heatwaves

30 SPECIAL REPORT

Nanoparticle Waste Pollution

33 GREEN CHALLENGES

Why India's Agroforestry Policy Deserves More Attention

37 TERRA YOUTH

46 WILDLIFE

The Invisible Network beneath Jangalmahal

49 PIONEER

56 GREEN EVENTS



12 FEATURE



30 SPECIAL REPORT



22 COVER STORY

10 ENVIRONMENTAL RESEARCH



37 TERRA YOUTH





Forest Fires Ravage Jammu & Kashmir's Rajouri Region

Massive forest fires swept through parts of the Rajouri Forest Division in Jammu & Kashmir during the last week of May 2026, alarming environmental authorities and local communities. Prolonged dry weather, rising temperatures, and strong winds intensified the fires, which spread rapidly across forested hills and damaged large stretches of vegetation. The blaze threatened biodiversity in the region and forced several wild animals to move into nearby villages and residential areas in search of shelter and food. Forest officials, firefighters, and local volunteers launched extensive operations to contain the flames, though difficult terrain hampered efforts. Environmental experts warned that increasing heatwaves and changing climate patterns are making Himalayan forest ecosystems more vulnerable to recurring summer wildfires.

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

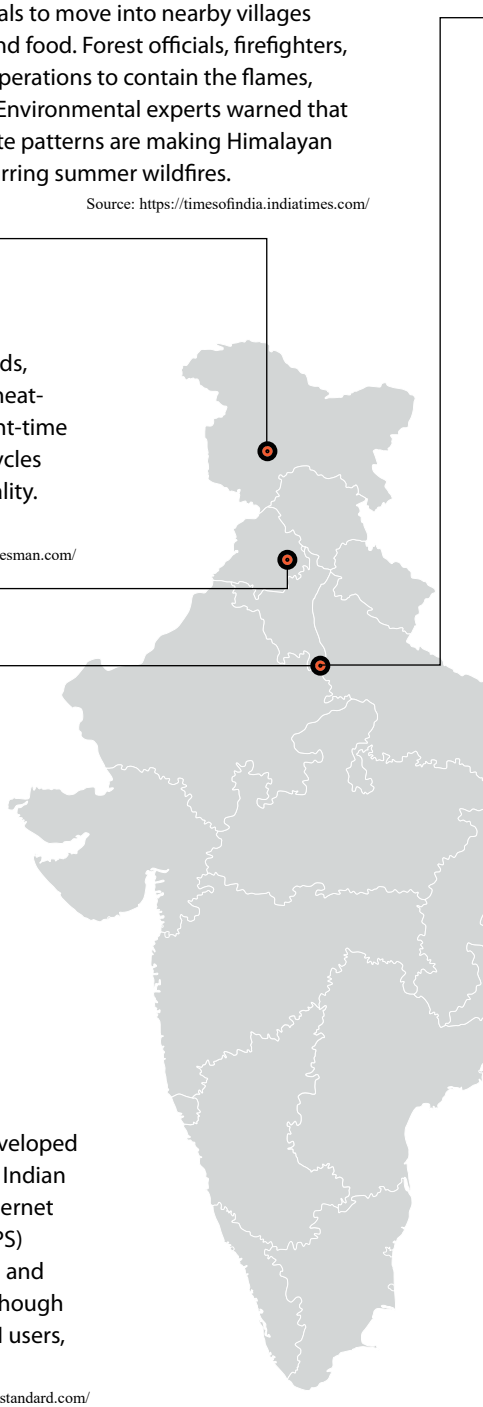
Rising Temperatures Threaten India's Wheat Belt

Punjab and Haryana are warming at half a degree per decade during the wheat season, with minimum temperatures rising nearly three times faster in Gujarat. A new study by Climate Trends, Wheat Under Stress: Climate Change, Rising Heat, and Adaptation Pathways in India's Major Wheat-Growing States, assesses ho w rising temperatures, particularly warmer winters, increasing night-time temperatures, and more frequent terminal heat events, are already disrupting wheat growth cycles across the country's five major wheat-producing states, reducing yields and affecting grain quality. The study arrives at a sensitive moment for Indian agriculture.

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







India Fifth Most Digital Economy Globally in 2026

India has emerged as the fifth most digitalized economy globally in 2026, overtaking major developed economies such as Germany, France, Japan and Canada in digital performance, a report by the Indian Council for Research on International Economic Relations (ICRIER) and the Prosus Centre for Internet and Digital Economy (IPCIDE) said. In the connect, harness, innovate, protect, and sustain (CHIPS) index for artificial intelligence (AI), India ranks fourth overall, with only the United States, China and Singapore ranking above it, according to the State of India's Digital Economy report for 2026. Though India has the world's second-largest talent pool and accounts for about 26 per cent of global AI users, the country lags in private AI investment capital and compute infrastructure, the report noted.

Source: https://www.business-standard.com/



Delhi's Rooftop Solar Capacity Hits 420 MW across 23,000+ Installations

Delhi's rooftop solar capacity has crossed 420 MW across more than 23,000 installations, with the city›s distribution companies reporting rapid uptake. Assuming an average household load of 2 kW, the installed base is sufficient to meet the daily electricity needs of over two lakh households and institutions, discom officials said recently. The BSES discoms—BRPL and BYPL—have energized more than 13,600 rooftop solar connections with a combined capacity of around 260 MWp (megawatt peak), a company spokesperson said. Megawatt peak measures the maximum output of intermittent sources such as solar and wind under optimal conditions.

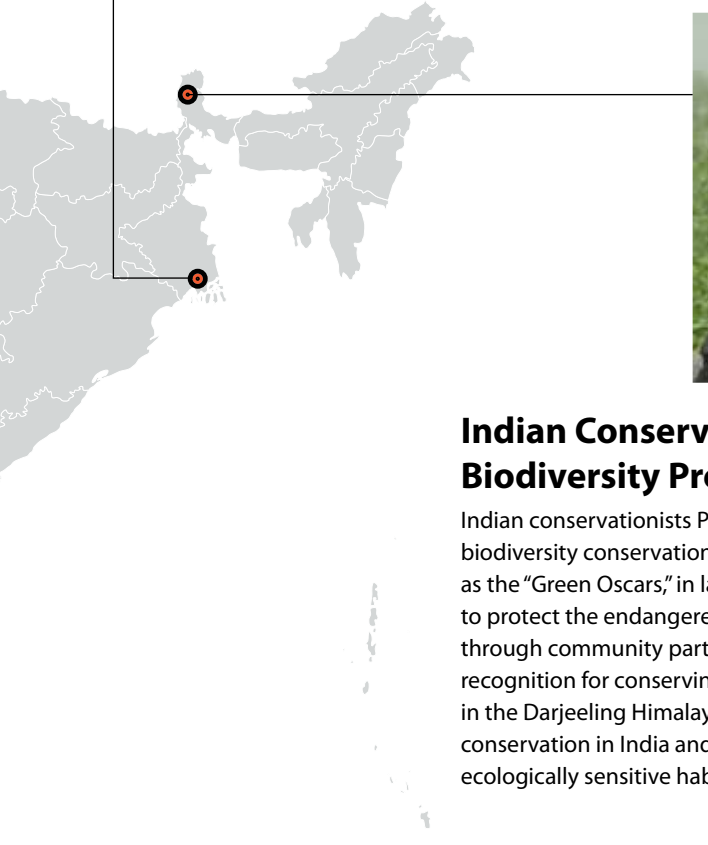
Source: https://www.energywatch.in/

India Faces Warnings of a Weak Monsoon and Severe Heatwaves

The India Meteorological Department (IMD) warned that the 2026 southwest monsoon could be the weakest in 11 years, with rainfall projected at only 90 per cent of the long-period average because of El Niño conditions. At the same time, several regions were forecast to experience prolonged heatwaves in June, raising concerns over agriculture, water shortages, public health, and inflation. Temperatures crossed 45°C in several states.

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







Indian Conservationists Win the "Green Oscars" for Biodiversity Protection

Indian conservationists Parveen Shaikh and Barkha Subba brought global recognition to India's biodiversity conservation efforts after winning the prestigious Whitley Awards, popularly known as the "Green Oscars," in late May 2026. Whitley Awards Shaikh was honoured for her work to protect the endangered Indian skimmer bird along the Chambal and Ganga river systems through community participation and habitat restoration initiatives. Meanwhile, Subba received recognition for conserving the rare Himalayan salamander and fragile wetland ecosystems in the Darjeeling Himalayas. Their achievements highlighted the growing role of grassroots conservation in India and underscored the importance of protecting lesser-known species and ecologically sensitive habitats amid rising environmental pressures and climate-related threats.

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

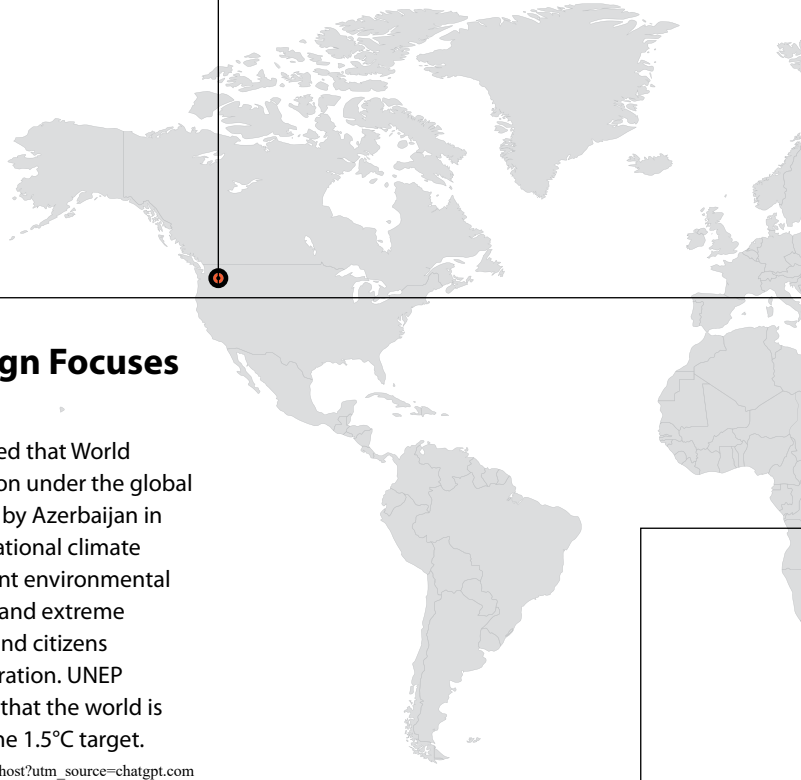


Scientists Alarmed over Proposed Cuts to US Ocean Monitoring System

Climate scientists criticized plans by the United States administration to scale down the Ocean Observatories Initiative, one of the world's most advanced ocean monitoring systems. The programme uses hundreds of underwater instruments to study ocean currents, marine ecosystems, and climate change impacts. Researchers warned that reducing the system could weaken long-term climate forecasting and scientific understanding of crucial ocean processes such as the Atlantic Meridional Overturning Circulation (AMOC). Environmental experts said the decision may significantly affect global climate research at a time when rising ocean temperatures and marine disturbances are intensifying due to climate change.

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





World Environment Day 2026 Campaign Focuses on Climate Action

The United Nations Environment Programme (UNEP) announced that World Environment Day on June 5, 2026, would focus on climate action under the global campaign slogan "#NowForClimate." The event is being hosted by Azerbaijan in its capital, Baku, reflecting the country's growing role in international climate diplomacy after hosting COP29. The campaign highlights urgent environmental signals such as rising temperatures, melting glaciers, wildfires, and extreme weather events while encouraging governments, businesses, and citizens to accelerate renewable energy adoption and ecosystem restoration. UNEP emphasized that climate action is no longer optional, warning that the world is rapidly approaching dangerous warming thresholds beyond the 1.5°C target.

Source: https://www.worldenvironmentday.global/2026/about/theme-and-host?utm_source=chatgpt.com

Indonesia's "Eternity Glaciers" Nearing Disappearance

Scientists and climate researchers warned that Indonesia's last remaining tropical glaciers in West Papua could disappear completely before the end of this decade. An expedition to the Puncak Jaya region found that nearly 95 per cent of the glaciers' area has vanished since 2002 because of rising global temperatures and changing weather patterns. Researchers described the melting as a powerful symbol of accelerating climate change and environmental degradation. The glaciers also hold cultural importance for Indigenous communities in the region. Experts warned that the rapid ice loss reflects the broader impacts of fossil fuel emissions and global warming on fragile mountain ecosystems worldwide.



Source: https://www.theguardian.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 Nino 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. The researchers said temperature records could be broken this year, causing widespread drought as well as fires, with the impact of human-induced climate change compounded by an especially strong "El Nino" effect.

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





Conservationists Alarmed by Drastic Cuts to Key UK Fund for Global Nature Protection

Conservation groups and environmental experts expressed concern after the United Kingdom announced major cuts to the Darwin Initiative, one of its longest-running international biodiversity protection funds. The decision will reportedly remove at least 89 countries from eligibility for conservation support, affecting projects across Africa, Asia, Central Asia, and Latin America. Critics warned that the cuts could undermine global efforts to protect endangered species, forests, wetlands, and fragile ecosystems at a time of accelerating biodiversity loss and climate change. Environmental organizations also argued that the move contradicts international commitments under the UN Convention on Biological Diversity. The UK government defended the decision, saying funds would be focused on areas with the greatest conservation impact.

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

Antarctica's "Doomsday Glacier" Faces Rapid Collapse Risk

Scientists studying Antarctica's Thwaites Glacier, often called the "Doomsday Glacier," warned that its eastern ice shelf could collapse within the year. Researchers said warming ocean waters are rapidly weakening the glacier, increasing the risk of accelerated ice loss and long-term sea-level rise. Experts estimate that the complete collapse of Thwaites could eventually raise global sea levels by around 65 centimetres, threatening coastal cities across the world. Scientists also warned that the glacier's destabilization could affect surrounding Antarctic ice systems, potentially contributing to even greater future sea-level rise driven by climate change and warming oceans.

Source: https://www.livescience.com/



Biodiversity Conservation Needs Finance

Not Just Intent

As the world marked the International Day for Biological Diversity on May 22, it is worth asking a simple but uncomfortable question: can biodiversity conservation succeed on moral appeal alone?
Article by **Sayanta Ghosh** and **Dr Jitendra Vir Sharma**.

For decades, the answer has effectively been yes in speeches, but no in practice. We have repeatedly affirmed that biodiversity is invaluable, that ecosystems sustain livelihoods, and that local communities are essential custodians of nature. Yet, when it comes to actual financing, implementation, and institutional support, biodiversity conservation still remains underfunded and fragmented.

India cannot afford to continue with this gap between ambition and action.

This matters because biodiversity is not merely about wildlife protection or scenic landscapes. It is the ecological foundation of food systems, water security, pollination, soil health, climate resilience, and rural livelihoods. From forests and wetlands to grasslands, coastal ecosystems and agro-biodiversity, nature supports both ecological stability and economic survival. When biodiversity declines, the costs are not abstract. They are borne by farmers, forest-dependent communities, fishers, women collecting biomass and water, and future generations inheriting weakened ecosystems.

That is why biodiversity conservation now needs to be discussed not only as an environmental responsibility, but also as a finance and governance challenge.

Public funding, though essential, is clearly not enough. Conservation programmes, habitat restoration, protection of commons, and biodiversity-friendly land management all require sustained finance over long periods. Short-term schemes and project-based grants rarely match the long ecological time needed for meaningful outcomes. If India is serious about biodiversity targets, it must create ways to mobilize larger and more durable flows of finance into conservation and restoration.


Photo courtesy: Sayanta Ghosh

This is where the idea of biodiversity finance becomes important. At its core, biodiversity finance means creating financial pathways that support measurable ecological outcomes. These may include public investment, CSR support, blended finance, philanthropic contributions, biodiversity-linked incentives, and emerging instruments such as biodiversity credits. But whatever the instrument, the key principle should remain the same: ecological stewardship must be recognized, measured, and rewarded.

The attraction of biodiversity-linked finance is obvious. It can bring new resources into conservation at a time when fiscal space is limited. It can support restoration of degraded ecosystems. It can help shift biodiversity from being treated as a cost centre to being recognized as a public good with measurable value. And if designed well, it can also strengthen local livelihoods

rather than treating conservation as a burden.

But the phrase *"if designed well"* is doing a lot of work here. India should not rush into biodiversity markets or biodiversity credits without first building the right framework. Unlike carbon, biodiversity cannot be reduced to a single universal metric. A forest is not just tree cover. A wetland is not just water spread. A grassland is not wasteland. Biodiversity includes habitat quality, species diversity, ecological function, landscape connectivity, and local stewardship. Therefore, any financing mechanism built around biodiversity must rest on credible baselines, measurable indicators, transparent monitoring, and clear rules against weak claims or double counting.

