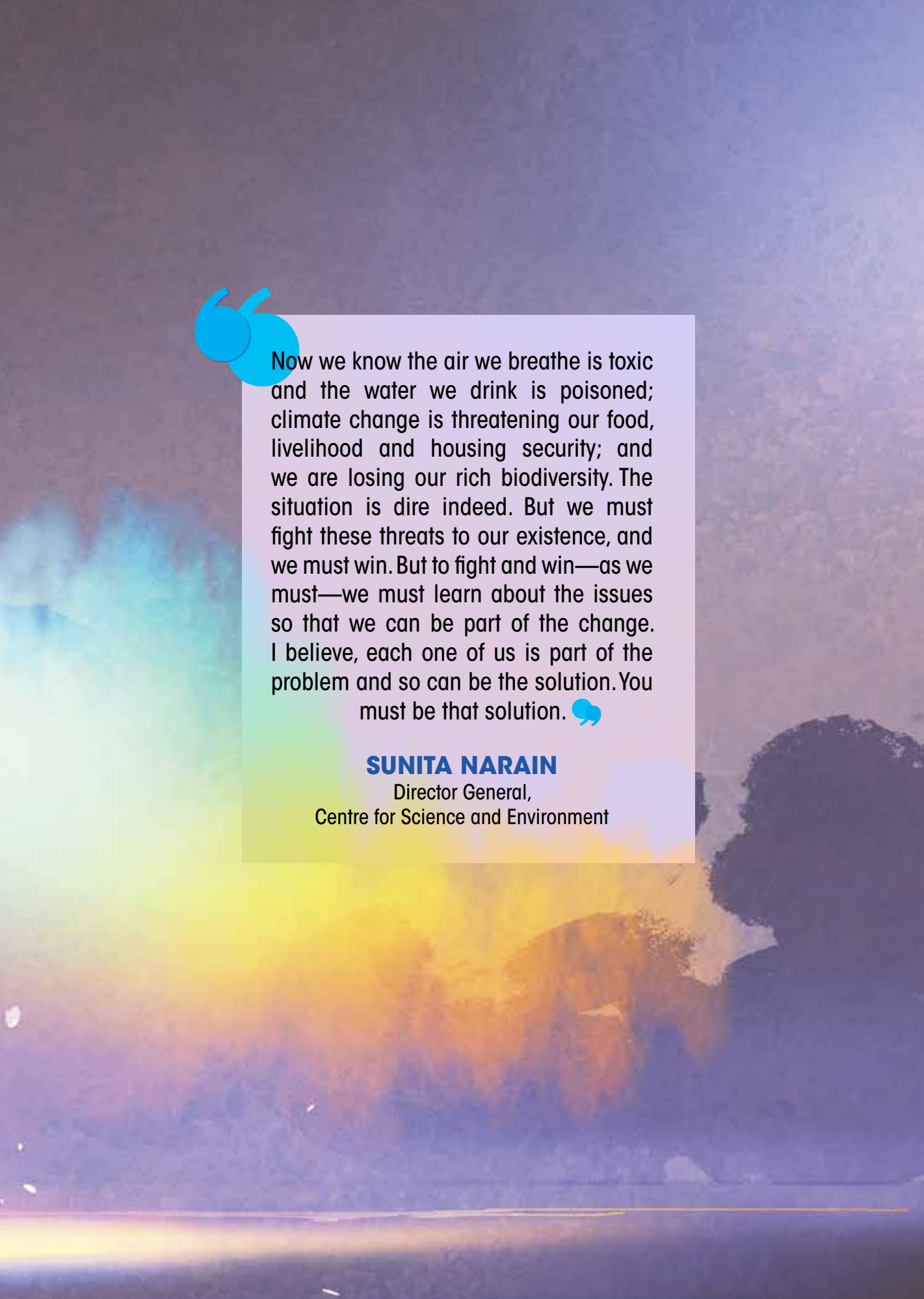
green EDUCATORS' NETWORK

The Climate Chronicle

Student perspectives on energy, equity and transition

2026-27





Now we know the air we breathe is toxic and the water we drink is poisoned; climate change is threatening our food, livelihood and housing security; and we are losing our rich biodiversity. The situation is dire indeed. But we must fight these threats to our existence, and we must win. But to fight and win—as we must—we must learn about the issues so that we can be part of the change. I believe, each one of us is part of the problem and so can be the solution. You must be that solution.

SUNITA NARAIN
Director General,
Centre for Science and Environment

The Climate Chronicle

Student perspectives on energy, equity and transition

2026-27

CONTRIBUTORS

Achintya Ghosal, Amruta Shukla, Amulya Yadav, Arya Dixit, Bisakha Hazarika, Chris Mannil Abraham, Dewanshi Narayan, Dimple Sharma, Elma Malik, Eshita Jain, Isha Khare, Kanak Singh, Kanishk Kumar R S, Kripa Charan, Kuhelika Bisht, Maanya Thatte, Manoj Kumar, Moumita Guin, Mridu Kapoor, Nitin Bisht, Prabhav Kumar, Resha Negi, Ritanshi Singh, Riti Bhuva, Shilpi Shukla, Shruti Sikder, Soumya Gurung, Surabhi Paraki, Tanisha Tangjang, Yaikhombi Thounaojam

MENTORS

Aditya Batra, Senior Director, CSE
Anshul Abbasi, Lead (Policy & Planning), Climate Centre for Cities, NIUA
Chandana Sasidharan, Program Research Fellow, WRI
Kiran Pandey, Programme Director, Environment Resource Unit, CSE
Neha Sakka, Spearhead, Trust EV Awareness Oath Program (TEVAOP)
Puja Das, Correspondent, Down to Earth
Richard Mahapatra, Managing Editor, Down to Earth
Souparno Banerjee, Senior Director, Environment Education, Publications & Outreach, CSE

PROGRAMME DESIGN

Tushita Rawat

EDITOR

Souparno Banerjee

DESIGN AND COVER

Ajit Bajaj, Ritika Bohra
Designed with AI assistance

PRODUCTION

Rakesh Shrivastava, Gundhar Das

We are grateful to Heinrich Böll Stiftung for their support for this publication.

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The articles have been compiled from assignments submitted by students as part of their project for the Agenda for Survival Programme. Participants are responsible for the information contained in and the data and sources used for their work.

Published by
Centre for Science and Environment
41, Tughlakabad Institutional Area, New Delhi-110 062
Phones: 91-11-4061 6000, Fax: 91-11-26085879
E-mail: cse@cseindia.org, Website: www.cseindia.org

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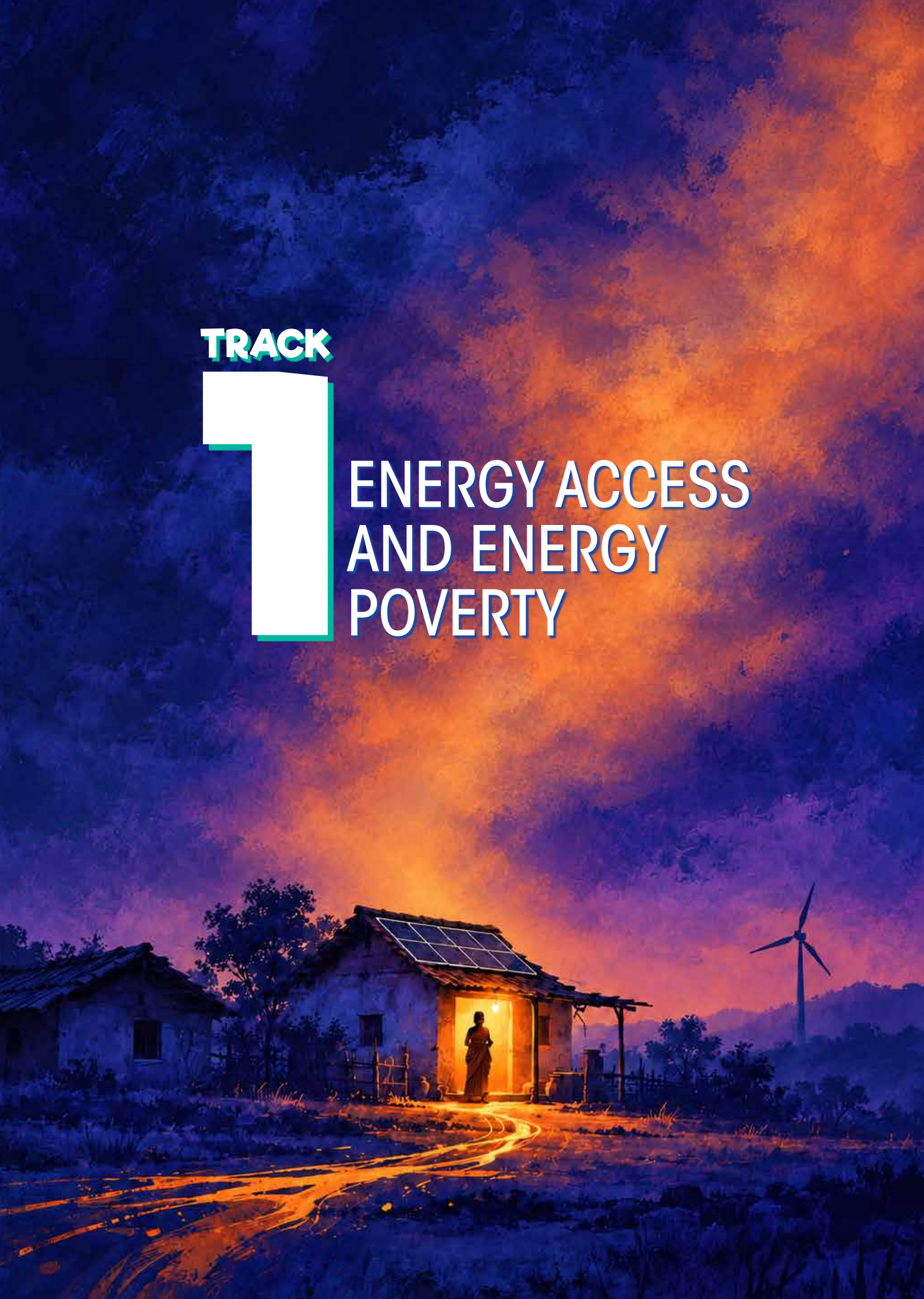
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TRACK
1
ENERGY ACCESS AND ENERGY POVERTY



Bishakha Hazarika

ENERGY ACCESS AND ENERGY POVERTY

A Transition for Whom?

Energy access, affordability and climate vulnerability in rural India – a case study from Assam

Robinson said this while addressing the International Energy Agency in 2015. A decade later, her words are a lived reality across rural Assam, where a household's electricity connection does not always mean it can afford, use or benefit from it.

In India, energy transition is being mainly described through numbers, such as so many crores of rooftop solar systems installed, gigawatts of renewable capacity, ambitious 2030 targets, and so on. But what does it look like from the inside of houses in a single flood-prone village on the banks of the Brahmaputra?

This case study turns to Dab Narikoli, a small village in Nagaon district of Assam, to ask: as clean energy systems get cheaper on paper, are rural households really able to afford, access and make use of them? The writer conducted a brief survey across 15 households in Dab Narikoli for her story.

> **There are 1.3 billion people living in energy poverty. For me, this is an intolerable failure of human solidarity.**
>
> Mary Robinson
> Former UN High Commissioner for Human Rights[1]



An old problem inside a new transition

Traditionally, energy poverty in India has been seen as the 'absence of wiring or connections'. Pachauri et al (2004)2 were of the opinion that there is more to energy poverty than just connection rates or volumes, and that inequality exists along the lines of affordability, reliability and fuel quality.

Assam introduces another deeper layer: it has a very high exposure index to climate-related natural hazards and extreme weather events. More specifically, according to a 2021 climate vulnerability assessment, 24 of its 27 districts are highly vulnerable and sensitive to climate change, predominantly because of floods, erosion and storms, repeated every year (WRI India, 2023).3 For households that are already struggling to pay their electricity bills, this adds to their challenge -- interruption of service is not an occasional emergency, but a seasonal certainty.

What the village said...

The survey of 15 households in Dab Narikoli shows how uneven this process is on the ground. Three of these households have no electricity connection at all as they cannot afford it; they rely on cheap battery-powered lights purchased in the local market. Of the 12 remaining connected households, only one has installed a solar panel – it could do so because the household has members who are government servants and have a more stable income.

This is not a story of broken or inaccessible technology. It is a story about the lack of purchasing power and resultant lack of access. When these 15 households were asked specifically about solar energy, five said they had never heard of it. The rest had heard of it but could not afford the panels or did not know where to get them from.

Affordability and access are two different barriers, and either can be insurmountable for a household.

A scheme that could help -- if it reaches the village

The Government of India launched the PM Surya Ghar Muft Bijli Yojana in February 2024. The scheme offers a subsidy of 60 per cent of the system cost for rooftop solar up to 2 kW and 40 per cent for the next 1 kW, with a limit of roughly Rs 78,000; this comes along with collateral-free loans of nearly 7 per cent interest and 300 free units of electricity per month (Ministry of New and Renewable Energy, 2024).

On paper, this scheme would be a game-changer for the three households in Dab Narikoli which are without an electricity connection. But in practice, its uptake depends on an existing connection, a bank account, an Aadhaar-linked online application, and the awareness that schemes like this exist – none of which are seamlessly available to many villagers in the country. This case study highlights a critical gap in information and infrastructure reaching the beneficiary. Without last-mile support, national schemes can reach only those privileged households which have reliable initial access to them.

When climate vulnerability enters the picture

Respondents in Dab Narikoli reported repeated disruptions to their electricity supply during floods, storms and heavy rainfall – this is where energy poverty and climate vulnerability converge. Poorer households are less able to afford back-up sources of energy such as solar with storage; they are also the least able to withstand outages when the grid itself goes down (WRI India, 2023). The households which are most vulnerable to climate shocks are the same ones that are least empowered – economically or otherwise – and hence, unable to prepare for these shocks.

A transition for whom?

The Dab Narikoli case does not argue or oppose against electrification or renewable energy. It simply asserts that counting the number of households that have received electricity connections is not sufficient. Three households in the village remain completely outside the electricity supply system; the sole household that has solar power is also the one with the most secure income. On paper, Assam's transition appears to be moving forward but on the ground it remains wildly inequitable in terms of the ability to afford, use and rely on clean energy.

A way forward

What should be the way ahead? Firstly, subsidy schemes like the PM Surya Ghar need active, local-level facilitation camps. There should be vernacular outreach and help for the unlettered, technologically disenfranchised, unaware high poverty and flood-prone villages, instead of a portal that assumes internet access, literacy and prior awareness.

Secondly, awareness campaigns on solar energy must be conducted village by village, since five out of the 15 households had never heard the term. Thirdly, for a flood-prone state, the energy policy needs to opt for decentralised, storm-resilient systems like solar with battery storage as a resilience investment for the community rather than a luxury upgrade. Access to power in rural Assam, ultimately, is not just a matter of infrastructure reaching a rooftop; it is a matter of who has the agency, the awareness and the government's support to make that access worthwhile.

Bishakha is doing her Master's in Urban Studies from Dr B R Ambedkar University in Delhi.