In other words, before creating a market, India must create a credible architecture of trust. This requires an institutional mechanism that can do several things at once. It should recognize methodologies, register projects, define rules for validation and verification, maintain a transparent registry, and oversee issuance and retirement of biodiversity-linked units or credits. Equally important, it should ensure that ecological gains are real, additional, and durable. Without such an institutional framework, biodiversity finance may quickly lose credibility or become vulnerable to greenwashing.


Photo courtesy: Sayanta Ghosh

India should view this not as a bureaucratic burden, but as a strategic opportunity. If the country can shape a credible domestic biodiversity finance framework early, it can avoid dependence on fragmented external models and build an approach that reflects Indian ecological realities and governance needs.

However, the most important test of any such framework will not be technical elegance alone. It will be whether it is community-centred. This is where many environmental finance discussions become weak. Biodiversity-rich landscapes in India are not empty spaces. They are inhabited, used, protected, and negotiated by communities. Forest-dependent households, pastoralists, fishers, tribal communities, and village institutions often play a direct role in sustaining biodiversity, whether or not their contribution is formally recognized. Any biodiversity finance mechanism that bypasses them will not only be unjust; it will also be ineffective.

That is why the principle of equitable sharing of benefits must remain central. If biodiversity creates value, then a fair share of that value must reach those who conserve it on the ground. This is not only a matter of social justice; it is also a matter of implementation logic. Conservation becomes stronger when communities have both rights and incentives aligned with ecological outcomes.

India already has important foundations for this conversation, including its biodiversity governance framework and the long-standing principle of Access and Benefit Sharing. The next step is to connect these principles with modern conservation finance tools in a way that is transparent, scientifically sound, and operationally practical.

On this International Day for Biological Diversity, the message should therefore


Photo courtesy: Sayanta Ghosh

be clear: biodiversity conservation cannot rely only on awareness campaigns, commemorative events, or broad declarations of intent. It needs finance, institutions, and incentives. It needs frameworks that reward restoration, protection, and stewardship. It needs mechanisms that are credible enough for investors, practical enough for implementation, and fair enough for communities.

Above all, it needs urgency.

India has both the ecological richness and the policy depth to shape a meaningful biodiversity finance pathway. But that potential will remain underused unless the country moves from scattered discussion to structured action. The real question is no longer whether biodiversity is valuable. That is beyond doubt. The real question is whether we are ready to build the financial and institutional systems that reflect that value.

If India gets that right, biodiversity conservation can become not only a moral imperative, but also a practical and investable national priority. ■

Mr Sayanta Ghosh is Area Convenor, Centre for Geospatial Technology Application, TERI and Dr Jitendra Vir Sharma is Senior Director, Water Waste and Natural Resources, TERI. The article first appeared on https://teriin.org/

Nitrogen Pollution

It is Changing How the World's Forests Breathe

Scientists have uncovered a surprising forest tipping point where too much nitrogen pollution can disrupt the soil's natural heartbeat and threaten its long-term resilience.

For centuries, forests have followed a remarkably consistent rhythm. Beneath the trees, roots and microscopic organisms steadily release carbon dioxide into the atmosphere as they break down organic material and fuel plant growth. Scientists call this process soil respiration, and it represents one of the largest carbon flows on Earth.

New research suggests that this natural rhythm is being disrupted by a growing and often overlooked form of pollution: excess nitrogen.

Nitrogen Pollution Is Reaching Forests Worldwide

On a cool spring morning, a forest floor may seem calm and still. Yet beneath the surface, billions of microbes are hard at work decomposing leaves, wood, and other organic matter. At the same time, tiny roots release carbon dioxide as they grow and function. Together, these processes create a steady exchange of carbon between the land and the atmosphere.

For decades, however, forests have been exposed to increasing amounts of nitrogen pollution. Fertilizers, vehicle emissions, and industrial activities release reactive nitrogen into the air, much of which eventually returns to the ground through rain, snow, or airborne particles.

Since the Industrial Revolution, human activities have roughly tripled global nitrogen deposition. Scientists have long known that excess nitrogen affects forest ecosystems. What remained unclear was why some studies found that nitrogen increased soil respiration while others found the opposite effect.

Solving a Longstanding Forest Mystery

To investigate, an international team of researchers assembled one of the largest datasets ever used to study soil respiration.

The analysis combined:

- 168 nitrogen addition experiments conducted in forests around the world
- 3689 observations of natural soil respiration
- Global maps showing nitrogen limited and nitrogen saturated forests
- High resolution nitrogen deposition data
- Measurements of both root respiration and microbial respiration

The team then used machine learning to model how forests worldwide respond to increasing nitrogen inputs. Their conclusion was surprisingly simple:





forests do not all react the same way. Instead, they generally follow one of two distinct pathways.

When Nitrogen Acts Like a Fertilizer

In forests where nitrogen is scarce, additional nitrogen can initially stimulate biological activity. These nitrogen limited forests are often found in boreal regions and remote mountain landscapes. When nitrogen becomes available, microbes become more active, roots grow faster, and organic matter breaks down more quickly. As a result, soil respiration increases.

But the benefits do not continue indefinitely. As nitrogen levels keep rising, the positive effects begin to fade. Toxicity can develop, readily available carbon sources become depleted, and the increase in soil respiration eventually levels off before declining. Researchers describe this pattern as an inverted U-shaped response. Soil respiration rises, reaches a peak, and then begins to fall.

When Nitrogen Pushes Forests Past Their Limits

The picture looks very different in forests that already contain high levels of nitrogen. In these nitrogen saturated ecosystems, additional nitrogen can push the system beyond its tolerance threshold. Microbial communities change. Sensitive species disappear. Fine roots shrink or die back. Soil acidity increases.

Rather than showing a gradual response, soil respiration can drop sharply. According to the study, this type of abrupt decline is common in regions that have experienced heavy nitrogen pollution for decades, including parts of Europe, eastern China, and the eastern United States. As a result, two forests receiving similar amounts of nitrogen may respond in completely different ways. One may experience increased soil activity, while another may suffer a major decline.

A Hidden Climate Connection

The findings matter because soil respiration is enormous on a global scale. Researchers estimate that carbon released through soil respiration is seven to eight times greater than annual fossil fuel emissions produced by humans.

Even relatively small changes can have significant implications. Overall, the study found that nitrogen deposition increases global soil respiration by roughly 5 per cent. Most forests remain nitrogen limited enough that additional nitrogen still stimulates biological activity. However, the decline in respiration observed in nitrogen saturated forests is not necessarily good news.

Lower carbon dioxide emissions from soil in these areas often reflect declining root activity and shrinking microbial populations. These are key components of healthy ecosystems and play important roles in building and maintaining soil carbon stores. In other words, less carbon dioxide release may sometimes signal a loss of ecosystem resilience rather than an environmental benefit.

A New Framework for Predicting Forest Responses

By combining thousands of observations with decades of ecological research, the scientists developed a new framework that helps explain both the gradual and abrupt responses observed around the world.

The framework incorporates:

- Biochemical limits
- Species specific nitrogen tolerance
- Changes in community composition
- Ecological tipping points
- Global nitrogen deposition patterns

For the first time, researchers say they can more reliably predict how nitrogen pollution will influence soil respiration across the planet.

Why Reducing Nitrogen Pollution Matters

Efforts to reduce nitrogen pollution are already underway because of concerns about biodiversity loss and air quality. The new findings suggest another important benefit. Reducing nitrogen inputs from agriculture, transportation, and industry could help protect the carbon stored in forest soils.

By preventing ecosystems from crossing nitrogen saturation thresholds, forests may be better able to maintain their natural carbon cycling processes and remain resilient as the climate continues to change. ■

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



Role of Critical Minerals in Clean Energy Transition

Securing Resources for a Low-Carbon Future

In this article, **Arvind Kumar** highlights that critical minerals—such as rare earth elements, lithium, cobalt, nickel, copper, and graphite—are essential for the global clean energy transition. These materials underpin technologies like electric vehicles, wind turbines, solar systems, and battery storage. As countries pursue net-zero goals, demand for these minerals is rising sharply, with clean energy systems requiring significantly more mineral inputs than fossil fuel-based alternatives. However, supply chains are highly concentrated and face challenges related to availability, affordability, and recycling. Addressing these constraints through diversification, innovation, and circular economy approaches is crucial. For countries such as India, securing sustainable access to critical minerals is vital for energy security and climate goals.



What are Critical Minerals?

Critical minerals list varies with country, time, and economic demand but consistently include rare earth elements (REE), lithium (Li), cobalt (Co), nickel (Ni), copper and graphite. The critical minerals value chain encompasses exploration, extraction, processing, refining, manufacturing into end-use items and components, recycling, and disposal. The rare earth production process is complex and expensive. As the European Commission highlighted in 2022, "Lithium and rare earths will soon be more important than oil and gas. Our demand for rare earths alone will increase fivefold by 2030."

Rare earth elements

The US Geological Survey (USGS) defines the REEs as a group of 17 elements composed of scandium, yttrium, and the lanthanides. The lanthanides include the following elements: lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), and lutetium (Lu). Rare earths are not particularly rare but are found in low concentrations in the earth's crust. The economics of locating and retrieving them are challenging. Rare earths are divided into two groups: light rare earths (lanthanum, cerium, praseodymium, neodymium, promethium, samarium) and heavy rare earths (europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium, scandium, and yttrium). One significant REE application is permanent magnets, without which wind turbines wouldn't turn and EV motors would not work.

There are four characteristics of REEs that distinguish them from other minerals. First, these elements are collectively known for their unique magnetic, catalytic, and luminescent properties, making them essential in a broad variety of high-tech and strategic applications (USGS, 2014). These include electronics, lighting, aerospace, defence, medical, and green technologies. These diverse applications arise from chemical properties that are similar across all REEs, hence their classification as a group, although slight differences in electronic configurations give individual elements specific specializations. Second, their applications usually involve small quantities but they are challenging to substitute due to their high specificity. Third, REEs have a relatively inelastic supply due to their nature as byproducts. Finally, REE production and processing are one of the most concentrated across mineral resources, with China controlling

more than 90 per cent of post-mining processing.

Rapidly adopting renewable energy technologies and phasing out fossil fuels are crucial for combating climate change. Achieving net-zero CO_2 emissions by 2050 will require a much faster deployment of clean energy technologies, from wind turbines and solar panels to electric vehicles and battery storage. Concomitantly, it will lead to demand growth for many minerals, including copper, cobalt, lithium, nickel, and rare earth elements. According to the International Energy Agency (IEA), critical minerals play a pivotal role in various clean energy technologies, from power generation and electricity networks to electric vehicles (EVs) and battery storage systems. For example, although solar photovoltaic (PV) plants and wind farms do not rely on fuels for operation, they typically require more critical materials for their construction than fossil fuel–based systems. Compared to conventional vehicle production, excluding aluminium and steel, EV production requires six times the amount of mineral resources. An onshore wind farm requires nine times more mineral input than a gas-fired plant of similar capacity (also excluding aluminium and steel). According to the IEA, since 2010, "the average amount of minerals needed for a new unit of power generation capacity has increased by 50 per cent as the share of renewables in new investment has risen." This trend highlights the critical connection between minerals and clean energy technologies, signifying a shift from systems reliant on fuel to those dependent on minerals.



REEs are critical to the energy transition due to their indispensable role in numerous clean energy technologies, particularly wind turbines and EVs. Elements such as neodymium and dysprosium are used to manufacture powerful permanent magnets, which are essential in high-efficiency generators that convert wind energy into electricity. Direct-drive wind turbines, favoured over gear-driven turbines for their superior reliability, require these high-efficiency generators. REE magnets are also used in electric traction motors, which are among the most energy-efficient devices available, offering energy savings of 20–40 per cent compared to conventional electric motors. Furthermore, incorporating small quantities (1–2 kg) of magnet REEs in an EV's motor can significantly reduce the need for other critical minerals in the vehicle's battery—like lithium, nickel, and cobalt—by as much as 60–80 kg per vehicle. This efficiency makes REEs crucial for not only improving EVs' performance but also reducing their overall material footprint. As the clean energy transition accelerates, the demand for these critical elements is expected to continue to rapidly increase.



Critical Minerals and Clean Energy Transition

The choice of clean technologies will determine the demand for different critical minerals in the coming years. Some minerals are essential for specific technologies, such as cobalt and lithium for batteries, while others, such as aluminium and copper, are widely needed across various applications. As

countries intensify their energy transition efforts, there will be significant shifts in the demand patterns for critical minerals. The demand for critical minerals is expected to rise sharply over the coming decades due to their essential role in the energy transition. Some of the most widely used critical minerals are given here.

Lithium

Often described as the "white gold" of the energy transition, lithium is a core part of lithium-ion batteries and therefore indispensable for EVs and stationary batteries. Lithium is also key to the second-most widely used technology, lithium-ion phosphate (LFP) batteries. By 2050, lithium demand is expected to reach between 1,200 and 1,700 kilotonnes (kt), depending on the climate scenario, representing a tenfold increase from current levels (165 kt in 2023). This surge is primarily driven by clean energy technologies: the EV industry will account for approximately 90 per cent of demand growth by 2050. Furthermore, the potential development of solid-state batteries with lithium metal anodes could open new markets for lithium in its metallic form, further boosting demand in the coming decades. Australia leads the global lithium production, contributing approximately 50 per cent of the total output.

Nickel

Nickel plays a crucial role in the production of high-performance batteries, which are ideal for EVs. It is predominantly used in the cathodes of lithium-ion batteries, where it enhances energy density, resulting in greater battery efficiency, better overall performance, and extended driving ranges for EVs. For these benefits, automakers increasingly favour high-nickel cathode chemistries, such as nickel cobalt aluminium (NCA) and nickel manganese cobalt (NMC). The demand for nickel and nickel-based compounds is growing significantly, driven primarily by increasing use of high-nickel battery chemistries in the EV sector. Global nickel demand, which hovered around 2.4 Mt per year between 2018 and 2020, surged to approximately 3.1 Mt in 2023, and all energy transition scenarios project that it will to continue to rise. Indonesia also holds the largest known nickel reserves, possessing over 40 per cent of the global total in 2023.

Cobalt

Cobalt is one of several constituents of the active cathode materials in lithium-ion batteries, which are crucial for powering EVs and for various energy storage systems. Cobalt's role in these batteries is to enhance energy density, prolong battery life, and improve rechargeability. Beyond batteries, cobalt is also used in superalloys for aircraft engines and magnets and other high-strength alloys that require resistance to corrosion and high temperatures. Production-wise, most cobalt is mined in the Democratic Republic of Congo (DRC), accounting for nearly three-quarters of global output.

Graphite

Graphite, a crystalline form of carbon, has traditionally been used in applications like lubricants, electrical conductors, and metallurgy. It is also a key component of battery anodes, so it is vital to EVs and stationary batteries. It is also used in electrodes in electric arc furnaces, one of the technologies for decarbonizing the steel sector. China is the world's largest producer of natural graphite, with more than three-quarters of the global total. The shift towards EVs and battery storage systems is set to more than double global graphite demand by 2030: it is projected to reach up to 18 Mt by 2050, a fourfold increase from 2023. Additionally, the move to electric arc furnaces for reducing



emissions in steel production is likely to further boost demand for graphite electrodes.

Copper

Copper is a uniquely important mineral for the energy transition, being integral to all major clean energy technologies, including EVs, solar photovoltaics (PV), wind turbines, and the electricity network. Copper's exceptional properties—such as superior electrical and thermal conductivity, durability, ductility, and corrosion resistance—make it indispensable for the efficient functioning and longevity of these technologies. EV batteries rely on copper anode current collectors; copper is also used in EV wiring and electric motors. Solar and wind installations rely on copper for efficient power generation and transmission. Likewise, the expansion and modernization of electricity grids depend heavily on copper to ensure reliable and effective energy distribution. Ensuring a secure and stable supply of copper is therefore paramount to successfully achieving global clean energy goals.

A report by IEA titled *'Mineral requirements for clean energy transitions'* has indicated that the availability of critical minerals will need to ramp up substantially to meet the goals of the Paris Agreement and avert some of the worst impacts of climate change. In order to build out enough clean technology to keep global temperature rise to 1.5–2 degrees Celsius, demand for nickel, cobalt and graphite is expected to grow by about 20 times while lithium demand is expected to grow to 40 times its current level. Demand for rare earth elements is expected to quadruple.

The availability and affordability of these critical minerals and REEs is a concern. Demand projections point to a large growth in critical minerals' consumption that far exceeds the rate at which new primary and secondary sources are currently being developed; this gap could delay the global transition



to a low carbon economy. The world will only be able to meet the goal of net zero emission by 2050 if massive new mineral supplies come online in a timely way.