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TRACK

2 JUST AND INCLUSIVE ENERGY TRANSITION FOR INDIA





Tanisha Tangjang

JUST AND INCLUSIVE ENERGY TRANSITION

The Smoke in the Kitchen

Why India's energy transition must start at the chulha

At first glance, this is seen as an ordinary photograph, one that almost does not register as significant. A girl sits beside a mud-and-brick stove, coaxing a flame out of a few sticks of firewood while a blackened kettle waits its turn over the fire. Smoke drifts up through the bamboo walls of the kitchen before finding its way out through gaps in the thatch. Nothing about the scene is unusual, and that is exactly the problem. Versions of this photograph could have been taken in millions of homes across rural India every morning; they will be taken again tomorrow, and the day after, largely unnoticed by the national conversation on energy transition.

That conversation -- when it happens -- usually tends to be about gigawatts and coal blocks, renewable capacity targets, the fate of coal-dependent districts, the future of mine and thermal-plant workers. Rarely does it travel indoors to the fuel that decides whether a woman breathes clean air or wood smoke several times a day, every day, for most of her adult life.

> **Gigawatts are the easiest thing to measure in a transition; a woman's lungs are not, which may be exactly why they have been left out for so long.**
>
> Tanisha Tangjang
> Zoology student, St Edmund's College, Shillong



By most measures of energy poverty, the kitchen is where India's transition is furthest behind. According to The National Family Health Survey (2019–21, around 41% of Indian households still primarily use solid fuels such as firewood, crop residue, dung cakes or coal for cooking. And the proportion is considerably higher in rural India, where more than half of households still light a fire like the one in this photograph.

The health cost of this dependence on solid fuels fall almost entirely on women and girls because cooking in most Indian households is still considered to be their job. The World Health Organization estimates that household air pollution caused due to solid-fuel cooking contributes to around 2.9 million deaths each year worldwide, with women and young children bearing the heaviest burden since they spend most of their time near the flames.

In India, researchers have linked biomass smoke exposure among women to a significant share of cases of chronic bronchitis, tuberculosis, cataracts and even stillbirths. However, these health problems are often overlooked in discussions of energy statistics as the type of fuel used for cooking is not always considered when looking at their causes. A recent clinical study in Mysuru gave a clear picture of the extent of the problem; switching just 34 women from biomass to sustained LPG use was enough to prevent one new case of chronic obstructive pulmonary disease. Across the hundreds of millions of rural Indians still cooking this way, clean cooking becomes less of a household inconvenience and more of a public health emergency that is hiding in plain sight.

India has already taken an important step towards addressing this problem through the Pradhan Mantri Ujjwala Yojana (PMUY), which was launched in 2016 to provide free LPG connections to women from poorer households. It is by most counts the largest clean-cooking programme in the world, with over 10 crore connections issued by 2025. It is a genuine achievement and it has changed the geography of who has access to gas.

But access and use turned out to be two different things. PMUY beneficiaries purchase an average of fewer than five cylinder refills per year, well short of the seven or eight refills a household needs to cook exclusively on gas. So, the chulha stays lit the rest of the year. Surveys by the Council on Energy, Environment and Water found that the cost of LPG refills is an important reason why women return to using firewood. Firewood may not require an immediate cash payment but its true cost is paid later, in a woman's lungs and in the hours her daughters spend collecting it instead of studying.

This is exactly the kind of gap a "just and inclusive energy transition" ought to take seriously. Justice in India's transition is usually concentrated around compensating coal workers and diversifying coal-dependent districts. This is also necessary, but the discussion should not stop there. Many of those same districts, including parts of Jharkhand, Odisha, Chhattisgarh, Bihar also carry among the highest rates of biomass cooking in the country. A woman living in these areas can live with the transition's costs twice over: an uncertain future for the mine employing her husband or brother, and an unchanged risk in her own kitchen that development statistics rarely register, because unpaid domestic labour has never been counted as labour. A transition measured only in retraining programmes and compensation for miners, while treating the kitchen as private and apolitical is not yet the inclusive transition it claims to be.

None of this argues for abandoning the Ujjwala scheme; instead it argues for finishing what it started. This means shifting the subsidy conversation from new connections, most of which now exist, towards sustained affordability of refills, so that the second, fifth and tenth cylinder are as easy to buy as the first. It also means strengthening last-mile delivery so that buying gas does not cost a woman half a day's wage in travel. Community-led efforts such as LPG panchayats should also be supported, where women can share their lived experiences with other women rather than depending only on official messaging. Since behaviour change around cooking is not always effective when it is imposed from above, women should have a greater role in shaping these efforts. Finally, the choice of technology whether gas, induction, solar-thermal or improved biomass stoves where nothing else is yet viable, should be made with the women who will use it rather than being decided for them in a document that they will never read.

India can meet every renewable energy target on schedule and phase down its coal mines with textbook fairness, and its energy transition will still be incomplete if the flame in a photograph like this one looks exactly the same a decade from now. Gigawatts are the easiest thing to measure in a transition; a woman's lungs are not, which may be exactly why they have been left out for so long. A genuinely just transition has to be judged by that harder, quieter metric too — not only by how fast the grid turns green, but by how soon the smoke in the kitchen finally clears.

Tanisha is a student of the Bachelor's programme in Zoology at St Edmund's College in Shillong, Meghalaya.

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Kripa Charan

JUST AND INCLUSIVE ENERGY TRANSITION

Vulnerabilities in India's Energy Transition Story

India's energy transition is not just a race to chase the '500 GW by 2030' target. It should also be seen as a subtle but firm endeavour to ensure the health of the planet, the living conditions of its people, and the continued development journey of the country in which no one is left behind. While the goal is to become more climate-conscious, there is also a need to ensure that our policies and actions do not stifle the voices of the vulnerable and the marginalised. It is imperative to ask questions about employment security and who the real winners and losers are in this path towards a net-zero goal.

For instance, do we ever stop and ask ourselves what will happen to coal workers in rural Jharkhand where the entire economy and livelihoods depend on coal and its mining, or to pastoralists in Uttarakhand whose grazing commons have been turned into solar parks? Vulnerability in the context of energy transition cannot be explained away as just a 'side effect'; it is a structural feature needing deliberate intervention.

Let us examine this issue through the prism of three broad themes: energy justice, just transition, and energy poverty.

On energy justice

The energy justice framework asks three distinct questions of any transition decision:

Who receives the benefits and who is harmed, who gets a voice in shaping this decision, and whose claims and identities are acknowledged. In essence, it echoes what Gayatri Spivak asked in her seminal 1988 essay, "Can the subaltern speak?"

When we talk about distributive justice, the flaws in India's story are very apparent. It



is observed that the coal-region workers absorb major job losses, while they are as good as invisible when it comes to receiving tangible gains from the shift to renewables. The question about who gets a voice in shaping the story has a clear answer: those in power, large NGOs, and academic researchers. The working classes, women and communities most exposed to change have consistently been largely absent from the room. In fact, we find that entire categories of people are structurally invisible -- informal coal workers, for instance, are not accurately counted in official statistics, and pastoralist communities affected by land acquisition for solar parks are rarely consulted because the land they depend on is classified as "unused" or "wasteland".

On just transition

The just transition lens centers on livelihood continuity as fossil fuel economies slowly wind down. India's coal sector is still a major job creator, employing millions, especially in states like Chhattisgarh, Jharkhand and Odisha. A shift from coal will lead to job losses for around 3,00,000 who depend either directly or indirectly on the non-renewable sector for their livelihood.

This vulnerability is compounded by the fact that workers from scheduled castes face disproportionate difficulty finding alternative employment once mines close. There are documented cases which tell us former miners were pushed into manual scavenging as a last resort. Gender is also similarly obscured, with women bearing a disproportionate share of the transition risk. They remain largely absent from formal labour statistics and transition planning, partly because their work and informal subsistence activities built around mining economies were never counted as labour in the first place.

On energy poverty

It is important to look towards a large section which lives in extreme destitution and might not be able to afford what energy transition brings with it. India still has a substantial population which is effectively outside reliable electricity access. Though decentralised renewables are often framed as an energy-poverty solution, upfront adoption costs can severely burden the very households this framing is meant to serve. India's own estimates put the capital required for its transition in trillions of dollars, but most of the discourse around mobilising that capital by means of green bonds, blended finance, private-sector instruments etc rarely engages with whether the resulting infrastructure is actually accessible to the households it is meant to serve.

India's energy transition is often recounted as a success story. But if we look closer through the lenses of energy justice, just transition and energy poverty, a more complicated picture emerges. Our energy transition story cannot be judged by targets and installed capacity alone -- real success depends on whether displaced workers find new livelihoods, whether affected communities are heard rather than overlooked, and whether ordinary households can actually afford to participate in the new energy system. Without attention to these vulnerabilities, the transition risks repeating the old inequalities in a new, greener form. A genuinely "just" transition means putting people, not just power capacity, at the center. It is very important that we do not overlook these lived realities of people and that we start measuring real outcomes and not just megawatts installed.

Vulnerability in the context of energy transition cannot be explained away as just a 'side effect'; it is a structural feature needing deliberate intervention.

Kripa Charan
Master's student, Tata Institute of Social Sciences

Kripa is doing her Master's in Environment, Climate Change, and Sustainability Studies from the Tata Institute of Social Sciences.



Chris Mannil Abraham

JUST AND INCLUSIVE ENERGY TRANSITION

Anatomy of a Conflict-in-the-Making

Navigating divergent clean energy investments and economic losses in India's coal vs renewable states

India's commitment to achieve net zero status in 2070 and 500-GW non-fossil energy generation by 2030 represents a colossal paradigm shift. However, this commitment has a dark underbelly of potential discontent among its federated states due to the uneven impact of decarbonisation in the country. India already has a "coal belt"; it will now witness the emergence of a "renewable belt".

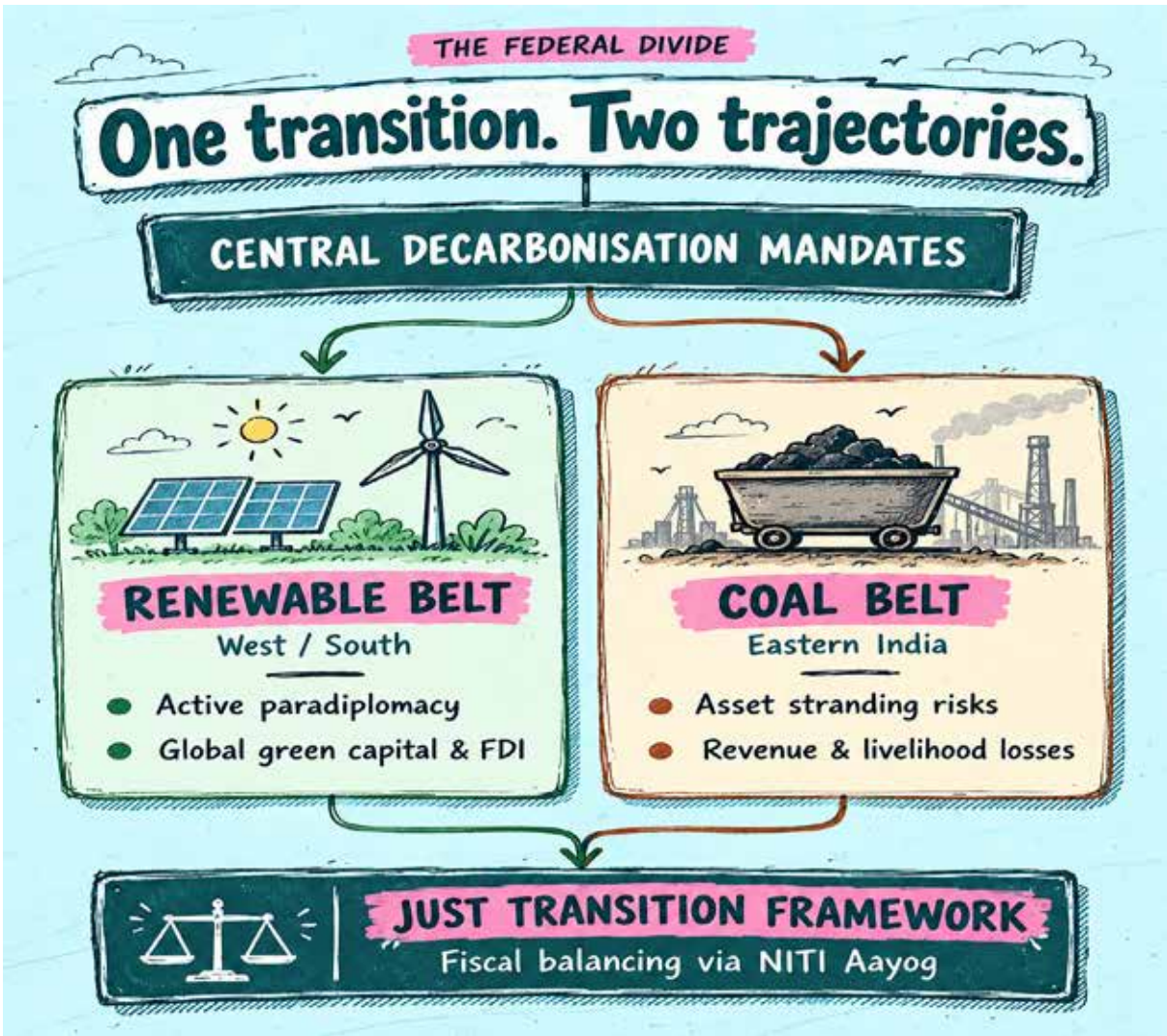
East Indian states such as Jharkhand, Odisha and Chhattisgarh are entrenched in a fossil fuel-dependent economy, while the West and South are showing a potential to emerge as global clean energy investment magnets. This could lead to fiscal and social unrest, mainly arising from decarbonisation obligations that the Central government may impose on the coal belt.

Navigating this tricky federal dilemma is what this article is about.

The IR and sustainability bridge

To understand the internal divergence in India, this article will try to bridge the IR concept of paradiplomacy (in which federated states engage in foreign policymaking without the involvement of the federal government) with the concepts of





'asset stranding' and just transition from sustainability management.

In an era where all nations are vying to host green capital, Indian states have become active foreign policymakers. Through paradiplomacy, progressive states are able to engage with the global green finance and FDI ecosystem and leverage themselves to receive disproportionate green investment. This creates the tension that is the focus of this paper.

If we examine this tension through the lens of sustainability management, we can see that coal-producing states face the risk of asset stranding. To mitigate the social costs, the Centre and states need to adopt a Just Transition Framework.

The coal belt: Structural vulnerability in Jharkhand and Odisha

The fiscal and social health of states like Jharkhand and Odisha are inextricably linked to the lifecycle of coal.

Revenue dependency: These states rely heavily on non-tax revenues generated through coal royalties, District Mineral Foundation (DMF) funds and National Mineral Exploration Trust (NMET) contributions. These funds directly finance local public infrastructure, healthcare and education.

Socio-economic and labour impacts: The employment landscape is heavily dominated by the fossil fuel ecosystem. Besides the formal employees of Coal India Limited (CIL), millions of informal workers like loaders, cycle-wallahs and local contractors are entirely

reliant on the coal economy. A premature phase-down of coal without alternate industrialisation threatens to trigger a depression and mass migration across these districts.

The renewable belt: Green capital aggregation in Gujarat and Rajasthan

In contrast, states in the West and South have leveraged their geography and policy agility to capture the clean energy boom.