There is a high concentration worldwide of countries and companies that have mining resources and processing facilities, few countries can completely meet their needs for the minerals that are critical to the energy transition from domestic sources.

Critical mineral recycling requires a sufficient feedstock of end-use products. This supply is constrained by lack of collection systems. Many viable end-use products remain in households, or end up in a landfill. Other end-use products, like lithium-ion batteries for EVs, are not expected to reach end-of-life in sufficient numbers in the near future.

Does Clean Energy Mean Less Mining?

While fossil fuels are dug up, transported around the world, and burnt once to create energy, critical minerals can be re-used and then recycled multiple times. To put it in perspective, approximately 15 billion tonnes of fossil fuels are currently mined and extracted each year. In contrast, the global mining of critical minerals for low-carbon energy amounted to seven million tonnes in 2020. While this amount could increase to 28 million tonnes per year according to the IEA, that equates to about 535 times *less* mining than under the current fossil-fuelled system. By transitioning from fossil fuel-powered energy to an all-renewable electric energy system, world has the potential to drastically reduce the need for extensive mining activities, contributing to a more sustainable and environmentally friendly future.

The Government of India has launched the National Critical Mineral Mission (NCMM) as a strategic initiative to secure the supply chain of minerals essential for renewable energy and storage technologies. The major objectives of the Mission are to secure domestic and foreign sourcing of critical minerals and strengthen value chains.

It is critical for India to secure a stable and sustainable supply of critical minerals, which are indispensable to national security, economic growth, and the transition to a clean energy future. Investment in alternative battery chemistries, material substitution, and efficient recycling processes can extend the life cycle of critical minerals and decrease overall consumption. Further government incentives to promote circular economy models will drive innovation in recycling technologies and sustainable mining practices. The transition towards a more sustainable mineral supply chain also requires proactive engagement with diverse stakeholders. ■

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



Mehram Nagar Street Art

Where Public Art and Environmental Awareness Come Together

Kusum Pandey is an accomplished mural artist who was the principal artist and chief coordinator of the street art project in Delhi's Mehram Nagar. Specializing in printmaking, the Nainital-based artist is the founder of the RangGeet Art Centre. In an interview with **N Kalyani**, the artist shares what it took to create the Mehram Nagar street art.

Street art. What role does it play in the life of the citizens of and visitors to a city?

Street art lives beyond art galleries. It belongs to everyone. It reflects local culture, history, and struggle. Street art speaks of social justice, environment, gender, identity, and equality. It's not just beautification—it is memory, protest, celebration, healing, and hope. It makes a city feel alive, connecting people to each other and to the place.



Please tell us about Delhi's Mehram Nagar street art project. What was the genesis of the larger street art project of which this was a part?
Lalit Kala Akademi, under the Ministry of Culture, Government of India, was entrusted with the responsibility of creating large-scale public art installations across multiple locations in Delhi for the UNESCO meeting 2024. The project was conceived at a historic moment as India chaired a UNESCO meeting for the first time. This initiative was undertaken as part of Project PARI (Public Art of India), a nationwide programme aimed at integrating art into public spaces and showcasing India's cultural and natural heritage.

Artists from across the country submitted layout proposals for different identified sites. My layouts were selected for execution at the Mehram Nagar site. At this site the focus was on visually representing seven of India's UNESCO



Natural Heritage Sites. The aim was to transform Mehram Nagar into an open-air gallery showcasing India's extraordinary ecological diversity to a global audience, bringing public art and environmental awareness together.

Which are the UNESCO Natural Heritage Sites that have been shown in the Mehram Nagar street art?
The UNESCO Natural Heritage Sites of India depicted are the Great Himalayan national park, Nanda Devi & Valley of Flowers national park, Keoladeo national park, the Western Ghats, Kaziranga national park, Manas wildlife sanctuary, and Sundarbans national park. These are ecologically sensitive landscapes.

What kind of research did the project involve?
A comprehensive study was undertaken to understand the geographical context, ecological systems, and defining natural attributes of each site. Detailed research was carried out on the flora, fauna, and avifauna characteristic to these regions. The murals were not only to enhance public awareness of India's outstanding natural heritage, but also to highlight the importance of its conservation and sustainable stewardship.

Please give us details of the landscape, flora and fauna of the various sites showcased in the murals. Starting with the east…



The Kaziranga National Park & Manas Wildlife Sanctuary murals show the floodplain ecosystems of the Brahmaputra River, characterized by extensive alluvial grasslands, wetlands, riverine forests, and sub-Himalayan forest landscapes. The flora depicted includes tall elephant grasses, wetland vegetation, and mixed deciduous forest species. The faunal representation highlights flagship and endangered species such as the one-horned rhinoceros, Asian elephant, and wild water buffalo. The avifauna is illustrated through migratory and resident bird species, both water birds and grassland-dependent species.

The murals depicting the Sundarbans mangrove ecosystem, located within the Ganga–Brahmaputra–Meghna delta, the world's largest deltaic region, show flora that is primarily the diverse mangrove species adapted to saline and waterlogged environments. Faunal representation features the royal Bengal tiger, estuarine crocodile, and spotted deer.

And then the other sites….

The Great Himalayan national park and the Nanda Devi & Valley of Flowers national parks represent the high Himalayan landscape, characterized by rugged mountain terrain, glaciers, alpine meadows, and deep valleys. The Great Himalayan national park exhibit showcases the ecosystem's characteristic fauna—the Himalayan tahr and snow leopard. The exhibit on the Nanda Devi and the Valley of Flowers national parks highlights alpine and sub-alpine flora and fauna. The faunal and avifaunal representations include the bharal (blue sheep), Himalayan monal (the state bird of Uttarakhand), and the Himalayan vulture. The floral elements feature alpine meadows, endemic and high-altitude plant species such as blue poppy, brahma kamal, Himalayan marsh orchid, and Himalayan slipper orchid, along with forest species that includes deodar and buransh trees.

The murals on the Keoladeo National Park illustrate the wetland vegetation, aquatic plant communities, and marshland ecosystems characteristic of the park. Both migratory and resident bird species, including the Siberian crane, pelican and sarus crane, and ducks, herons, and peafowl are shown as the avian biodiversity. Also depicted are fauna such as the nilgai and wild boar.

The Western Ghats are represented by murals signifying it as one of the world's important centres of floral endemism. The plant diversity illustrated includes tropical evergreen, semi-evergreen, and moist deciduous forests, shaped by the region's monsoon-driven climate and complex topography. Then, around natural landmarks such as the Dudhsagar waterfall, moisture-rich conditions support luxuriant plant growth. The murals therefore depict ferns, mosses, climbers, grasses, and moisture-loving understory plants thriving in these high-rainfall zones.

What were the challenges in the execution of this project? How did you meet these challenges?

The scale of the site posed a significant challenge. With walls rising up to 40 feet, scaffolding and cranes became essential tools. Artists worked fully equipped with safety gear. Primarily young artists were chosen, many of whom were experiencing work at such elevations for the first time. Ensuring their safety was my foremost priority. Training sessions were conducted to prepare them for working at height, and strict safety protocols were enforced throughout the





process.

Positioned along one of Delhi's busiest roads leading to the international airport, the site experiences uninterrupted traffic movement. The proximity of a tunnel intensified the noise, making even basic conversation difficult. To adapt, we introduced loudspeakers and walkie-talkies, which significantly improved coordination and allowed work to continue safely and efficiently.

What kind of media was used to create the murals? What was the methodology?

The project began with meticulous surface preparation with a primer coating on the walls, followed by carefully transferring the layouts as line drawings onto the surface.

Technology and machinery played a crucial role. Airless spray systems were used for priming, projectors helped transfer drawings accurately, and a combination of compressors and brushes was employed for painting. High-quality emulsion and acrylic paints ensured durability and visual clarity. Executed in the month of July, the heat helped paint layers dry quickly.

What was your role as the principal artist and chief coordinator of the project?

I was to create meaningful public art of the UNESCO Natural Heritage Sites. My role required an in-depth research of each site, the development of a cohesive visual narrative, and guidance of the artist team. Every mural was to be both artistically compelling and ecologically accurate.

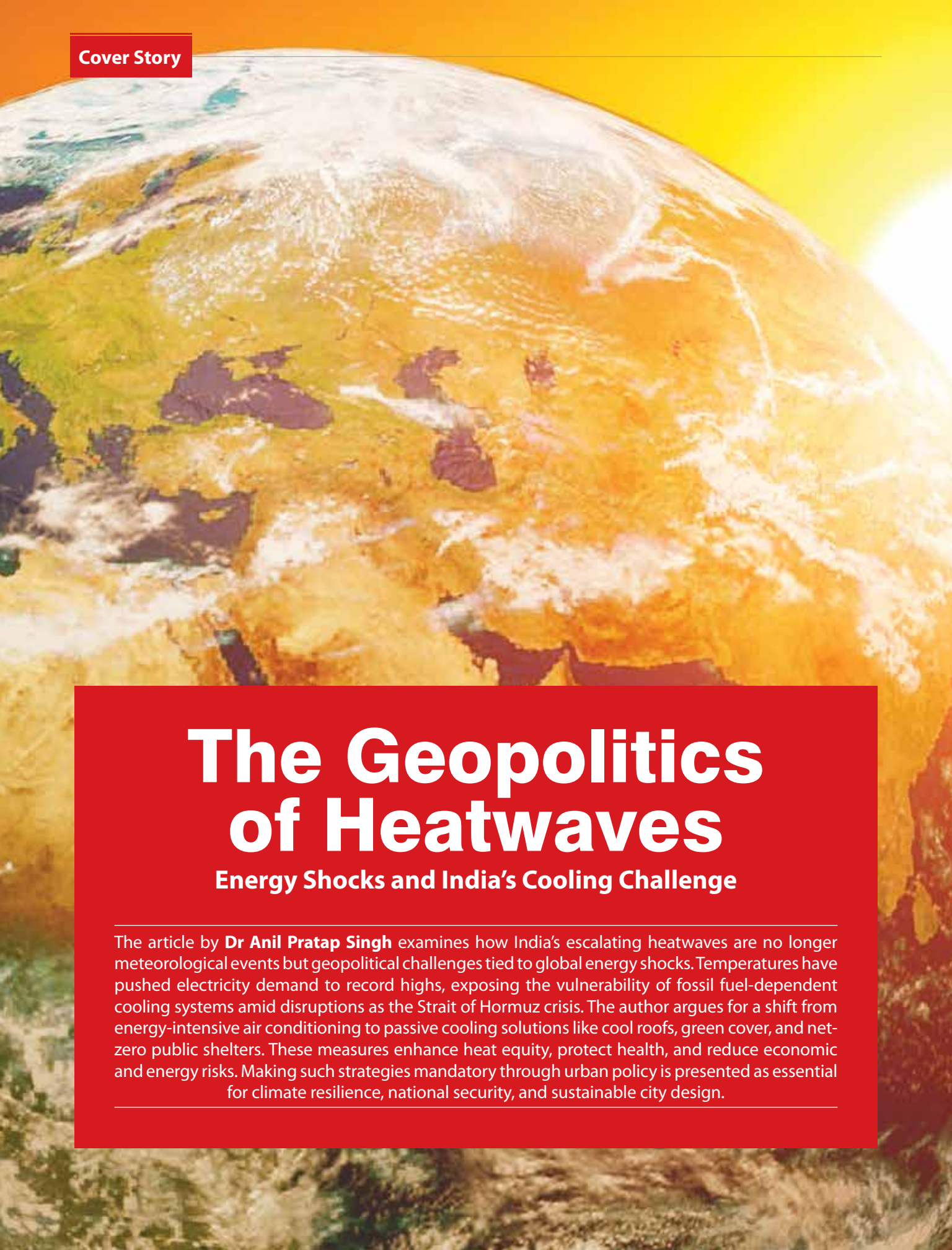
I was to both lead the artistic vision and oversee the execution of the murals. The responsibility therefore carried creative accountability and deadline pressure. The drawing layouts I had submitted to the Lalit Kala Akademi were to be exactly executed on the walls. I was also to select the artists. Having previously worked on large-scale murals on high-rise structures, I brought with me practical experience in managing height, scale, and on-site coordination.

How was it to work with a large team of artists to execute the project?

Alongside me were three other lead coordinators and one technical assistant, supported by a team of around 40 artists. Coordinating such a diverse group required constant communication, adaptability, and trust.

I chose to work largely with young artists, many of whom were still pursuing their master's degrees. They required structured mentorship and guidance to apply their skills effectively. I conducted orientation sessions to explain the project's scope, challenges, and learning opportunities. Artists were encouraged to choose their roles. Those hesitant about working at height contributed to the lower sections, while those keen to gain new experience, volunteered for elevated work. Notably, several women artists demonstrated remarkable confidence and initiative in taking on these challenges.■





The Geopolitics of Heatwaves

Energy Shocks and India's Cooling Challenge

The article by **Dr Anil Pratap Singh** examines how India's escalating heatwaves are no longer meteorological events but geopolitical challenges tied to global energy shocks. Temperatures have pushed electricity demand to record highs, exposing the vulnerability of fossil fuel-dependent cooling systems amid disruptions as the Strait of Hormuz crisis. The author argues for a shift from energy-intensive air conditioning to passive cooling solutions like cool roofs, green cover, and net-zero public shelters. These measures enhance heat equity, protect health, and reduce economic and energy risks. Making such strategies mandatory through urban policy is presented as essential for climate resilience, national security, and sustainable city design.


50
40
30
20
10
0
-10
120
100
80
60
40
20
0



As India navigated another intense May, our urban climate strategy faces a dual, compounding challenge, one meteorological, the other profoundly geopolitical. It was encouraging to witness lawmakers, scientists, and planners gather in New Delhi recently, on May 15, for the Climate Parliament Round Table on Urban Heat Islands (UHI). At this high-level forum, an underlying, painful truth took centre stage: 'we cannot fix a crisis with simple warnings when our city infrastructure itself creates the heat'. Urban heat islands are far more than simple weather anomalies; they represent structural failures in design. This extreme weather exposes an unfair gap in urban survival, demanding heat equity. Today, city cooling is inseparable from global realities, as rising urban temperatures collide directly with energy shocks from the ongoing US-Iran conflict.

The Geopolitical Pressure on Active Cooling

For decades, we relied on power-intensive air conditioning to escape rising urban heat. This year, that reliance has exposed a massive vulnerability. Recent blockades in the Strait of Hormuz and damage to Persian Gulf infrastructure have sent global energy markets into a historic crisis.

This international vulnerability is now colliding with unprecedented tension on our domestic infrastructure. This summer, India's peak power demand horrified all historical records, shooting up to an all-time high of 260.5 gigawatts (GW) as severe heatwaves forced a massive surge in air conditioning usage. Crucially, the national grid also hit a record non-solar peak of 247.2 GW late at night. This post-sunset spike highlights a dangerous reality: even after solar generation drops to zero, our cities remain so intensely hot that active cooling demands threaten grid stability around the clock.

Because India imports most fuel, this domestic demand surge directly intersects with global instability. In a serious warning, the International Energy Agency (IEA) Executive Director, Dr Fatih Birol, called the fuel supply shortages from the blocked Strait of Hormuz the 'greatest global energy security challenge in history.' Dr Birol clarified that the current crisis is not a global shortage of oil itself, but rather a severe problem of 'dislocation and logistics.' He revealed that he has been in direct emergency consultations with global energy ministers, including India's Petroleum Minister, Hardeep Singh Puri, to manage the fallout of these shipping disruptions.

As world fuel prices rise and markets fluctuate, our heavy reliance on fossil fuels to run air conditioners is exposed as a major strategic weakness. When international conflicts threaten our energy supply lines, active cooling stops being a reliable safety net and becomes an unaffordable luxury. This shift from vulnerability to strategic independence is not unprecedented. During the global oil shocks of the 1970s, the fossil-fuel-poor Philippines was forced to innovate, making a bold, early bet on indigenous

geothermal energy out of pure necessity. Today, as the 2026 Strait of Hormuz disruptions expose the extreme fragility of imported fuel chains once again, that underdog technology has become their ultimate economic shield.

India stands at a similar crossroads this summer. This energy crisis is the ultimate warning that we must stop simply managing emergencies and completely change how we design our cities. Since power-heavy cooling is becoming unsustainable due to global supply shocks, we must drive our own structural innovation: quickly shifting to natural, passive design methods that keep buildings cool without a single watt of electricity.

Natural Cooling for All: The Cool Roofs Revolution

This is the exact point where 'Cool Roofs' and heat equity shift from being a progressive green choice to a critical matter of national security. Unlike power-hungry air conditioners, passive solutions like solar-reflective coatings, cool pavements, and urban green canopies require absolutely zero electricity or fuel to run. They protect our cities completely off the grid. The physics behind this strategy are remarkably simple and effective. Instead of acting like a thermal sponge that traps the sun's energy all day, a cool roof acts like a mirror. By reflecting solar radiation back into the atmosphere rather than absorbing it into the building's concrete structure, these specialized coatings can lower indoor temperatures by a vital 2°C to 5°C. When applied at a community-wide scale, this simple physical shift delivers massive, overlapping benefits.

In low-income areas where families cannot afford air conditioning, a cool roof serves as a literal lifesaver against severe heatwaves. This infrastructure directly shapes public health. As highlighted by *The Scientist*, extreme heat is a major driver of metabolic illness; for





instance, pregnant women exposed to sustained heat spikes face twice the risk of developing gestational diabetes. Researchers found that densely built, hot concrete surfaces actively worsen these health dangers, while green cover and cool roofs suppress them. Because poorer settlements are highly exposed to heat-absorbing building materials, providing passive cooling is a critical intervention to protect mothers and future generations. Worsening this threat, a recent BBC report warns that rising temperatures are driving a dangerous surge in climate-related infectious diseases.

This shift from tracking mere temperature to understanding total physical heat stress is driving a major policy change within India's scientific establishment. Recognizing that old rules fail to match changing climate realities, the India Meteorological Department (IMD) is actively revamping its criteria for declaring heatwaves. By moving towards localized, percentile-based thresholds that factor in the deadly mix of high humidity and trapped nighttime warmth, the IMD is acknowledging that extreme heat can no longer be judged by a single, nationwide number. When official warning systems upgrade to capture the true, suffocating weight of heat stress, our urban planning must change too. Passive infrastructure like cool roofs provides the perfect equalizer, cooling down the exact built-environment heat that modern weather alerts are now forcing us to flag.

Lowering indoor temperatures by just a few degrees also significantly reduces the heat inside a building. This means existing fans and coolers do not have to run constantly, protecting our vulnerable power grids during peak summer months, especially during those volatile, late-night hours when solar power drops to zero but air conditioning demands stay dangerously high. Furthermore, when entire blocks implement reflective roofs and cool pavements, the whole

neighbourhood stops radiating heat back into the night air. This breaks the dangerous cycle of 24-hour urban warming. For people living in crowded city areas, this simple fix can prevent heat-related medical emergencies. The truth is that urban heatwaves do not punish everyone equally. Richer neighbourhoods have green spaces and smart, cool architecture. Meanwhile, poorer settlements become literal ovens, trapping families under tin sheets and hot concrete.

This urban divide is backed by striking global data. A landmark study analysing nearly 9,000 cities worldwide found that urban trees cut the heat island effect by half, but they are concentrated heavily in wealthy areas. Lower-income neighbourhoods have up to 15 per cent less tree cover and are noticeably hotter. Because the communities facing the most severe heat are the least likely to have natural shade, passive infrastructure like cool roofs provides an essential equalizer, offering permanent, zero-cost cooling to those who need it most.

Cool roofs give everyone an equal chance to stay safe in extreme heat. Because they lower temperatures naturally, they permanently ease the pressure on our electricity grid. Most importantly, they protect our poorest families, not just from the dangerous weather, but from the constantly changing costs of world fuel markets.

Economics of Passive Cooling

Beyond public health, the financial argument for passive infrastructure is undeniable. This reality is strongly backed by the BloombergNEF (BNEF) *New Energy Outlook 2026* report. BNEF analysts point out that following the pandemic and the war in Ukraine, the current conflict in the Persian Gulf represents the third major shock to global energy this decade. These back-to-back crises have set off security alarms worldwide, forcing nations to break away from imported fossil fuels. The report notes that Asian economies heavily reliant on imported energy—particularly India, which spent between 3 and 6 per cent of its GDP on fuel imports in 2025—stand to gain the most from reducing their exposure to volatile global markets.



Passive solutions allow India to turn these big-picture strategic goals into immediate, real-world savings at the street level. Every single rupee invested in reflective cool roofs saves multiple rupees by cutting down peak electricity demands and avoiding heat-related medical costs. When a city lowers its average outdoor temperature by even 1°C, it slashes millions of dollars from its collective power bill and helps shrink the national trade deficit.





Anand Mahindra praises Jodhpur's Net Zero Cooling Shelter built for extreme heat relief. Courtesy: https://economictimes.indiatimes.com/

Instead of burning through precious foreign exchange reserves to buy emergency fuel during an international shipping crisis, these municipal investments stay entirely at home. By funding passive cooling, we build a resilient domestic industry, from the local manufacturing of solar-reflective coatings to immediate jobs for application crews right in our urban settlements. This simple shift transforms a severe climate threat into a local economic engine, ensuring our cities are no longer held hostage by global conflicts.

Building Climate-Resilient Cities by Law

To turn these insights into a lived reality, India's urban governance must mirror the institutional push advocated by global climate frameworks. We must bridge the gap between energy security and municipal execution through four decisive pillars:

a. **Bylaw Re-engineering**: We must move passive cooling out of voluntary 'green building' brochures and mandate it directly into municipal building codes for all affordable and public housing projects.
b. **Blue Infrastructure as Heat Sinks**: We need to reclaim and restore urban wetlands, ponds, and historic stepwells *(baolis)*. These water bodies act as natural, localized climate regulators that cool down intense urban heat zones.
c. **District Cooling Grids**: We should treat cooling as a centralized public utility in upcoming smart-city projects. This will drastically cut overall energy demands compared to individual, power-hungry air conditioning units.
d. **Cross-Sectoral Accountability**: We must establish a unified governance framework where municipal corporations, health departments, and urban development ministries are jointly held accountable for meeting specific, safe thermal targets.

Keeping our citizens safe from extreme heat is no longer just a moral duty, it is becoming a matter of international law. As Vanuatu's Climate Change Minister, Ralph Regenvanu, recently highlighted, the International Court of Justice (ICJ) has made it clear that nations have a legal obligation to prevent climate harm. Providing passive, off-grid cooling to vulnerable communities is a direct way for India to meet this global standard. It changes urban survival from a matter of charity into a guaranteed human right.

To achieve this, India must stop treating urban climate strategies as optional 'green' choices and turn them into strict municipal laws. We must bridge the gap between global legal duties and real-world city planning. Furthermore, this critical legal reality took centre stage globally at the 13th Session of the World Urban Forum (WUF13) in Baku, where UN Secretary-General António Guterres declared that providing safe, climate-resilient housing is a fundamental human right. At the same time, the UN Environment Programme (UNEP) specifically called for integrated heat-risk governance to combat worsening urban temperatures.

A National Blueprint for Cooler Cities

Modern urban planning cannot happen in isolation. Forward-thinking laws, global energy awareness, and simple science prove that cooling our cities is no longer a luxury or an afterthought. It is a national necessity. This need is made even more urgent by the rise of risky, desperate global technology experiments. As revealed in a May 2026 report by *Politico*, a private company has just unveiled a secret plan to spray millions of tonnes of tiny, sunlight-reflecting dust into the sky to artificially dim the sun. This kind of corporate engineering treats our entire atmosphere like an unproven laboratory, risking unknown damage to nature.

On the other hand, turning natural, non-electric cooling methods into mandatory city building laws offers a safe, democratic approach. We do not need to gamble with the sky to save our cities and we simply need to change how our buildings absorb heat right where our citizens live.

As international energy crises reshape the global economy, India has a historic window of opportunity to break its dependence on unstable foreign fuels. Shifting to natural, off-grid cooling is no longer just a green ideal. It has become a matter of national security, public health, and climate justice for every single citizen.

Zero-AC Public Heat Hubs

Moving from big city policies to immediate, life-saving action requires more than just legal rules; it demands genuine human empathy. Millions of frontline workers—like delivery riders, street vendors, and manual labourers, cannot simply choose to 'stay indoors' during a severe heatwave. For them, heat protection must be available right now on the very streets where they work. To bridge this gap, municipal corporations must treat cooling as a mandatory public utility, turning ordinary roadside waiting zones into highly engineered, zero-electricity recovery points.

A brilliant real-world example of this strategy took centre stage in May 2026 with the success of the Jodhpur Net-Zero Cooling Shelter. Built as a pioneering grassroots initiative under the city's Heat Action Plan alongside local municipal authorities, this simple public shelter dropped indoor temperatures by a staggering 8°C compared to the scorching 48°C desert heatwaves outside, all without using a single watt of active air conditioning.

The shelter works naturally by following a simple four-phase cooling cycle:

Phase 1: *Blocking the Sun*: Solar panels completely cover the roof. Instead of letting the harsh sun bake the building, these panels capture the solar energy and use it to power small exhaust fans, completely shielding the shelter's shell from direct heat.

Phase 2: *Catching the Breeze*: Built-in wind towers on the roof naturally catch the hotter air moving above the street level. The towers channel this air downward into the room, using natural wind pressure instead of heavy, power-hungry mechanical compressors.

Phase 3: *Natural Chilling*: The captured air is pushed downward through thick, traditional *khus* (vetiver) root screens that are kept damp by a small solar misting system. The hot air naturally drops its temperature as it evaporates the water, instantly sending a chilled breeze indoors while filtering out street dust.

Phase 4: *Locking in the Cool Air*: The inside walls are lined with traditional lime-plaster *(surkhi)* and local stone that naturally absorb humidity. At the same time, solar fans at the highest points of the ceiling continuously vent out the rising hot air, keeping the internal atmosphere stable and fresh.



This achievement caught the attention of prominent industrial leaders and urban planners alike. Business leader Anand Mahindra publicly praised the project, noting that its true driving force was not complex technology, but fundamental human empathy.

Holding up to 45 people at a time, the shelter acts as a critical public health relief hub, offering cold water, oral rehydration solutions (ORS), and quick first aid for heat exhaustion. For a delivery worker stepping off the melting asphalt, a short 15-minute rest inside this shelter serves as a literal lifesaver, helping the body cool down and preventing dangerous heat stroke. By weaving these net-zero public hubs into dense city intersections, urban planning returns to its truest purpose: protecting vulnerable human lives right where they work.

The severe heatwaves of 2026 show that relying on power-hungry air conditioning is a dangerous trap. When international conflicts block fuel shipping lines, running ACs becomes an expensive luxury we cannot guarantee. India must stop just managing emergencies. We need to cut ties with unstable foreign oil and gas to protect our cities.

Simple, low-cost successes like Jodhpur's zero-AC cooling shelters and reflective cool roofs prove we can save lives completely off the power grid. Making these natural cooling methods mandatory by law changes urban survival from a choice into a matter of national security, public health, and true fairness for every citizen. ■

Dr Anil Pratap Singh, General Secretary & Founder Director, Global Science Academy (GSA), Basti, Uttar Pradesh and Host, "Green Talk with Anil Pratap Singh" & UP State Head, Munsif TV.

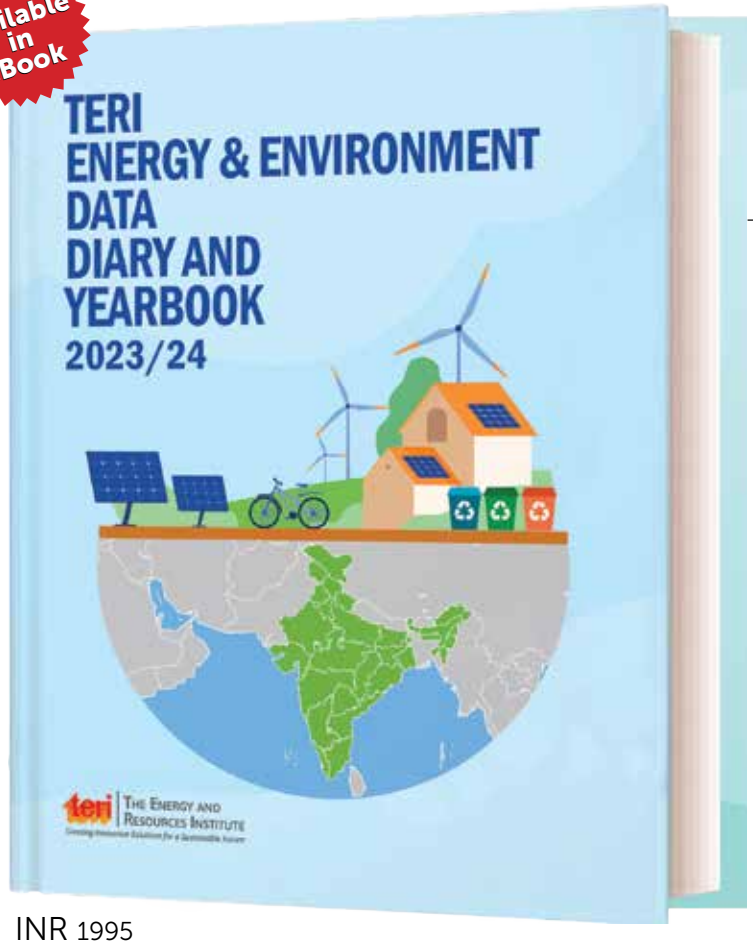
The Most Comprehensive Annual Data Diary and Yearbook on

India's Energy Sector and its Impact on Environment

Available in eBook

Order Now & Save

30% on eBook



INR 1995

- TEDDY is an annual publication brought out by The Energy and Resources Institute (TERI) since 1986, which presents latest information on energy supply, energy demand, and environment.
- It seeks to support policy research and decision-making by providing policymakers and researchers with the facts and data which can further be used to develop actionable solutions warranted by rigorous analysis.
- Each edition of TEDDY contains India's commercial energy balances that provide comprehensive information on energy flows within different sectors in the economy.

- *Institutional orders limited to 10 copies*
- *Special e-package for corporate users*

Web: http://teriin.org/projects/teddy

Place your order at teripress@teri.res.in

teri

Nanoparticle Waste Pollution

Irresponsible Dumping, Risk factors, Ecological and Human Impact

Philip John recounts his research journey in nanomedicine, focusing on metal nanoparticles synthesized from marine seaweeds and their therapeutic promise. While evaluating their efficacy, toxicity, and biocompatibility across cellular systems, he became concerned about the overlooked issue of nanoparticle waste and nanotoxicity. He highlights the invisible irreversible environmental and human health risks arising from improper disposal and accumulation. Drawing on his findings, the author stresses the urgent need for rigorous, long-term studies, clinical validation, and robust nanowaste management protocols, warning that scientific advances without such safeguards risk becoming irresponsible and unsustainable.

The life of a research scholar unfolds in a high-pressure, demanding environment, often portrayed as that of a "gentleman learner" navigating a chaotic landscape. My research in nanomedicine—particularly examining nanoparticles derived and synthesized from marine seaweeds and their impact on human health and disease pathology—did not merely culminate in a reflective conclusion. It also opened the door to a new area of inquiry that many researchers and scientists have been hesitant to address: the subject of nanotoxicity. I chose to focus on this overlooked, bifurcated, and inherently dichotomous dimension—an unexpected yet compelling trajectory in my research journey.

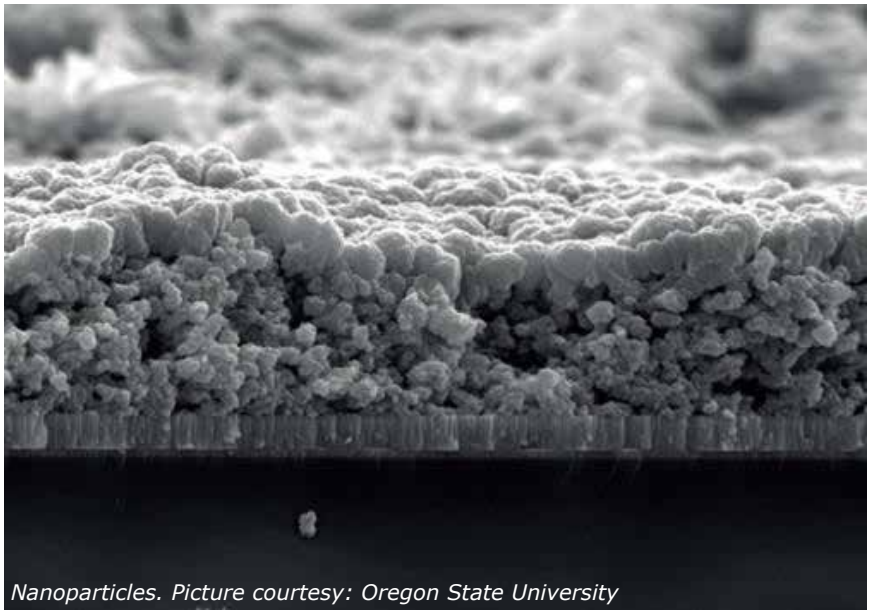
My ultimate concern was, is and will always be about the unanswered question of dumping of synthesized nanoparticles once the work is finished. How it will affect the environmental atmosphere and human life. We may not see its dumped physical form as we see mega landfills or macro level garbage dumps. Nanotoxicity caused by nanopollution is invisible to the naked eye, and, as the proverb suggests, the devil's finest trick is to persuade us that it does not exist. Yet, nanotoxicity is very real, and over time it may become an irreversible threat—hazardous and potentially infectious to both the environment and human health, regardless of the route of its synthesis (physical, chemical, or biological).