Investment attraction: These states have created vast solar and wind parks (like the Khavda Renewable Energy Park) backed by streamlined land acquisition policies and robust single-window clearance mechanisms. This has made them a prime destination for global institutional investors and domestic conglomerates.

Economic buffers: While the eastern states scramble to protect their dying industries, these renewable-rich states are building future-proof industrial bases around green hydrogen manufacturing, battery storage assembly and electric vehicle production ecosystems.

The federal friction points

This economic divergence creates intense friction points within India's federal architecture, mostly concentrated in three areas:

Fiscal asymmetry and GST disruption: The transition directly threatens state treasuries. Coal-producing states collect significant revenue from clean energy cesses and mineral royalties. As the Central government pushes to phase down coal, these revenues will dwindle. Furthermore, the modern Goods and Services Tax (GST) regime is consumption-based (not production-based); since coal states are producers rather than heavy consumers of electricity, they lose out on downstream tax benefits.

Renewable Purchase Obligations (RPOs): The Ministry of Power mandates strict RPO targets which forces all state electricity distribution companies (DISCOMs) to purchase a set percentage of their power from renewable sources. For coal-heavy eastern DISCOMs that are already financially distressed and locked into long-term Power Purchase Agreements (PPAs) with thermal plants, buying expensive cross-state green power exacerbates their insolvency.

Grid infrastructure prioritisation: Central transmission planning (led by the Power Grid Corporation of India) heavily prioritises building Green Energy Corridors to evacuate power from western and southern fields. Eastern states argue for equal federal focus on grid modernisation and flexible thermal power operations in their regions.

A policy blueprint: The domestic revenue-sharing mechanism

To resolve these structual tensions, India requires a formal domestic revenue-sharing mechanism that redistributes the economic windfalls of the green transition to cushion the losses in coal-dependent states. This mechanism can be operationally institutionalised through a Federal Green Transition Fund (FGTF) structured via the Finance Commission and coordinated by NITI Aayog.

> **India's energy transition cannot succeed if it is a zero-sum game between its states.**
>
> Chris Mannil Abraham
> Master's student, Sustainability Management

India's energy transition cannot succeed if it is a zero-sum game between its states. If the economic anxieties of the coal belt are not addressed by federal policy, sub-national resistance from affected state governments can delay India's climate targets. By bridging the concepts of sub-national diplomacy and cooperative federalism, India can turn the structural challenge into an opportunity for equitable growth. A robust domestic revenue sharing mechanism ensures that the financial gains from the sun-drenched plains of Gujarat and Rajasthan secure a viable economic future for the communities of the eastern coalfields. Ultimately, a just transition for India is a political and economic necessity for the long term sustainability of the nation.

Chris is studying for his Master's degree in Sustainability Management at the Indian Institute of Forest Management in Chandigarh.



Isha Khare

JUST AND INCLUSIVE ENERGY TRANSITION

Are India's Coal-dependent States Ready for Just Transition?

When coal declines, are there places for people to go? A comparative study of Jharkhand and Odisha

India's transition away from coal is almost always presented as a shift towards renewable energy. But for regions that depend on coal, this transition raises a tough question: where do the people in those regions go when coal becomes scarce, or its mining is stopped? The answer to this question requires us to match local vulnerability to local job availability and livelihood security -- something the existing literature does not yet do.

Let us take examples from Jharkhand and Odisha; coal and its mining is a key factor in their economies.

A just transition entails much more than providing momentary support to workers when a mine is closed; it involves preparing people for the future.

Research on India's coal transition has already established that the burden of coal phase-down will not be equally distributed. A district-level vulnerability study found that the risks are concentrated in



coal-dependent districts, rather than being spread evenly across the country. Another recent study of coal-mining areas in Chatra, Jharkhand and Jharsuguda, Odisha shows that coal dependence is particularly concentrated close to mines and that the two regions differ in factors such as skills, landholding and social security coverage.

Taken separately, these findings tell us a lot; but together, they point towards another aspect: knowing where people are vulnerable does not necessarily tell us whether suitable alternatives exist for them. A region may be highly dependent on coal, but it does not automatically mean its workers want to remain in coal employment. Research from rural Jharkhand has found that respondents can prefer non-coal jobs, with factors such as wages influencing their choices. The concern, then, may not simply be people's willingness to leave the coal mining sector; it may be whether there are realistic alternatives available to them.

This is where I see a gap in the existing discussion on India's just transition. We have studies identifying vulnerable districts, and still others showing how coal dependence varies within those districts; we also have studies examining employment preferences. What we do not have are studies that connect these three things: the vulnerability of a place, the characteristics of its people, and the availability of jobs that could realistically replace coal-related livelihoods.

For example, creating renewable energy-specific jobs elsewhere in the state does not automatically help a worker in a mining-dependent community. If the new job requires relocation, different skills, or qualifications that the worker does not have, the opportunity is not accessible to her or him.

Similarly, a skill-development programme cannot be considered a successful transition measure simply because people have been trained. The more important question is, whether that training connects them to actual employment.

This makes the idea of a just transition much more local. Jharkhand does have an economy beyond mining, including agriculture, manufacturing, construction and services. The issue is not that alternative sectors do not exist. Rather, employment opportunities and economic activity are unevenly distributed, while coal-related livelihoods are particularly concentrated around mining areas. Research on rural Jharkhand has found a pronounced concentration of coal-related livelihoods within five kilometres of active mines.

The same question can be asked of Odisha. Instead of comparing the two states on the basis of coal production, a more useful comparison would examine whether their coal-dependent regions have the economic diversity, skills, infrastructure and institutions needed to absorb workers and households impacted by declining coal activity.

This also changes how transition planning should be approached. The objective should not simply be to identify sectors that could grow after coal. It should be to identify which sectors can provide accessible and decent livelihoods to the people currently dependent on coal, and where those opportunities need to be created.

A just transition entails much more than providing momentary support to workers when a mine is closed; it involves preparing people for the future.

Isha Khare
Master's student, Forestry Management, IIFM Bhopal

In the cases of Jharkhand and Odisha, this could imply going beyond the renewable energy industry into manufacturing, eco-restoration, agriculture, tourism, waste management and service industries. The appropriate alternatives, however, will depend on the characteristics of individual districts and communities.

India's energy transition is already being discussed in terms of targets, investments, and technologies. The next step is to look more closely at the places where the transition will be experienced. Whether Jharkhand and Odisha succeed at a just transition will depend less on which new industries appear, and more on whether the people currently dependent on coal can access work in them. Answering that will require district-level assessments that connect vulnerability, skills and infrastructure to real employment opportunities, not just broad claims about growth.

Isha is doing her Master's in Forestry Management from the Indian Institute of Forest Management (IIFM), Bhopal.



Achintya Ghosal

JUST AND INCLUSIVE ENERGY TRANSITION

PM Surya Ghar 2.0

Three tests for India's rooftop solar subsidy equity, DISCOM economics and grid integration

The Pradhan Mantri Surya Ghar Muft Bijli Yojana (PMSGY), India's flagship rooftop solar programme launched by the Prime Minister in February 2024, aims to put rooftop solar on one crore households by March 2027, each generating up to 300 free units a month. Central Financial Assistance (CFA) is roughly Rs 30,000 for 1 kW, Rs 60,000 for 2 kW and Rs 78,000 for 3 kW and above, plus collateral-free bank loans and DISCOM incentives.

PMSGY covers only one slice of the rooftop market, which added 7.9 GW in 2025, up 72 per cent year-on-year against utility-scale solar's 54.6 per cent. As the scheme moves into its next phase, three questions will decide whether it succeeds: Who is actually able to participate and who benefits? Can the distribution system absorb what gets built? And does the electricity that gets generated arrive when and where it is needed?