Picture courtesy: Emoody26

During my research journey, I became an engaged observer in the fascinating world of natural seaweeds and a quiet spectator in the realm of human-synthesized nanoparticles. Let us explore each category both briefly and in depth, as my research focused on evaluating the potency and efficiency of metal nanoparticles—often termed "magic bullets"—derived from therapeutically active seaweeds. The study also examined their toxicity,

therapeutic potential, and host cellular biocompatibility in both prokaryotic and eukaryotic cells. Just as certain seaweeds possess inherent therapeutic properties, some nanoparticles too exhibit significant bioactivity. In this context, it becomes important to understand their origin and evolution, while also drawing attention to the emerging issue of nanoparticle pollution, the lack of adequate nanowaste management systems, and the potential repercussions these pose for both public health and the environment.

The prefix 'nano' refers to a Greek prefix meaning 'dwarf' and depicts one thousand millionth of a metre (10–9 m). A nanoparticle is usually defined as a particle measuring between 1–100 nanometres (nm) in diameter even smaller than the visible light wavelength (400–700 nm), and demands the use of electron microscope. The development and growth of nanoscience especially "nanoparticles" can be traced to the ancient times (4th–5th century BC) of the Greeks, Romans and Democritus era, when inquisitive persons were tackling the billion-dollar gold question of whether the so called 'matter' is continuous, or whether infinitely split into smaller pieces, or composed of small indestructible particles. The



Nanoparticles. Picture courtesy: Oregon State University

Lycurgus cup, (British Museum collection) illustrates as one of the most outstanding achievements in ancient glass industry since it is the oldest famous example of dichroic glass and is recognized as one of the oldest synthetic nanomaterials. A similar colour effect is demonstrated in late medieval church windows, shining and illustrating a luminous red and yellow colour due to the fusion of gold and silver nanoparticles into the glass. During 1970–1980, researchers used the term "ultrafine particles" while referring to nanoparticles. However,



during the 1990s, the term "nanoparticle" had become more common in public domain. The nanoparticles are generally classified into the organic (dendrimers, micelles, liposomes and ferritin), inorganic (metal and metal oxide based) and carbon based and nanoparticles are manufactured by either physical, chemical or biological templates such as plants, microbes, seaweeds, etc.

The European Technology platform on Nanomedicine (ETPN) proposed the term "Nanomedicine" as: "The application of nanotechnology to achieve success in healthcare industries that exploits the improved and primarily novel physical, chemical and biological properties of materials at the nanoscale level." The European Medicines Agency (EMA) refers to nanomedicine as "a system designed for clinical applications that is composed of at least one nanoscale component, resulting in specific beneficial characteristics like better targeting and bioavailability of therapeutics, novel ways of therapeutic action, and nanostructured surfaces and scaffolds for engineered tissues." However, the core idea of nanomedicine—to generate a therapeutic effect specifically in the target organ—is not new in the present time. Almost a century ago,



Paul Ehrlich proposed the concept of "magic bullet"—an entity able to recognize a precise target and provide a therapeutic action in the concerned particular target. A selected tissue, cell type, or disease marker is often the main target in nanotherapy. At present, the concept of magic bullet includes combination behaviour of three constituents: (a) drug; (b) targeting moiety; and (c) pharmaceutical carrier. Nanomedicine presents good advantages over conventional therapies. These advantages include the extremely small size of nanomaterials or nanoparticles used in nanomedicine, which results in a large surface-to-volume ratio. This property is highly beneficial for fine-tuning the surface characteristics of nanomaterials. Their lipophilic or hydrophilic nature can be readily encapsulated within various nanosystems or nanocompartments, thereby enabling effective dosing that is often not achievable in traditional therapies due to solubility limitations.

Moreover, nanoparticles can protect encapsulated active agents from antagonistic external environments, modify the pharmacokinetics of active compounds, and enable controlled release. This leads to reduced dosing frequency and prolonged therapeutic activity. Additionally, they can be directed to specific target sites, thereby enhancing localized therapeutic efficacy while minimizing unwanted side effects.

As described before, in my research work, I synthesized metal nanoparticles from beautiful marine seaweeds. Let the readers know and dive into the world of marine seaweeds first.

Seaweed is commonly the name for the numerous macroscopic, multicellular species of macroalgae found mainly in and around marine regions all around the world. They are broadly classified into either Rhodophyta (red), Phaeophyta (brown), and Chlorophyta (green colour) macroalgae. They have a pivotal role in Mother Nature including many scientific breakthroughs and even contributing in producing more than 50 per cent of earth's oxygen and also becoming a fantastic sanctuary for the marine creatures. Due to their significant role in marine ecologies and their capacity in absorbing carbon dioxide, recent development and attention has been on cultivating and conserving seaweeds since it can act as a powerful and potential climate change mitigation strategy for biosequestration of carbon dioxide gas. Other associated benefits include reduction in nutrient pollution, expansion of habitats for coastal aquatic species, and particularly depletion in local ocean acidification. The Intergovernmental Panel on Climate Change (IPCC) special report on the Ocean and Cryosphere in a Changing Climate recommends and encourages further such meaningful mitigation tactics and plans.

Seaweeds occupy a wide range of ecological niches. Some of the deepest-living species are red macroalgae, while others have adapted to thrive in tidal rock pools. Seaweeds are also rich in dietary fibre, with total fibre content ranging from about 10–75 per cent in brown seaweeds, 10–59 per cent in red seaweeds, and 29–67 per cent in green seaweeds. Seaweeds contain particularly soluble dietary fibre ranging from 26–38 per cent, 9–37 per cent, and 17–24 per cent in brown, red, and green species, respectively. Edible seaweed contains 33–62 per cent fibre on a dry-weight basis—significantly higher than in most higher plants—and these fibres consist largely of soluble fractions.

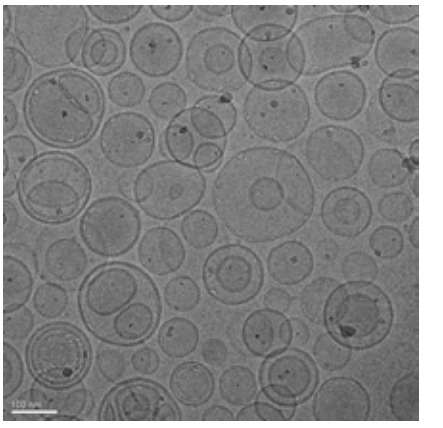
The total protein content in brown, green and red algae ranges from 1–24 per cent, 4–44 per cent and 5–50 per cent of the dry weight, respectively, which varies from species to species depending upon the geographic habitat whereas lipid concentration in seaweed ranges from 0.4 per cent to 5 per cent dry weight, with abundant saturated fatty acids (SFA) and palmitic acid in majority species. Seaweed species are rich in diverse amount of specific bioactive compounds such as total polysaccharides, agar, algins/ alginic acid/ alginates, total protein, lectins, phycobilliproteins, taurine, kanoids (kainic and domoic acid), PUFA (omega-3 fatty acids), phlorotannins, carotenoids, iodine, calcium, vitamin B12, vitamin C, alanine, amino butyric acid, citrulline, hydroxyproline, laminarin, fucoidans, sulphated galactofucans, Floridian starch, carrageenans, xylans, sulphated galactans, sulphated rhamnose, fucoxanthin and ulvans, etc. The secondary metabolites of seaweeds

have high diversity range as compared to those present in the leaves of higher plants. Isoprenoids (e.g., terpenes, carotenoids, steroids), polyketides (e.g., phlorotannins), amino-acid-derived natural products (e.g., alkaloids), and shikimates (e.g., flavonoids) are the major groups of secondary metabolites found in macroalgae. The above mentioned bioactive compounds and secondary metabolites have magnificent therapeutic potentials and are valued for their anticancer, antioxidant, antihypertensive, anticoagulant, antidiabetic, antiobesity, anti-inflammatory, antimicrobial, antiviral, antiulcer, antiangiogenic, immunomodulatory, hepatoprotective activities, wound healing, and neuroprotective activities. Therefore, edible seaweeds can be taken as food supplements in daily intake and also they are positively valuable for gut microbiome. In today's scenario, seaweed can be used in wastewater treatments, domestic sewage treatment, and maintaining the marine food chain efficiently.

Several researches have been done separately over the therapeutic effects of both pristine and functionalized nanoparticles over various diseases. Well, out of my curiosity in my research work I wanted to test the potency and efficiency of metal nanoparticles (magic bullets) generated from potent and therapeutically efficient seaweeds and study its toxicity, therapeutic effects and host cellular biocompatibility testing on both prokaryote and eukaryote cells both *in vitro* and *in vivo* conditions. Those comparative and oxymoron results and empherical research made a profound reflection on my own acts. Here, what I understood is, initial results may be encouraging but how long it will be effective in the long run. The term 'nanotoxicity' depends heavily on nanoparticle concentration (including cellular uptake and excretion), as well as on nanoparticle degradation and erosion. It is particularly influenced by the release and disposal of nanoparticles from laboratories, whether occurring once or multiple times, and regardless of whether the particles are in pristine, functionalized, or composite forms.

Wide population sampling, multilevel clinical trials and foremost, long and extended time frame study is crucial and emergency call for effective clinical trials rather than believing in small-scale pilot studies when it comes to nanoparticle clinical studies. Anyhow in case of metal nanoparticles usage in human body, the complete absorption is not possible in every case and a very small portion will be eliminated from the body increasing the toxic condition known as "tissue accumulation" and even after dispersion and erosion into the external natural environment, how nanoparticles and





natural components will interact with each other negatively paving their way to interfere in the biogeochemical cycle and food chain process of nature over the course of time. What will be its time bounded and unbounded repercussions? Well, the case of organic and biodegradable nanoparticles is a totally different matter because they do not pose a serious threat to nature as the former (MNPs) do—at least not to the same extent (even though studies on their biodegradability are still in the queue and mainly limited to short-duration, pilot-level research).

According to my conclusion, however much the scientific community tries to produce nanoparticles in whatever form, if there is no clear understanding or serious protocol regarding waste management and biodegradation systems for certain nanoparticles, all such scientific nano-experiments are useless and simply meant for time-pass or blind publications (a form of mental myopia). As the saying goes, "one has to build the shed first before buying the buffalo."

There is genuine research in nanotoxicology that has repeatedly warned and highlighted the need for a proper nanowaste management system, but do we follow it in practice, and whom do we rely on? ■

Philip John is a PhD research scholar, author, science communicator and an international conference best paper awardee and his research interests include biomedical research, clinical research, and environmental sustainability.

Reaping the Easy Gains

Why India's Agroforestry Policy Deserves More Attention

In this article, **Vijayalakshmi K P** and **Harshel Suares** highlight the significance of agroforestry as a practical and scalable solution to India's environmental and developmental challenges. They discuss how traditional practices, strengthened by the National Agroforestry Policy (2014), can enhance productivity, livelihoods, and ecological resilience. The article emphasizes agroforestry's role in climate mitigation, land restoration, and meeting national and global commitments. It also examines initiatives like GROW that use geospatial tools to identify suitable areas for expansion. While outlining existing policy and scientific support, the authors draw attention to persistent challenges such as regulatory barriers and market constraints, underscoring the need for coordinated reforms to realize its full potential.

Agroforestry—the intentional integration of trees with crops and/or livestock—is both an age-old tradition and a modern solution to some of India's most pressing challenges. Long before sustainability became a global priority, Indian farmers were practicing diverse agroforestry systems such as home gardens, shifting cultivation, and silvi-pastoral models. These systems ensured a steady supply of essentials such as food, fodder, fuel, fibre, fruits and organic manure, while maintaining ecological balance. The strength of agroforestry lies in the natural interactions among its components, which improve soil fertility, enhance biodiversity, and stabilize productivity over time.

Building on this strong traditional foundation, India made a historic move by becoming the first country in the world to introduce a dedicated National Agroforestry Policy (NAP) in 2014. This policy recognizes agroforestry as a key strategy for sustainable land use and rural development. It aims to enhance farm productivity, improve profitability and promote environmental sustainability by integrating trees into agricultural landscapes. Importantly, the policy aligns with broader national priorities, including increasing forest and tree cover to 33 per cent, strengthening food and nutritional security, and contributing to climate goals such as achieving net-zero emissions by 2070. In many respects, agroforestry represents a "low-hanging fruit"—a solution that offers quick, cost-effective gains while delivering long-term benefits.



In the current era of climate uncertainty and resource scarcity, agroforestry is increasingly viewed as a powerful nature-based approach. It addresses multiple challenges simultaneously—ranging from food and energy security to environmental conservation and employment generation. By combining trees with crops and livestock, farmers can diversify their income sources and reduce risks associated with climate variability. Trees play a crucial role in improving microclimates, conserving soil moisture and reducing erosion, thereby enhancing the resilience of farming systems. At the same time, agroforestry contributes to



climate change mitigation by capturing and storing carbon in biomass and soils.

The relevance of agroforestry extends beyond national boundaries, as it supports several global commitments. It contributes directly to the Nationally Determined Contributions (NDCs) under the Paris Agreement, the Bonn Challenge for land restoration, the United Nations Sustainable Development Goals (SDGs), and the United Nations Convention to Combat Desertification (UNCCD). Within India, it is closely linked to initiatives such as the Green India Mission, the National Action Plan on Climate Change, and the vision of Atmanirbhar Bharat. The growing importance of agroforestry was also highlighted in the Union Budget (2022–23), which emphasized promoting agroforestry and private forestry to enhance farmer incomes and restore degraded landscapes.

Scientific and institutional support has played a critical role in advancing agroforestry in India. Organizations like the Indian Council of Agricultural Research have developed region-specific models that demonstrate how agroforestry can be both economically viable and environmentally beneficial. These efforts have helped bridge the gap between traditional knowledge and modern science, enabling farmers to adopt improved practices suited to their local conditions.

Despite these advancements, India faces significant challenges related to land use and natural resource management. The country's large and growing population places immense pressure on land, leading to declining per capita availability. Rapid urbanization, deforestation and unsustainable agricultural practices have further contributed to land degradation. A substantial portion of India's land is now degraded, and millions of hectares are classified as wastelands. These trends threaten not only environmental health but also the livelihoods of millions of farmers who depend on land for survival.

Transforming these degraded and underutilized lands into productive systems is essential for sustainable development, and agroforestry offers a practical pathway to achieve this. By integrating trees into these landscapes, it is possible to restore soil fertility, improve water retention and generate additional income streams. Recognizing this potential, a major initiative known as GROW (Greening and Restoration of Wastelands with Agroforestry) has been undertaken under the guidance of NITI Aayog. This initiative uses advanced geospatial technologies such as remote sensing and Geographic Information Systems (GIS) to identify and prioritize wastelands suitable for agroforestry

interventions.

The findings of this initiative highlight the immense scope for expansion. Large areas across the country have been identified as highly or moderately suitable for agroforestry, particularly in states such as Rajasthan, Madhya Pradesh, and Maharashtra. Such scientific mapping enables targeted planning, ensuring that resources are directed to areas where they can have the greatest impact. The use of digital platforms has further enhanced accessibility, allowing policymakers, researchers and practitioners to analyze data and design location-specific interventions.

At present, agroforestry already covers a significant portion of India's land area, but there is still vast untapped potential. Expanding agroforestry into degraded lands can play a crucial role in achieving national targets such as restoring millions of hectares of land and creating additional carbon sinks. It also offers opportunities for improving rural livelihoods by generating employment and providing diversified income sources. In this way, agroforestry contributes not only to environmental sustainability but also to economic growth and social well-being.

However, the widespread adoption of agroforestry is not without challenges. Farmers often face regulatory barriers related to tree harvesting, transportation, and marketing. Inconsistent policies across states create confusion and discourage investment in tree-based systems. Market infrastructure for agroforestry products is still developing and price fluctuations can affect profitability. Additionally, the long gestation period of certain tree species may deter small and marginal farmers who require quicker returns.

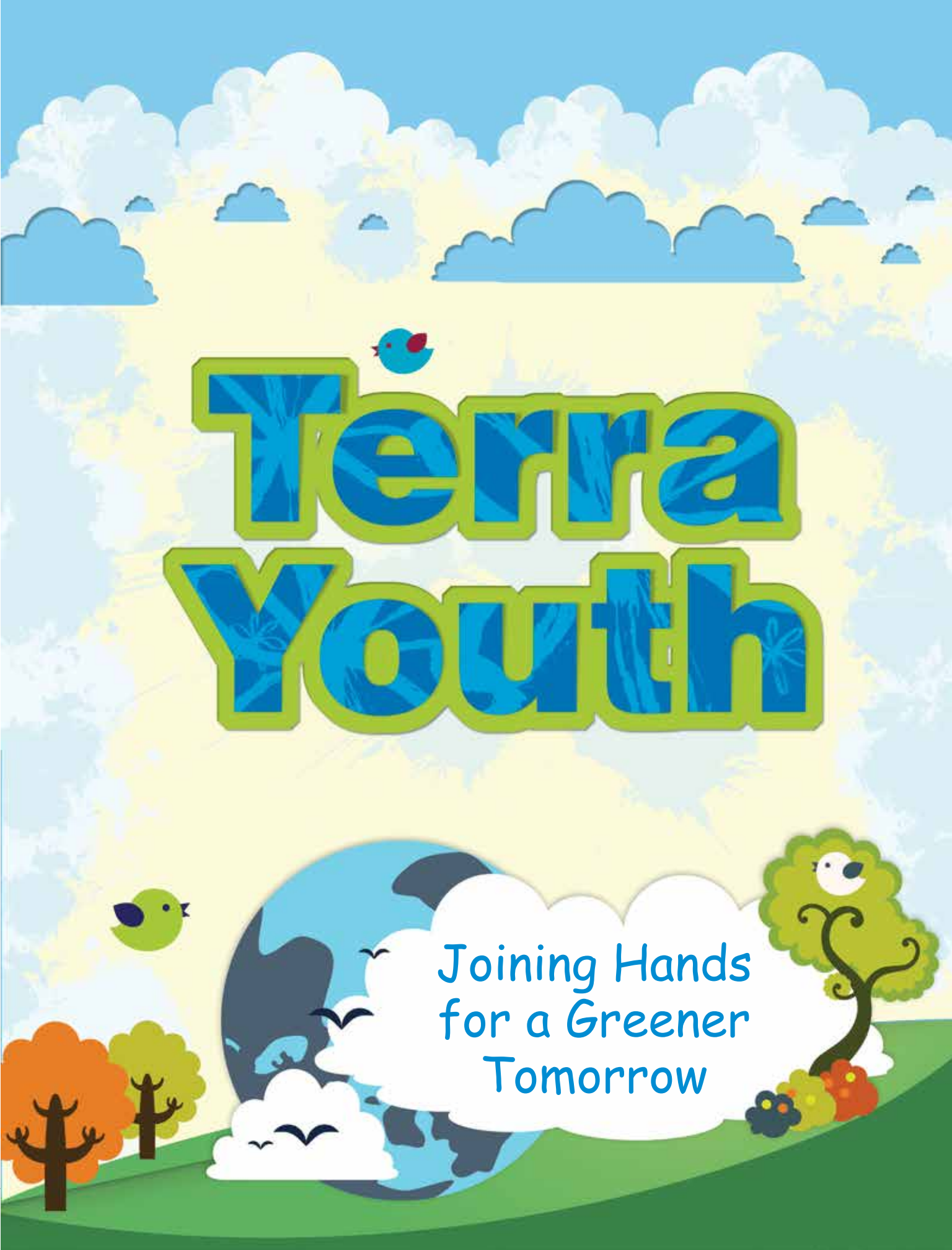
Addressing these challenges requires a coordinated approach involving policy reforms, institutional support, and capacity building. Simplifying regulations, improving market access and providing financial incentives can encourage farmers to adopt agroforestry on a larger scale. Strengthening extension services and promoting awareness about the benefits of agroforestry are equally important. By creating an enabling environment, it is possible to unlock the full potential of agroforestry as a transformative land-use system.



In conclusion, agroforestry stands out as a practical, efficient and scalable solution to many of India's development challenges. It bridges the gap between agriculture and forestry, offering a holistic approach to land management that delivers economic, environmental, and social benefits. The National Agroforestry Policy (2014) has provided a strong foundation, but greater attention and action are needed to translate its vision into reality. With increasing pressures from climate change, land degradation and population growth, the need for sustainable land-use systems has never been more urgent. Agroforestry, with its proven benefits and wide applicability, holds the key to building resilient landscapes and securing a sustainable future. It is not merely an option—it is one of the easiest and most effective pathways to achieve inclusive and sustainable growth in India. ■



Vijayalakshmi K P, Assistant Professor, College of Forestry, Department of Silviculture and Agroforestry, Ponnampet, Karnataka and Harshel Suares, Assistant Professor, College of Agricultural Sciences, Department of Forest Resource Management, Iruvakki, Karnataka.


Terra Youth
Joining Hands for a Greener Tomorrow

Crisis or Catalyst for Change?

From Turmoil to Transformation

The article by **Anaiya Giare** examines how war, particularly the Iran–Israel conflict, has unintentionally accelerated a shift towards sustainable packaging. Disruptions in oil supply and rising costs of petrochemicals have forced industries to reconsider reliance on virgin plastics. Companies are increasingly adopting recycled materials, paper-based alternatives, and minimalist designs to cut costs and reduce environmental impact. Supply chain instability has also encouraged localized production, lowering carbon footprints. However, sustainability gains remain uneven, as economic pressures can lead to lower-quality materials. Ultimately, the piece highlights how crisis-driven compulsion—not voluntary responsibility—has spurred environmental progress.

War leads to humanitarian crisis, war leads to displacement, war leads to loss of life… Recently, war has led to an unprecedented impact, a push towards sustainability. While this is unfortunate, that something as destructive as war has triggered this, the shock in the supply chain still feels like a small win for the planet. The recent Iran War has had ripple effects beyond geopolitics: shortages and price spikes in plastic- and petrochemical-based materials have led to shifts in packaging.

The plastic we use in our daily lives is heavily dependent on fossil fuels. Raw materials used in plastic packaging, such as ethylene and propylene, are primarily derived from oil and natural gas. When war disrupts energy production or trade routes, the consequences are immediate. The supply shortages lead to industries dependent on these materials being forced to adapt. The recent conflicts have led to instability in the oil markets, and the restrictions on exports have increased the cost of production of virgin plastic significantly. This makes it less accessible and economically viable for many companies, leading to a notable shift towards alternative packaging materials.

One of the most significant changes by these producers is the switch towards recycled plastics. The use of recycled polyethene terephthalate, for example, has allowed companies to reuse existing materials rather than having to rely on newly produced fossil fuel-based plastics. This not only reduces their environmental



impact but also their dependence on the fluctuating and unstable global energy markets. An aim that should have been driven by sustainability has now occurred as a response to resource scarcity.

At the same time, there has been a strong resurgence in paper-based plastic worldwide. Materials such as molded pulp, cardboard, and biodegradable fibres are being used widely across industries. These materials are easier to source locally, and since they are comparatively less affected by fluctuations in the price of oil and gas, they are a more suitable option for multiple producers. This has led to companies shifting to these materials in uncertain times, also demonstrating environmental benefits.

It is astonishing to see how actions that should have been taken as a part of voluntary corporate social responsibility, and to reduce the impact producers have on the environment, are now being forced onto producers due to unforeseen circumstances and challenges. Another example of the same is the simplification of packaging design. As raw materials become more and more expensive, companies are rethinking the amount of packaging that is truly required. Extra layers, unnecessary plastic wraps and overly complex designs, things that were never a priority to companies as long as they did not increase costs significantly and attracted consumers, are now being reevaluated. Lightweight packaging has become a priority for many producers, since it uses fewer materials and even reduces their transportation costs, a vital factor when fuel prices are high. Minimalism, which was once a branding choice and encouraged for the motive of sustainability, is not being driven by supply constraints and goals of cost efficiency.

Moreover, war has disrupted shipping routes, increased insurance costs and created huge delays in international trade. These impacts on global logistics have been significantly affected, and the spillover is prompting businesses



to rethink their supply chains. The shift from global sourcing towards localized production leads to companies sourcing materials closer to home. This reduces their exposure to international disruptions while simultaneously reducing their carbon footprint, reinforcing the move towards more sustainable packaging.

To add to that, supporting government policies also plays an important role in accelerating these changes. Whether it is a response to environmental concerns or to supply chain instability, many countries have strengthened regulations around packaging waste and recycling. Even regions that are not directly affected by conflict have seen multinational companies adapting their packaging to meet stricter global standards. War, when it comes to packaging, has acted as a catalyst that sped up regulatory as well as industrial transitions.

However, at the same time, it is necessary to know that not all the impacts are positive. In a few cases, when companies face economic strain, they may opt for cheaper and lower-quality materials that tend to be non-biodegradable and hard to recycle. Furthermore, plastic packaging is essential in humanitarian aid operations and military operations, since it is durable, flexible and usable for long periods of time. These limitations of sustainability in times of crisis show the side that many are overlooking.

Lastly, rising inflation, party driven by the war, has also made consumers more price sensitive. The cost-push inflation has, in some cases, forced companies to find solutions that are both environmentally conscious and also cheap. Reducing packaging as a solution acts as a solution to both the problems, achieving goals such as reducing production costs while minimizing environmental impact.

In conclusion, conflicts such as the Iran–Israel conflict have indirectly stimulated a transition towards sustainable packaging by disrupting the flow of multiple plastic-dependent systems. The shortage of petrochemical materials and a rise in energy costs have forced industries to take action. I believe that it is extremely unfortunate that such progress is rooted in crisis, since it highlights how we only act when there is external pressure, and not when the planet needs it. ■

Anaiya Giare is a Grade 12 student at the Shri Ram School, Moulsari, Gurgaon. She has been a passionate environmental activist since she was in Grade 6.

Bizarre Facts

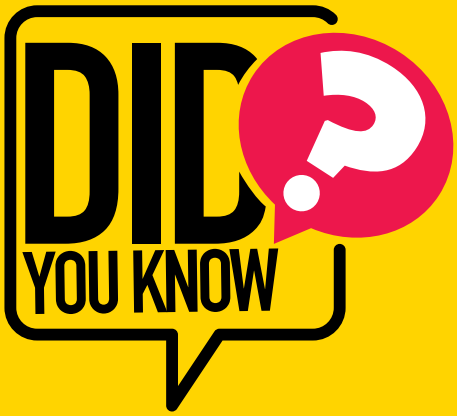


1. Mudskippers walk on land.
2. Air pollution can travel across continents.
3. Only 1 per cent of Earth's water is usable for humans.
4. Wood frogs can survive with ice inside their bodies by producing natural antifreeze chemicals.
5. A single lightning bolt is hotter than the Sun's surface.
6. Sea cucumbers fight with their internal organs.
7. Crows remember human faces for years.
8. Axolotl can regenerate limbs, spinal cord, parts of its brain, and even sections of its heart.
9. Some ants explode themselves to defend their colony.
10. Wombats produce cube-shaped poop.



Did You Know?

- Coral reefs support about a quarter of marine life.
- Soil is one of the richest habitats on Earth. A teaspoon can contain more microbes than there are people on the planet.
- The Amazon rainforest produces a massive share of oxygen.
- Plastic is the most common ocean pollutant.
- Earth's oxygen mostly comes from the ocean. Tiny marine organisms called phytoplankton produce over half of the oxygen we breathe.
- Rising carbon dioxide can increase plant growth temporarily, but it also disrupts ecosystems, rainfall patterns, and biodiversity.
- Sloths can hold their breath longer than dolphins.
- The pistol shrimp is one of the loudest animals on Earth.
- Certain tarantulas tolerate frogs that eat ants threatening their eggs — a bizarre mutual partnership.



Source: Internet

SOS Children's Villages India

Protecting Vulnerable Children from Climate Impacts through Care

Established in 1964, SOS Children's Villages India provides children without parental care or at the risk of losing it a value chain of quality care services that goes beyond childcare alone, ensuring comprehensive child development. Their customized care interventions, such as Family Like Care, Family Strengthening, Kinship Care, Short Stay Homes, Foster Care, Youth Skilling, Emergency Childcare, and Special Needs Childcare are aimed at transforming lives and enabling children under our care into self-reliant and contributing members of society.

Climate change is creating a wider gap for children lacking parental care by stripping away their stability and opportunities, putting them at risk of disruption in education and outdoor activities. Extreme temperatures and unpredictable weather disrupt their daily routines, making those already at risk even more vulnerable to the loss of a secure environment, notes Mr Sumanta Kar, CEO, SOS Children's Villages India.



SOS Children's Villages India has observed a significant rise in heatwaves and unpredictable rainfall, which directly impacts children's mental health and physical well-being. These natural calamities reduce their safe "play time," which is essential for their social development and friendship-building.

The most immediate challenge is the disruption of "holistic development" due to extreme heat and weather shifts. Children are losing access to the outdoors, sports, and educational tours, which are vital for their growth beyond the classroom. Mr Sumanta Kar, CEO, SOS Children's Villages India, says, "Environmental instability leads to frequent school closures during extreme heat or floods, directly hindering educational progress. Physically and emotionally, the lack of a stable outdoor environment prevents children from engaging in necessary social and physical activities. Climate change is no longer a distant threat; it is a current reality affecting the most vulnerable among us today. We must act now to fulfill our responsibility to the children, providing them with the safe, healthy planet they deserve to inherit."

SOS Children's Villages integrates sustainability into operations through solar panels, rainwater harvesting, and sewage treatment plants. Practical solutions like water ATMs and ecobricks are implemented in the communities they work for, to manage waste and conserve resources effectively. Children within SOS Children's Villages are encouraged to pursue formal education in Environmental Science to build long-term expertise. Daily life in the village also involves hands-on participation in plantation drives and learning the optimal use of water, air, and forest resources.

Earth Day 2026 theme, "Our Power, Our Planet," represents a dual responsibility. Elders must ensure they pass on a safe planet that children rightfully deserve, while children are empowered to understand their duties in protecting it. It is about recognizing that the planet is their inheritance. While initiatives are being taken through government and NGO efforts, the gap lies in understanding that this is a global movement. There is a need to establish robust reporting and response mechanisms to identify and support children specifically affected by climate risks. Collaboration should focus on both immediate crisis preparedness and long-term corrective solutions for displaced or affected youth. Looking ahead, the priority is to institutionalize climate preparedness across all locations, ensuring children are protected from calamities, while continuing to scale green infrastructure. It is a collective responsibility to protect our planet so that we can give a safe and better future to the generations coming after us. ■

For more information, please visit: www.soschildrensvillages.in or contact: christo.shajan@soscvindia.org.

Digital Platforms

Helping Indians Take Action for the Environment

Digital platforms are increasingly empowering Indians to move from environmental awareness to active participation. Driven by citizen science, users are contributing vast amounts of biodiversity data through initiatives like bio-blitzes and mapping, supporting thousands of global studies. In India, platforms such as WeNaturalists, iNaturalist, Pl@ntNet, iNaturewatch Birds, and ObsIdentify enable individuals to document species, engage communities, and connect with experts. These tools are transforming everyday interactions with nature into meaningful contributions to research and conservation. As climate challenges grow, such platforms are becoming vital infrastructure, bridging local knowledge with policy action and shaping a more participatory, data-driven approach to environmental stewardship.

India's environmental challenges are intensifying but so is citizen participation, with digital platforms playing a crucial role in turning everyday users into active environmental contributors. The rise of citizen science is at the heart of this shift, as thousands of Indians now engage in biodiversity mapping and bio-blitz initiatives, contributing to global platforms that have collectively amassed over 300 million observations powering more than 7000 scientific studies. Closer home, similar initiatives have already aggregated over 1.6 million biodiversity observations and 58,000+ species records, underscoring the scale at which public participation is shaping environmental data in the country. As climate action increasingly depends on localized, community-driven insights,



these platforms are evolving beyond tools to become critical infrastructure for environmental decision-making and awareness.

WeNaturalists

WeNaturalists is a global ecosystem for nature that connects individuals, communities and experts in conservation, sustainability and ecotourism, while also providing opportunities for people to collaborate, find job opportunities, showcase their work, and support environmental initiatives.

WeNaturalists focuses on community-based action: building student-led initiatives on climate change; connecting scientists and professionals in the natural economy, etc. Programmes such as Campus Champions are helping to engage many thousands of students across India, thereby transforming digital interaction into real-world impact.

iNaturalist

Citizen science platform iNaturalist enables users worldwide to collect and share observations about plants, animals and ecosystems; these observations are then compiled into a global biodiversity database that scientists and researchers can use.

For Indian users, the iNaturalist app provides a great way to collect and record observations of the various types of biodiversity they encounter in their everyday lives, thereby helping to support conservation efforts and research about that biodiversity.

Pl@ntNet

Pl@ntNet is an application that allows individuals to upload images of plants for crowd-sourced identification and species suggestions; this provides a growing global database for interpreting biodiversity and contributing to scientific knowledge about plants. In a country such as India where the variety of plants can be overwhelming, Pl@ntNet serves as a tool to allow citizens to participate as active contributors to the documentation of the ecological community.

iNaturewatch Birds

This app for urban biodiversity was designed with India in mind and enables users to identify common birds while also collecting valuable data for climate-related ecological studies.