Let us look at the second and third questions. The problems of transmission congestion, evening capacity shortages and curtailment are systemic challenges across India's broader renewable transition; utility-scale solar and wind and rooftop solar operate within and alongside these constraints. But PMSGY 2.0 cannot be designed as though these problems do not exist. Net-metered power is only as valuable as the local feeder's capacity to absorb it, and the "free electricity" promise depends on the grid having power to deliver in the evening.

India's solar sector in 2026

India's solar capacity has grown roughly 58-fold in a decade -- from



2.8 GW in 2014 to over 160 GW by mid-2026. The country has the third largest solar capacity globally after China and the US. Having added 37.9 GW in 2025, India's total capacity has crossed 524 GW.

But capacity is not the same as delivered power. Thermal plants still carry most of the generation, especially in the evenings; nearly 80 per cent of the country's renewable capacity sits in just a handful of states. The bottleneck has shifted from building capacity to integrating and load-managing

Who participates and who benefits?

PMSGY's more telling number is its conversion funnel, not its growth. In a national household survey by the Council on Energy, Environment and Water (CEEW), 57 per cent of respondents were aware of rooftop solar, 26 per cent considered themselves potential adopters, 5 per cent had started installation and only 1.4 per cent had completed it. Conversion, not awareness, is the scheme's core adoption problem.

That gap plays out unevenly across states. Solar and wind investment sits overwhelmingly in the west and south (Gujarat, Rajasthan, Maharashtra, Karnataka, Tamil Nadu), while coal remains the backbone of the east and centre (Jharkhand, Chhattisgarh, Odisha, Madhya Pradesh, West Bengal). The states best at building renewable capacity aren't necessarily where the transition's economic and employment consequences will be felt most; in coal-dependent states, distributed solar intersects with how local economies adapt.

By December 2025, five states held over 70 per cent of the installed PMSGY capacity: Gujarat (7.42 lakh beneficiary households), Maharashtra (6.35 lakh), Uttar Pradesh (3.30 lakh), Kerala (1.82 lakh) and Rajasthan (1.22 lakh). Gujarat's lead traces to its SURYA Gujarat subsidy (2009, revived 2019-2022 at 40 per cent), which left it with a ready vendor network and digitised process; 14 states and UTs also run their own subsidies atop the CFA.

A December 2024 ministry review flagged many states (like West Bengal, Bihar, Jharkhand, Odisha etc) as lagging. There isn't a single explanation why some states lag: consumer awareness, how proactively a DISCOM processes connections and whether a state layers its own incentives on top of the Central subsidy can all matter, in different combinations, in different places. In Bihar, an underfinanced DISCOM struggling to prioritise rooftop connections can be an institutional constraint; inhospitable terrain and thin vendor coverage can compound this in the north-east and hill states. West Bengal's DISCOMs are financially healthier, so its lag points more toward a vendor-network and consumer-outreach gap.

The deeper equity question, though, is not simply that wealthier households adopt more; it's that rooftop solar's economics is structurally tied to consumption levels, tariff structures, roof ownership and access to capital -- so a uniform capital subsidy cannot map clearly who can actually benefit. Household economics diverge sharply as per consumption patterns: the lowest-consumption households (75 units a month or below, 1 kW) run negative monthly cash flow, break even only after 20-plus years and post negative net present value (NPV); the highest-consumption households (400 units, 3 kW) break even in about two years. Even moderate-consumption households show negative NPV over 20 years despite a positive monthly cash flow.

> **A subsidy that is uniformly available is not the same thing as a subsidy that is equitably usable.**
>
> Achintya Ghosal
> Master's student, Ecology and Environment Studies, Nalanda University

This isn't only about who has the money. India's slab-based tariff leaves lower-consumption households with too small a bill for solar to meaningfully offset, whatever their income.

Participation also has structural barriers beyond economics: ownership papers, a sound roof, a smartphone and cash flow to cover installation before the subsidy arrives. An estimated 30-40 per cent of housing stock is excluded on technical grounds alone; renters (roughly 25 per cent of the urban population) are excluded wherever they do not own the roof; and informal settlements, home to an estimated 65 million people, sit almost entirely outside the scheme's reach. A subsidy that is uniformly available is not the same thing as a subsidy that is equitably usable.

Can the distribution system absorb the generation?

This is where DISCOM economics and rooftop solar most directly collide, though the relationship isn't simply that every exported unit is a DISCOM loss. Distributed solar can reduce DISCOM costs where it offsets expensive daytime power procurement or defers new generation-capacity needs. It creates costs where it erodes the cross-subsidy that keeps DISCOM

finances afloat, where it requires new equipment to manage local voltage, or where the DISCOM must still maintain full network capacity to serve a household through the evening and night regardless of how little it bills that household for daytime units.

Indian DISCOMs recover only around 85 per cent of supply costs on average; the rest is cross-subsidised from commercial and industrial (C&I) tariffs. Rooftop solar is most economical for exactly the higher-consumption residential and C&I customers who fund that cross-subsidy, so their exit is more likely to land on the cost side of that ledger than the savings side. Which effect dominates, on a given feeder or in a given state, is an empirical question PMSGY 2.0's own data should be built to answer, not an assumption to build the subsidy on.

Net metering compounds the uncertainty: it remains a state subject despite the MNRE and Forum of Regulators guidelines, with states differing on net metering, gross metering, net billing and group or virtual net metering. Anubha Shukla of Husk Power Systems calls the lack of an end-to-end installation-quality guarantee the industry's central weakness: "Panels last 25 years, but inverters and other balance-of-system parts typically last closer to 10," she says. This gap that shows up as reduced generation and reduced consumer trust long after the subsidy has been paid out.

At the technical level, distribution -- not transmission -- is where rooftop solar itself creates a genuine, PMSGY-linked challenge: reverse power flow and voltage rise on low-voltage feeders in high-rooftop-penetration pockets of Gujarat, Rajasthan and Delhi. What these feeders need is not the grid-forming (GFM) inverter technology now under discussion for utility-scale battery storage. GRID-INDIA's January 2026 paper proposes GFM capability for BESS installations above 50 MW in weak-grid or remote locations, a transmission-connected application aimed at replacing the stability once provided by synchronous generators. Rooftop-scale distribution feeders instead need inverters capable of reactive power (volt-VAR) support, which manages local voltage rise directly rather than providing system-wide frequency and voltage anchoring.

DISCOMs also can't manage what they can't see. Without advanced metering, DISCOMs cannot tell when net-metered rooftop solar generates, how much is consumed on site, or how much flows back, which worsens forecasting and load management. After a government Expert Committee on Energy Statistics found this data wasn't uniformly recorded, an MNRE order of 17 August 2026 directed inverter manufacturers to report daily generation to the National Portal via a uniform API mapped to each inverter's serial number a step toward closing the visibility gap this question depends on.

Does the electricity arrive when and where it's needed?

An Economic Advisory Council to the Prime Minister (EAC-PM) paper found roughly 24 GWh of solar was wasted daily on an average in May 2026: this was more than a quarter of Delhi's daily consumption. The the grid fell short of peak non-solar-hour demand on 36 of 61 days between April and May 2026, against six days in solar hours: a deficit in evening capacity, not generation. On May 21, 2026, peak demand hit 270.8 GW at 3:45 PM versus 224.1 GW at 8 AM, a 46.7 GW swing in under eight hours. In a parliamentary reply on July 28, 2026, the government said India held back 8,133 GWh of solar power in April-June 2026 alone, since renewable projects are being commissioned faster than the transmission lines needed to carry their output projects are awarded, but can't lock in firm power-purchase agreements. These are transmission-level, system-wide constraints that predate and extend beyond PMSGY; India is simultaneously managing oversupply and undersupply on the same day, curtailing solar at midday while falling short by evening and no amount of added rooftop capacity alone resolves that.