Involving both students and educators, it transforms birdwatching into a form of citizen science used to monitor environmental changes over time.

ObsIdentify

ObsIdentify is an Artificial Intelligence (AI) species identification tool that allows users to identify plants and animals simply by point-and-shoot photography and submit their observations to biodiversity databases.

It represents the convergence of ecology and technology to produce a valuable resource for real-time environmental engagement and action-oriented data collection.





Conclusion

The emergence of these platforms signals a larger shift from awareness to distributed, data-driven environmental action. Citizen science in India is already generating massive volumes of biodiversity data, with nationwide initiatives and challenges documenting everything from rare species to medicinal plants across ecosystems.

However, the next step lies in translating this data into impact whether through policy, conservation strategies, or sustainable livelihoods. As more Indians come online and climate urgency grows, digital platforms like these will play a defining role in shaping how individuals engage with the environment not as passive observers, but as active contributors to the planet's future.





UNESCO Warns a Tsunami in the Mediterranean is Inevitable

The Mediterranean Sea is widely perceived as having a low tsunami risk. History and recent modelling technology have demonstrated that destructive waves have already hit the French coast and could do so again. The results of a project carried out in Nice and along the French Riviera show why anticipation and preventive evacuation measures remain the only truly effective means of saving lives. Tsunamis, formerly known as tidal waves, raz-de-marée in France or maremoti in Italy, are among the most destructive natural phenomena. Triggered by earthquakes, underwater landslides or volcanic eruptions, they spread rapidly over long distances before releasing their energy near the coast in the form of sudden submersion and extremely powerful currents.

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

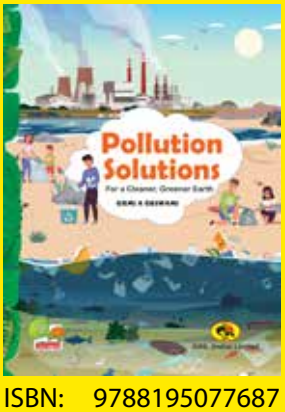
Scientists Use DNA from Poop to Save the World's Rarest Marsupial

New research from Edith Cowan University (ECU) may provide an important boost for efforts to save the world's rarest marsupial. The Gilbert's potoroo, a critically endangered species found only in Western Australia, has fewer than 150 animals left in the wild. Scientists from ECU and the Department of Biodiversity, Conservation and Attractions (DBCA) are working together to better understand what the small marsupials eat so conservation teams can identify suitable new habitats and help secure the species' future. "We are looking to recover the species through translocations, which is moving organisms from one location to another to create an insurance population in case anything was to happen in their existing populations," School of Science PhD student Rebecca Quah explains. "In doing that, one of the challenges was trying to determine what they are eating and where those resources can be found. Mycophagus—or fungi-eating mammal diets are quite hard to study because a lot of fungi remain undescribed."

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



To know more... Read



ISBN: 9788195077687

POLLUTION SOLUTIONS
FOR A CLEANER, GREENER EARTH

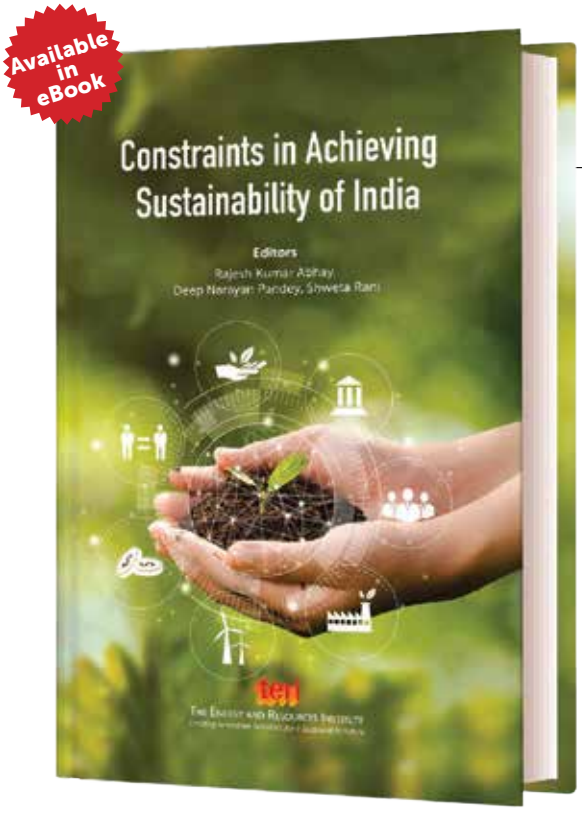
Urmi A Goswami

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.

Available at: amazon.in flipkart amazon kindle Google play teri bookstore

Study of the challenges to sustainable development via scientific means



Major topics covered

- Sustainable Development: concept, components and history
- Environment, Culture, and Sustainable Development
- Sway of Indian Cinema in Diffusing Environmental Sentience
- Poverty Lines and Poor in India
- Sanitation Workers and Associated Problems for the Sustainability of Religious Events
- Assessment of Basic Infrastructure Development and Associated Issues in India

ISBN: 9789394657120 • Price: ₹550.00

Purpose of the book is to develop, contribute, and disseminate scientific knowledge pertaining to the issues related to sustainable development. The chapters are developed so that the contents can facilitate comprehension of the major constraints in achieving sustainability including but not limited to environmental, social, economic, and governance-related issues from local, regional, to national level. Resource management, climate change, agriculture, population, education, women, poverty, infrastructure, crime, corruption, governance, are the other relevant topics that have been both identified and suitably discussed. *Constraints in Achieving Sustainability of India* can be utilized as a guiding tool for realizing sustainability in development, especially, in the Indian context.

The Energy and Resources Institute
Attn: TERI Press
Darbari Seth Block
IHC Complex, Lodhi Road
New Delhi – 110 003/India

Tel. 2468 2100 or 4150 4900
Fax: 2468 2144 or 2468 2145
India +91 • Delhi (0)11
Email: teripress@teri.res.in
Web: http://bookstore.teri.res.in

To purchase the book, visit our online bookstore at http://bookstore.teri.res.in or send us your demand draft or cheque in favour of TERI, payable at New Delhi (outstation cheques are not accepted).

The Invisible Network beneath Jangalmahal

Fungal Networks Shaping the Fate of Sal Forests

Sal forests are vital to the environment, especially in laterite regions. Can the forests of Jangalmahal in West Bengal truly regenerate on the strength of an invisible web beneath the ground? wonders **Shamim Haque Mondal**.

Can the sal forests of Jangalmahal in West Bengal truly regenerate on the strength of an invisible web beneath the ground? Research by a Canadian forest scientist, conducted on the other side of the world, is prompting that question once again. For many years, we have viewed forests merely as collections of individual trees.

The idea that a forest signifies "wood," "economy," or "government forestry projects" has long dominated this perspective. But Canadian ecologist Suzanne Simard claims that the forest is actually a much more complex living system than that. Trees are not alone; they are connected to each other through extensive networks of fungi under the soil. He popularized the concept of the "Web of Things." "We have seen the forest wrong for a long time," Simard said in an interview. Not only do plants compete, but they also interact and form relationships with each other through subterranean fungi. "According to him, through this network, plants can exchange water, nutrients, and even chemical signals. Large and old trees play an important role in this network, which he metaphorically refers to as the Mother Tree. "When we cut down forests, we're actually destroying the very organisms that help keep the Earth's climate stable," he said.



This idea initially surprised many scientists. Some have called it revolutionary, while others have criticized it as exaggerated. But whatever the controversy, one thing is clear—the relationship of plants to mycorrhizal fungi below the ground is real and plays an important role in many forest ecosystems. And here comes the question. The geographical reality of the sal forests spread over vast areas of West Midnapore, Jhargram, Purulia, and Bankura is in many ways strikingly similar to this concept.

The roots of sal trees form strong mycorrhizal relationships—this phenomenon has been shown many times in Indian forest studies. This network of fungi spreads through the soil, attaches to the roots of the plant, and helps the plant to collect nutrients from the soil. The soil type of Jangalmahal is mainly laterite—low in nutrients, low in water-holding capacity, and dries quickly in summer. It is difficult to collect nutrients for plants in such soil. But the fine threads of the fungus can spread deep into the soil and collect phosphorus, nitrogen, and other small minerals and provide them to the plant. As a result, plants grow and survive.

The fungal species found in the sal forests of Jangalmahal—such as



Astraeus, *Russula*, and *Scleroderma*—are part of this mycorrhizal network. Local indigenous communities have long relied on these fungi, or wild mushrooms, as a source of both food and income. In other words, the people of Jangalmahal have long been familiar with the network that scientists are only now beginning to describe. For them, forests are not merely a source of livelihood, but a living environment.



But today's reality is entirely unique. The structure of sal forests has changed over time due to excessive logging, forest fires, grazing by livestock, and monoculture afforestation for rapid timber production. In many places, old trees have been cut down, which has also broken the fungal network below the ground. Newly born plants often struggle to survive. Environmentalists directly link the crisis of forest regeneration to the destruction of soil microbial networks.

Environmental issues closely intertwine with the politics of this region. Jangalmahal has long been at the centre of development and security politics. On the one hand, the tendency to use the forest as an economic resource; on the other hand, the forest-dependent lifestyle of the local people—this conflict has been going on for a long time. Public afforestation projects often plant fast-growing trees that are convenient



for timber production but not always compatible with the local ecosystem, leading to a decline in biodiversity and disruption of native species habitats. As a result, the forest has gradually become a kind of artificial plantation.

This area is where Simard's research has created new controversy. If the forest is really considered a complex living network, then the whole forest will be cut down and planted again—this idea is called into question. Because then it is understood that cutting down the forest means not only cutting down the trees but also destroying the invisible network below the ground. And if that network is broken, forest regeneration becomes very difficult.

However, there is no scientific evidence to support this idea. Some researchers believe that the concept of "mother tree" or mutual cooperation among trees has been overstated. They say that nutrients can be transferred between plants, but it is not always correct to interpret it as human-like social behaviour, as the interactions are more about survival and resource competition rather than altruism, which suggests that while trees may share resources, this does not imply a social structure akin to human communities. Simard himself admitted that his ideas might seem somewhat "revolutionary" to mainstream science. But he argues that we must rethink forests during the climate crisis.

This debate becomes irrelevant when we contemplate the future of the sal forests of Jangalmahal. Here, the forest is not merely an environmental concern; it is deeply intertwined with land politics, mineral economics, and rural livelihoods. There may exist an unseen network beneath the soil of Jangalmahal that sustains the forest. Repeatedly disrupting this network makes regeneration increasingly difficult, as it disturbs the delicate ecological balance and the relationships among the various stakeholders involved in forest management.

This issue is not only political but also scientific. Is the forest simply a storehouse of timber, or is it a living ecosystem in which humans are integral participants? The future of these forests depends on how we answer this question. If the forest is understood as a complex, living network and the biodiversity of old trees and soil is preserved, the greenery of Jangalmahal may yet recover its strength. But if it is viewed merely as a resource, that invisible network will collapse—and with it, the sal forests of Jangalmahal—leading to biodiversity loss, ecological disruption, and severe impacts on the communities that depend on them. ■

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

Adapting to Climate Change

A Community Radio Initiative

This article by **Sarita Brara** highlights how community radio is helping farmers adapt to climate change through timely, expert-driven guidance. Programmes like *Tohfa-e-Kudrat – Jal, Jangal, Jameen* broadcast practical advice on climate-resilient crops, water conservation, and sustainable farming. Farmers such as Abdul Razak in Haryana and Rekha in Rajasthan have significantly improved yields and incomes by adopting recommended practices, including new wheat varieties and better irrigation methods. The initiative also promotes rainwater harvesting, drip irrigation, and use of solar systems and AI-based groundwater monitoring. With real-time weather updates and interactive platforms, the radio serves as a vital link between scientific knowledge and rural communities, enabling farmers to reduce risks, conserve resources, and build climate resilience.

Farmers are the most affected by climate change. The shifting pattern of weather impacts the production of their crops and ultimately their incomes. Abdul Razak a farmer in Regarh village of Nuh in Haryana is no exception. His wheat crop production was greatly affected because of untimely rains and storms. But while listening to agricultural scientists in a programme *Tohfa-e-Kudrat – Jal, Jangal, Jameen* aired over a community connect radio, he learnt about the climate change resistant variety of wheat. Razak who owns 10 acres of land, sowed the variety of wheat PBW 147 suggested by experts in the next season and the yield was much more than he had expected. He also changed over to the varieties of mustard and tomatoes suggested by the experts. Now, he no longer suffers losses due to climate change. In fact, production of his crops has increased.

Rekha, a farmer from the small village of Poothi in Ramgarh tehsil of Alwar district, Rajasthan, has also benefited from shifting to a climate-resilient variety of wheat. This Rabi season, she was able to harvest nearly double the yield compared to the previous season. She attributes this improvement to the knowledge she gained from listening to the *Jal Jangal Jameen* programme. Earlier, she says, wheat production from one bigha of land never exceeded 10–12 maunds. This season, however, the yield rose to over 25 maunds. For the first time, Rekha was able to sell a portion of her wheat after setting aside enough for her family's needs, earning nearly ₹7,000.



"I keep transistor by my side to listen to the programme while doing my household chores as the tips given by experts relating to sowing of seeds to taking care of plants and harvesting the crop. Rekha has nearly two bighas of land and grows cotton, wheat, millets, mustard, and other vegetables.

The Community Radio Connect FM 107.8 covers around 300 villages across four districts—Alwar, Deeg, Khairthal-Tijara in Rajasthan, and Nuh

(Mewat) in Haryana. The signature programme *Tohfa-e-Kudrat – Jal, Jangal, Jameen* (Water, Forests, Soil), a daily programme focusses on natural resource management and climate change awareness. Experts from Krishi Vigyan Kendra give their advice and suggestions over this community radio on shifting to climate change resistant crops, timing of sowing and harvesting of different crops as per the changing weather patterns.

One of the patterns observed due to climate change is a shift in rainfall distribution. Earlier, rains were spread over longer periods, allowing for gradual absorption. Now, rainfall tends to come in short, intense bursts—it does not rain, it pours. This makes it essential to ensure that water is not lost through overflow and flooding, but is effectively captured and stored.

Pooja Oberoi Murada who is the Principal lead of the outreach programme of S M Sehgal Foundation running the Community Radio says that farmers are advised to dig in farm ponds to store rainwater which can be used for



irrigation and the ponds can be used for fishery purposes as well. The farmers are also educated on the use of solar system for irrigation and other purposes and the government subsidies for the same. The Foundation has also constructed 70 check dams in the region. The farmers are also advised to use AI technology censors for measuring the levels of ground water. This technology enables real time data collection, analysis and prediction by use of sensors and this enhances monitoring of groundwater levels. The farmers are also advised to go in for drip irrigation and sprinkling so that not a drop of water is wasted.





Pooran Chand Saini from Thakarbass village in Alwar in Rajasthan is among the regular listeners of the programme aired over the radio. Saini who has shifted to drip irrigation says he is now able to save water and follows whatever suggestions are given to check the depleting levels of ground water. Other farmers also say that the consumption of water has greatly reduced.

"We have been able to save on electricity and time spent in the fields. Earlier irrigation would take four to five days, but now, the same work was completed in just 1–2 hours," says Saini.

"I have come to understand the importance of conserving water and not wasting a single drop. I've also learned how cutting down trees in forests affects the climate," says Rekha. She feels that the large forest area near her small village must be protected, and that it is important for the local community to ensure that no trees are cut. She also notes that rising temperatures, even during what used to be the peak winter season, are adversely affecting agricultural crops.

The programme broadcast over this community radio station also provides real-time weather information received from the Meteorological Department. Saini is of the opinion that in the present scenario of climate change forecast of weather as well as others kinds of suggestions are indeed crucial for farmers like him. "Right forecast can help minimize the losses to a great extent," he feels.

The farmers are also advised how to deal with setting frost in the fields that affects the crops as well as harmful impact of stubble burning like pollution and how to avoid this practice. Fakat Hussain, Station In-Charge of Community Radio Connect says such information is also aired during farmers' meetings and *Kisan Goshtis* (farmers' meetings) and farmers can also interact through phone calls and WhatsApp listener groups.

The number of community radios which play a vital role in climate change adaptation across India has increased over the last decade and today more than 500 community radio stations are running in different parts of the country. Serving as a bridge between scientific knowledge and grassroots realities, initiatives like Radio Connect provide authentic and real-time information to educate farmers on climate-resilient farming techniques, weather forecasts, government schemes, and market trends. ■

Sarita Brara is a senior writer and a regular contributor to this publication.