What it points to is that the next phase of rooftop solar policy needs to move from supporting solar-only installations toward supporting grid-responsive distributed energy systems generation paired with storage and inverter intelligence that can be called on when the system actually needs it, not just whenever the sun is out. India's storage build-out currently lags far behind its solar build-out: China has around 155 GW of storage against roughly 1,000 GW of solar, India about 2.7 GW against 162 GW. China's added storage equals roughly 30 per cent of its added solar capacity; India's is around 1 per cent. India's dependence on China for lithium-ion cells also exposes storage expansion to the same supply-chain risks that shadow the rest of its clean-energy manufacturing. China has used co-location of storage with new renewables to cut curtailment; India has moved in a similar direction through viability gap funding for storage and the

National Framework for Promoting Energy Storage Systems, though at a smaller scale and without a comparable co-location requirement. A NITI Aayog assessment estimates that an unused NMC lithium-ion battery stored at 40°C for a year could retain about 65 per cent of its capacity, making thermal management and chemistry diversification such as Reliance's vanadium-flow system in Gujarat a live design question for Indian storage, not a settled one.

Grid-scale battery storage is where grid-forming technology currently belongs. GRID-INDIA's proposal for GFM-capable BESS above 50 MW is a bulk-system tool for a grid moving away from synchronous generation. Distributed pilots like the Modhera solar village, which combines advanced inverters, storage and islanding capability at village scale, show what integrated design can do locally. But scaling that combination is the task PMSGY 2.0 faces if it wants rooftop generation to count as useful electricity rather than just installed capacity.

Recommendations for PM Surya Ghar 2.0

On who benefits:
Low-consumption households have the weakest financial case for individual ownership, but that weakness is partly a function of subsidised, below-cost tariffs on the lower slabs their bills are small partly because the price they pay for power is already held down, not only because they use little of it. Raising the universal capital subsidy doesn't address this, since the constraint is the limited bill against which the investment recovers. What might: evaluating low-consumption households' solar value against the actual cost of supplying them, not just their subsidised bill and channelling that value through utility-led aggregation, RESCO and other third-party ownership models for low-consumption households, renters, apartment residents and anyone with limited upfront liquidity that can capture system-level value individual net metering cannot.

On distribution absorption: DISCOM incentives should be tied to the institutional conditions that actually determine whether consumers can adopt and benefit connection processing speed, feasibility-check turnaround, vendor oversight rather than only to installation counts. Beneficiary and cross-subsidy transparency should be a condition of continued scale-up: missing income, housing-type and urban/rural beneficiary data make it hard to tell whether the scheme is closing the equity gap in Question 1 or widening it. Distribution-level reactive-power (volt-VAR) capability, not grid-forming technology, should be the technical requirement attached to inverters on high-rooftop-penetration feeders.

On grid value:
Generation-based incentives and the proposed Digital Solar Passport (a verified electronic record that stores official details, asset specifications and performance data for a rooftop solar installation) should launch only alongside advanced metering and inverter-level generation reporting, phased by DISCOM readiness; this will ensure that payments reward actual performance rather than installed capacity. PMSGY 2.0 should prioritise storage on feeders where rooftop penetration already causes reverse flows or evening flexibility needs, recognising integrated solar-BESS-inverter systems and rewarding controlled export and voltage support rather than generation alone.

On implementation: States with strong adoption but emerging feeder-level stress need storage and smart metering; low-adoption states with adequate grid capacity need vendor development and financing support; states with weak DISCOM capacity need institutional support before further installation targets are imposed. One national target, applied uniformly, keeps misreading three different problems as one.

Conclusion

PM Surya Ghar's first 2.5 years show that a large public subsidy can build a residential rooftop-solar market at unprecedented speed reaching millions of households, building a national vendor ecosystem and making rooftop solar mainstream. What it hasn't yet shown is that installation counts answer the three questions this piece has traced. Asking these questions does not weaken the case for rooftop solar; it simply changes what success should measure. Not the largest number of installations, but the greatest useful contribution from each: systems that generate reliably, households that genuinely benefit, DISCOMs that can integrate them sustainably and electricity delivered when and where it's needed. That requires a shift from a capacity-led subsidy towards a performance-, equity- and grid-aware one. The first phase built the market. This phase has to answer for who it serves, what it costs the system and what it's actually worth to the grid.

Achintya is doing his Master's (MSc) in Ecology and Environment Studies from Nalanda University in Bihar.



Surabhi Paraki

JUST AND INCLUSIVE ENERGY TRANSITION

From the Ground Up

What India's energy transition plans can learn from the grassroots

Almost every day, we find headlines about India's energy ecosystem -- particularly on renewable energy -- in our daily newspapers. But do we realise that they are all missing one thing: the stories of people? These articles talk about gigawatts and net-zero targets, but rarely do they mention a name of a person, or of a village, or a family whose life revolves around such ecosystems. This is where the idea of Just Transition comes in.



Just transition: A brief history

The phrase Just Transition did not emerge out of a climate summit, or an academic paper. It began with the American oil, chemical, and atomic energy workers of the 70s and 80s as they watched their workplaces shutting down, and wanted a say in what came next for their livelihoods. This idea made its way through various labour circles, eventually emerging with the climate movement – the world's environmental diplomats finally caught up to it in 2015, when this idea was mentioned in the preamble of the 2015 Paris Agreement. Conversations were furthered through the Solidarity and Just Transition Silesia Declaration at COP24 in 2018, and were reaffirmed through the Just Transition Declaration at COP26 in 2021, formalising what was once only an abstract concept.

The driving force of Just Transitions is that it is a movement that emerged from the workers themselves, and was not handed down to them via policy frameworks or government intervention. Somehow, in the attempt to give this movement constitutional and legal validity, the grassroots approach that gave the movement its foundation seems to have been lost. This article aims to examine stories of success from across the world that show why bottom-up is the way that Just Transition frameworks are best implemented.

India's coal economy isn't a footnote in the story of our country's development, it is the lede, particularly in states like Jharkhand, Chhattisgarh and Odisha. Jharkhand alone holds 40 per cent of India's mineral reserves and produces around 27 per cent of the country's coal, with coal and petroleum together accounting for roughly a third of the state's own revenue. Entire districts like Dhanbad, Bokaro and Ramgarh have built their local economies, informal and formal, around coal for generations and continue to do so.

But here's the issue with transitioning away from that: it isn't just swapping energy sources. It's dismantling and rebuilding the economic backbone of entire regions, while the people who live there rarely get to design their blueprint. National targets and financing deals get negotiated disjointedly in Delhi, Geneva or Glasgow, while the communities who will feel every consequence of the shift are, at best, consulted after the fact.

Global contexts: What the world has gotten right (and what we can learn)

Hope for the future gleams through in a few areas across the globe: some places have figured out that you can't just decree a transition into existence. An example is Germany's Coal Commission, which brought together unions, industry, environmental groups and affected regions to negotiate the country's coal phase-out plan, resulting in a 2038 exit date and dedicated support for coal-dependent regions and their workers. Scotland went a step further, building a Just Transition Commission whose entire mandate was to keep workers and communities at the centre of decision-making. Spain closed its coal mines through a Just Transition Institute that negotiated individual regional agreements instead of a single blanket policy.

The driving force of Just Transitions is that it is a movement that emerged from the workers themselves, and was not handed down to them via policy frameworks or government intervention.

Surabhi Paraki
MA student, Public Policy and Sustainable Development, TERI School of Advanced Studies

The pattern across these examples makes it clear: transitions that actually held up were negotiated, not announced via government circulars. Compare that to a few Just Energy Transition policies in the other countries, like Indonesia's or Vietnam's, where finance flows in, but support still tends to cater to the small percentage of formal coal workers, leaving informal workers, small businesses and broader communities with far less institutional backing. The lesson isn't that finance is bad, it's that finance without genuine local power-sharing repeats the same top-down pattern, just with better funding behind it.