CBAM, IBAM and Viksit Bharat@2047

Balancing Carbon Compliance with India's Manufacturing Ambitions

In this article, **Dr Pooja Sehbag** examines Europe's shift from coal-based industrialization to climate-focused regulation through the Carbon Border Adjustment Mechanism (CBAM), which effectively prices carbon on imports. It highlights India's limited flexibility under its EU FTA and debates the proposal for an India Border Adjustment Mechanism (IBAM). While IBAM could retain revenue domestically, high compliance costs—especially for MSMEs—pose risks. Through this piece, the author argues India should navigate through a balanced approach vis-à-vis European CBAM while keeping its 2047 target in sight.

What began as the European Coal and Steel Community (ECSC) under the Schuman Plan in 1951 is today poised to implement the Carbon Border Adjustment Mechanism (CBAM), with the overarching objective of advancing decarbonization and achieving carbon neutrality. The ECSC subsequently evolved into the European Union (EU) in 1993. The shift from facilitation of regional cooperation on coal to carbon regulation captures a deeper metamorphosis.

Though the historical data on European coal—reserves, production, and consumption—is thin, the heavy reliance on coal is evidently visible. Europe, as the cradle of the Industrial Revolution, has consumed coal for its industrialization throughout the 19th and 20th centuries. Britain, Germany, France, and Belgium were among the major coal-producing countries, while Southern European countries, including Italy, Spain, and Portugal, remained structurally dependent on coal imports. This centrality of coal as dominant industrial and transport fuel is evident in the post-war settlement following the World War I. The Treaty of Versailles incorporated explicit coal-related provisions, underscoring coal's



role as both an economic asset and a strategic liability. The German Saar Basin was placed under League of Nations administration (1920–1935), with France assuming control of its coal mines as compensation for wartime destruction. This reflects how deeply coal was embedded in Europe's industrial and geopolitical architecture.

Historically, Europe relied heavily on coal for industrial development. However, coal consumption declined during the early 2010s, culminating in the launch of the European Green Deal (EGD) in 2019, and the subsequent introduction of CBAM in 2023. The EGD identifies[1] "tackling climate and environmental-related challenges" as "this generation's defining task," thereby framing decarbonization primarily as a climate-driven commitment. According to the Energy Institute's Statistical Review

[1] Details available at <https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF>



of World Energy,[2] the European Union accounted for only 7.3 per cent of global proven coal reserves at the end of 2020, while the Asia-Pacific region held nearly 42 per cent. The same report shows that the EU possesses merely 0.1 per cent and 0.2 per cent of global oil and gas reserves, respectively. Though the EU advances decarbonization through the EGD and CBAM, coal is not yet fully phased out in the region; Germany and Poland produce nearly 70 per cent of EU coal, with phase-outs planned by 2038 and 2049. This indicates that countries with relatively greater coal availability continue to calibrate their energy transitions in line with domestic resource endowments. Consequently, it raises an open-ended question as to whether the EGD and CBAM are driven solely by climate commitments or are also influenced by considerations of long-term resource constraints?

Now, EU has operationalized the CBAM. Conceptually, it is framed as a corrective instrument to address carbon leakage and ensure a level playing field for European manufacturers who operate arguably under stringent carbon constraints. In practice, however, it functions as a mechanism that effectively monetizes carbon at the border. It mandates that exporting countries either adopt low-carbon production pathways or pay a carbon price aligned with European benchmarks.

India's Strategic Response to CBAM

India's Free Trade Agreement (FTA) with the EU, signed on January 27, 2026, does not provide any country-specific exemption from CBAM for India. Nor has there been recognition of India's existing accreditation architecture. However, article 3(a) in Annex 14-A of the Agreement introduce a limited opening by providing for a "technical dialogue on implementation of carbon border adjustment measures, including: their product scope, and embedded emissions coverage; monitoring, reporting and verification (MRV) processes, and the possibility of taking into account the carbon price effectively paid in the other Party (i.e., India) under a carbon emission reduction scheme, calculated on greenhouse gases covered by such a measure and release during the production of goods".

Within this limited window, a few of policy researchers have suggested that India could consider instituting its own border carbon mechanism—India

[2] Details available at <https://www.energyinst.org/statistical-review?utm_source=chatgpt.com>

Border Adjustment Mechanism (IBAM).[3] The underlying logic is straightforward: if carbon pricing is inevitable for exports to Europe, imposing a domestic carbon-linked charge at the point of export would ensure that the associated revenue remains within India rather than accruing to European jurisdictions.

However, this proposition raises several operational and strategic questions requiring careful consideration: the keyword in this provision is "possibility", the acceptance of any IBAM-like mechanism would be contingent upon the EU recognizing India's accreditation mechanism as credible. The fact is EU has not so far recognized India's existing accreditation systems. This implies that, for any adjustment to be credited at the European border, Indian IBAM-like framework would still need to comply with EU-aligned MRV standards.

This is not a trivial requirement. Developing robust MRV systems entails significant compliance costs—data infrastructure, third-party verification, and ongoing reporting obligations. For large firms, these costs may be absorbable; for MSMEs, they could constitute a material burden. The



question, therefore, is not merely about regulatory alignment, but about the broader economic trade-offs involved.

From a macroeconomic perspective, the relative weight of this trade exposure warrants careful consideration. As per official estimates, Private Final Consumption Expenditure (PFCE) accounts for 61.5 per cent of GDP, while total exports constitute roughly 22–23 per cent of GDP. That means, consumption is the primary macro driver, not exports. Within this export basket, the EU's share is approximately 16 per cent, translating into only about 3.5–3.7 per cent of GDP. In other words, the segment of the economy directly exposed to CBAM-linked adjustments is modest in aggregate terms.

This raises a fundamental policy question: how far should India recalibrate its export and production frameworks for a trade segment that accounts for less than 5 per cent of GDP, and around 15 per cent of its exports? When weighed against the additional infrastructural and financial costs—particularly in terms of MRV compliance—the risk of unintended consequences becomes apparent. There is a possibility that such measures could inadvertently de-incentivize India's manufacturing sector, especially those operating on thinner margins- MSMEs.

At a time when India is navigating a critical phase in its development trajectory, with the 'Viksit Bharat@2047' vision foregrounding industrial expansion, policy choices must be carefully sequenced. The imperative is to strengthen, not constrain, domestic manufacturing capabilities. Any external alignment—CBAM compliance or IBAM-like experimentation—must therefore be evaluated not only through the lens of trade access, but also in terms of its implications for India's broader developmental priorities. ■



Dr Pooja Sehbag is Research Associate at the Chintan Research Foundation. Views expressed are personal.

[3] Details available at <https://www.thehindu.com/opinion/op-ed/keeping-indias-carbon-money-at-home/article70935857.ece>



SUBSCRIBE

TerraGreen

INDIA'S LEADING MONTHLY ENVIRONMENTAL MAGAZINE

http://terragreen.teriin.org

TerraGreen promotes the concept of sustainable development. Launched in June 2004, this magazine from TERI is an effort to bring forth information and knowledge in the fields of energy, environment, and sustainable development. The magazine is in keeping with our mission to expand the base of environmentally conscious readers and popularize sustainability issues at the local level. TerraGreen aims to provide the readers with the necessary inputs to enable them to be a part of the process of change. The magazine stays away from all jargon, so that the educated, informed, yet lay readers are updated on all that happens around them everyday.

Tick one	Term (yrs)	No. of issues	Cover price		You pay		You save	
			₹	US$	₹	US$	₹	US$
	1	12	840	122	800	116	40	6
	2	24	1680	234	1510	211	170	21
	3	36	2520	302	2270	272	250	30

*Name of the Customer (IN BLOCK LETTERS).....

Designation..... Company / Organization.....

City..... State.....PIN.....Country.....

Email.....

PAYMENT PROCEDURE

Enclosed a Cheque/Draft number.....drawn in favour of 'TERI' payable at New Delhi for

₹/.....for 1/2/3/ year subscription of TerraGreen.

To SUBSCRIBE or make online payment, visit: http://bookstore.teri.res.in/TerraGreen

For subscription related queries,
contact: +91 11 2468 2100 / 7110 2100
Email: teripress@teri.res.in

THE ENERGY AND RESOURCES INSTITUTE
Darbari Seth Block, IHC Complex, Lodhi Road, New Delhi – 110 003
Tel. 2468 2100 or 7110 2100, Fax 2468 2144 or 2468 2145, India +91 • Delhi (0) 11
http://terragreen.teriin.org

Green events

FORTHCOMING MONTHS

CII GreenCo Summit 2026
June 18–19, 2026
New Delhi, India
https://cam.mycii.in/

Global Conclave on Plastics Recycling and Sustainability (GCPRS)
July 2–5, 2026
New Delhi, India
https://10times.com/

Global Solar Expo (Delhi Edition)
July 9–10, 2026
New Delhi, India
https://globalsolarexpo.com/delhi-expo/

Global Sustainability Summit (GSS) 2026
July 23–24, 2026
New Delhi, India
https://gss2026.iisdindia.in/

Eco Sustain Expo
July 30–August 1, 2026
Hyderabad, India
https://10times.com/

TerraGreen

EARTH MATTERS

FEEDBACK FORM

PLEASE TICK YOUR CHOICE.

1. **Which section(s) did you find the most interesting?**
   ☐ TERI Analysis ☐ Environmental Research ☐ Feature
   ☐ In Conversation (Interview) ☐ Cover Story ☐ Special Report
   ☐ Green Challenges ☐ Terra Youth ☐ Review

2. **In your opinion, which section(s) need(s) improvement?**
   ☐ TERI Analysis ☐ Environmental Research ☐ Feature
   ☐ In Conversation (interview) ☐ Cover Story ☐ Special Report
   ☐ Green Challenges ☐ Terra Youth ☐ Review

3. **What do you think about the look and feel of *TerraGreen*?**
   ☐ Brilliant ☐ Design is not a priority, content is
   ☐ Average ☐ Needs improvement

4. **In your opinion, what aspect(s) of *TerraGreen* need(s) improvement?**
   ☐ Choice of stories ☐ Handling of issues ☐ Language
   ☐ Design ☐ Presentation

5. **Please rate *TerraGreen* on a scale of 1–5 (5 being the best).**
   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

6. **What issues would you like *TerraGreen* to cover?**
   .....
   .....

7. **Which other environmental magazine(s) do you read?**
   ..... ☐ None

8. **Any further suggestions?**
   .....
   .....

YOUR DETAILS

Name: .....

Profession:.....

Tel.: .....

E-mail: .....

The most innovative suggestion will get a surprise gift.

The Energy and Resources Institute
Attn: TERI Press
Darbari Seth Block
IHC Complex, Lodhi Road
New Delhi – 110 003/India

Tel. 2468 2100 or 7110 2100
Fax: 2468 2144 or 2468 2145
India +91 • Delhi (0)11
Email: teripress@teri.res.in
Submit online: http://bookstore.teri.res.in/terragreen

May 2026

ADVERTISE IN...

TERRAGREEN

Circulation information

Industries, Ministries, PSUs, Corporates, Multi and Bilateral Agencies, Universities, Educational Institutions, and Research professionals.
Readership of 40,000

General information

- Monthly
- All colour
- Matte paper
- Number of pages: 56



Technical specifications

Finished size:	20.5 cm × 26.5 cm
Non-bleed ad size:	17.5 cm × 23.5 cm
Half page ad size:	17.5 cm × 11.75 cm
Bleed size (3 mm bleed on all sides):	21 cm × 27.5 cm
Artwork preference:	Print ready, minimum 300 dpi (tiff, eps, pdf, or cdr) files with all fonts with high quality print proofs and progressives for colour reference.

Advertisement tariffs (₹)

Position	Card rate for single issue(INR)	quarter contract (3 issues) (INR)	bi-annual contract (6 issues) (INR)	annual contract (12 issues) (INR)
Advertorial (per page)	100,000	255,000	480,000	900,000
Back Cover	100,000	255,000	480,000	900,000
Inside Back Cover	75,000	191,250	360,000	675,000
Inside Front cover	75,000	191,250	360,000	675,000
Inside Full Page	50,000	127,500	240,000	450,000
Inside Half page	30,000	76500	144,000	270,000

GST & taxes additional as applicable

Subscription

One year ₹840 / $122 • Two years ₹1680 / $234 • Three years ₹2520 / $302

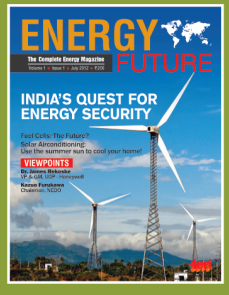
ENERGY FUTURE

Circulation information

Industries, Ministries, PSUs, Corporates, Multi and Bilateral Agencies, Universities, Educational Institutions, and Research professionals.
Readership of 25,000.

General information

- Quarterly
- All colour
- Matte paper
- Number of pages: 96



Technical specifications

Finished size:	20.5 cm × 26.5 cm
Non-bleed ad size:	17.5 cm × 23.5 cm
Half page ad size:	17.5 cm × 11.75 cm
Bleed size (3 mm bleed on all sides):	21 cm × 27.5 cm
Artwork preference:	Print ready, minimum 300 dpi (tiff, eps, pdf, or cdr) files with all fonts with high quality print proofs and progressives for colour reference.

Advertisement tariffs (₹)*

Ad location	Back cover	Inside back cover	Inside front cover	Inside full page	Inside half page	Inside quarter page	One-sixth page
Single issue	60,000	50,000	50,000	40,000	20,000	12,000	7,000
Two issues	114,000	95,000	95,000	76,000	38,000	22,800	13,300
Three issues	171,000	142,500	142,500	114,000	57,000	34,200	19,950
Four issues	228,000	190,000	190,000	151,000	76,000	45,600	26,600

Subscription

One year ₹800 / $80 • Two years ₹1600 / $160 • Three years ₹2400 / $240

Contact details

Sanjeev Sharma
Email: sanjeev.sharma@teri.res.in
<Extn 2443>

Bank details for NEFT:

The Energy and Resources Institute
Bank: State Bank of India
A/c Number: 62002345487
IFSC Code: SBIN0020511
Website:http://bookstore.teri.res.in/TerraGreen

The Energy and Resources Institute
Darbari Seth Block, IHC Complex
Lodhi Road, New Delhi – 110 003
Tel: 011 2468 2100 / 7110 2100
Fax: 011 2468 2144 / 2468 2145
Website:http://bookstore.teri.res.in

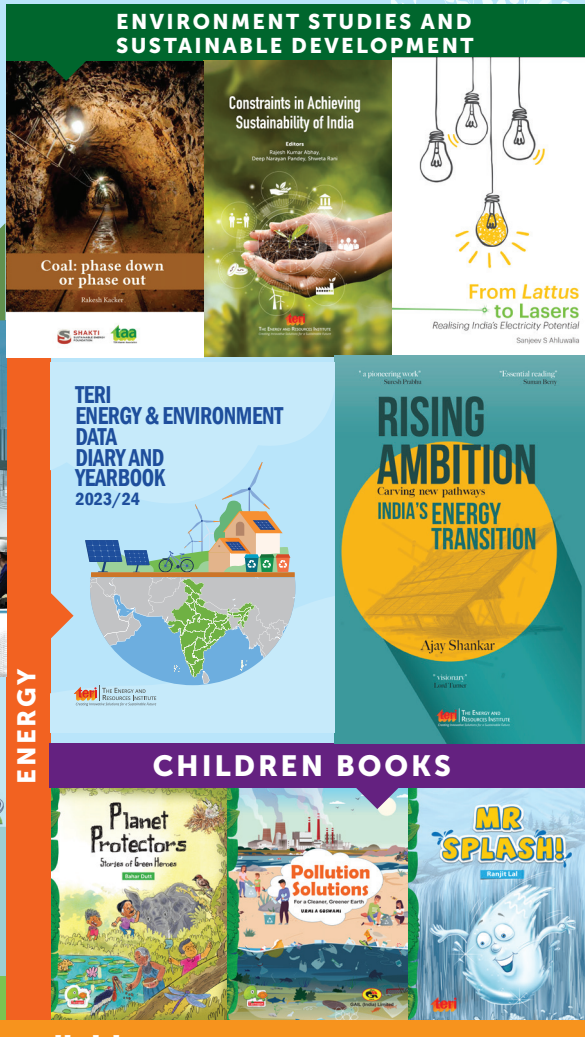
No. of Pages 56 without Cover

Postal Regn. No. DL(S)-17/3328/2020-22
RNI No. DELENG/2008/24157
ISSN No. 0974-5688

OPEN YOURSELF TO A WHOLE NEW WORLD OF ENVIRONMENT INTELLIGENCE!

PRESERVE • CONSERVE
INSPIRE • LEARN

ORDER YOUR COPY TODAY



TERI publications also available at

amazon.in flipkart.com GET IT ON Google play LEARNERLIBRARY mintbook Experience Reading
amazonkindle ShopClues.com infibeam.com paytm kopykitab Same textbooks, klick away

For more information, log on to http://bookstore.teri.res.in