Indian contexts: Where we stand, and where we are headed

India, too, has its own grassroots wins. Take Hasdeo Arand in

Chhattisgarh, a forest so ecologically vital it's been called the "lungs of central India", home to elephants, sloth bears, and Adivasi communities who have lived there for generations. For decades, coal blocks kept getting allocated in this forest despite government research agencies themselves warning against it. So, what turned the tide? The Chhattisgarh Bachao Andolan, a grassroots movement. Led by activists like Alok Shukla who organised local resistance persistently enough that by 2022, the state government cancelled 21 planned coal mines, saving roughly 445,000 acres of biodiversity-rich forest.

Then there's Jharkhand, which is attempting something different: building in the consultations from the start. Its Task Force on Sustainable Just Transition ran a process that went beyond the usual state-level committee meeting. It held conferences, departmental consultations and meetings all the way down to the district, block and Panchayat level, specifically to make sure local voices shaped the framework rather than just responding to it. While it has its drawbacks due to the Task Force being largely advisory, it is an honest attempt that can be studied and replicated.

What next: A roadmap for the future

When we take lessons from these case studies from across the world, and in our own backyard, a fairly clear roadmap starts to emerge:

First, consultations need to transform into co-decisions. Germany and Scotland's methods worked because affected communities had real authority at the table, not just a seat at it. Jharkhand's Panchayat-level consultations are a genuine step in that direction, but they need a permanent, empowered governance structure rather than a lime-bound advisory Task Force.

Second, India's laws need to be revisited, updated and appropriately enforced. Local governance structures need to be strengthened to allow action at the first rung of the ladder so the voices of those who are directly affected by energy transition policies are heard by the policymakers.

Third, resistance movements like Chhattisgarh Bachao Andolan shouldn't have to keep winning the hard way. If a grassroots movement can save 445,000 acres of forest through sheer organising persistence, imagine what is possible if that same community power were built into policy from day one.

Just Transition, as a phrase, was born from workers organising for a say in their own future. It would be a strange kind of irony if, decades later, we let it become something done to communities rather than with them. India has both the cautionary tales and the genuine wins to build something better: it is mostly a question of whether we're willing to listen to the villages, not just the ministries.

Surabhi is a First Year student of MA in Public Policy and Sustainable Development, at the TERI School of Advanced Studies.

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TRACK

3

GENDER AND ENERGY





Mridu Kapoor

GENDER AND ENERGY

Women and the Air They Breathe

The problem of indoor air pollution and its solution



Women face air pollution differently compared to men, especially in a country like India. Historically, women have been the custodians of energy through traditional gender roles. To justify these roles, they spend much more time in kitchens using biomass, firewood or coal. This increases their susceptibility to indoor pollutants, leading to a higher risk of respiratory illnesses and other health problems. Certain studies have shown that air pollutants affect women during pregnancy, leading to silent miscarriages and diseases like depression.

In 2016, the Ministry of Petroleum and Natural Gas (MoPNG) had introduced the Pradhan Mantri Ujjwala Yojana (PMUY) as a flagship scheme to make clean cooking fuel available to rural households. This scheme makes Liquefied Petroleum Gas (LPG) available to underprivileged households which were otherwise dependent on traditional (polluting) cooking fuels.

The total number of connections released under PMUY as of September 2026 is 105,683,896. Despite its wide reach, the scheme's implementation has been criticised primarily because of its high recurring costs, low regular utilisation, and sudden changes in subsidy policies. In June 2026, the scheme was targeted for cutting down the annual quota of subsidised LPG refills to just four cylinders per year. Further, the recurring cost of LPG cylinders is a hurdle for low-income families, due to which such households develop a habit of 'fuel-stacking'. Fuel stacking is essentially using the LPG cylinder sparingly while continuing to rely on traditional biomass like firewood, dried dung and crop residue for everyday cooking.

India imports most of its LPG. The 2026 US-Israel conflict with Iran has disrupted the PMUY's distribution network. There is physical scarcity and delivery delays. This has forced these households to move back to traditional fuels, disregarding the indoor air pollution that women face.

To reduce the heavy dependence on LPG imports, enhance efficiency and lower indoor air pollutants, India is moving towards e-cooking or electrification of cooking. The 'Go Electric Campaign' launched by the Bureau of Energy Efficiency (BEE) makes the public aware of the benefits of induction appliances. The National Efficient Cooking Programme (NECP), deployed by Energy Efficiency Services Limited (EESL), rolls out energy-efficient induction cookstoves. The BEE star labelling system has introduced mandatory star-rating standards for induction hobs to help consumers identify energy-efficient models. PM-Surya Ghar Scheme links household rooftop solar installations directly to electricity savings, making daily e-cooking operation significantly cheaper.

E-cooking saves operational costs and the time spent by women for collecting firewood; it enhances energy security and eliminates indoor combustion emissions. All in all, it safeguards women's health and drives economic empowerment. Free time allows women to pursue education, job training, or paid work outside the home – they gain control over household money and decision-making powers. Programmes promoting modern energy cooking often train local women as micro-entrepreneurs and community leaders.

This transition ensures energy sovereignty. Energy sovereignty is the right and ability of individuals, communities, and nations to independently control, govern and make decisions about their own energy generation, distribution and consumption. Empowering women as central owners and operators of decentralised renewable energy is critical to achieving true energy sovereignty in India.

Empowering women as central owners and operators of decentralised renewable energy is critical to achieving true energy sovereignty in India.

Mridu Kapoor
MBA student, Sustainability Management, TERI School of Advanced Studies

Mridu is doing her MBA in Sustainability Management from the TERI School of Advanced Studies.



Maanya Thatte

GENDER AND ENERGY

Powering HER Enterprise

A case study of UN Women-UNEP's Women's Entrepreneurship for Sustainable Energy (WESE) Programme in India

Why do Indian women, who manage household energy needs in rural areas, find very little attention as entrepreneurs, workers or decision-makers in clean energy? And can a joint UN programme change that? This case study follows the WESE programme from its COP21 launch in 2015 through its India work up to 2021.

Energy poverty in India is not gender-neutral. Fuel collection typically falls to women and girls, consuming several hours of their week (Bennitt et al 2025). An estimated 4.3 million people die prematurely each year from household air pollution caused by solid fuel use, with the exposure being far higher among women and young children (Agrawal & Yamamoto 2014).



The hours spent gathering biomass also limit women's access to education and economic independence (Romanello et al 2023).

Women are similarly under-represented in the industry itself, holding a mere 32 per cent of the world's roughly 11.46 million renewable energy jobs in 2019 (Jafarinejad et al 2021). Against this backdrop, the WESE programme asked a simple question: What if women moved from being passive consumers of energy to turning into producers, distributors and decision-makers?

Existing narratives and evidence

UN Women and UNEP launched WESE jointly at COP21 in 2015, arguing that women entrepreneurs show more than twice the business capacity and success of men, and yet face structural barriers. A study of over 1,000 enterprises in Rwanda found women sold significantly more solar lighting units than men on an average (Barrón et al 2020).

The WESE programme came to India in 2017, and started working with women as both consumers and value-chain players. Its strongest documented result is the 'Promoting Women's Entrepreneurship through Solar Drying' project with S4S Technologies. Sixty dryers were introduced across two states (30 each), with 60 women trained and linked with the dried-food value chain through buy-back arrangements: average daily incomes rose from Rs 100 to Rs 300. Another 185 women were trained to manage solar rooftop systems.

In Aurangabad, 200 rural women farmers were given solar conduction dryers; the group showed a 36 per cent rise in its Dietary Diversity Score in the lean season compared to a control group. Aided by market linkages and some hand-holding, they could earn from selling dried produce (Nagwekar et al 2020).

But the barriers have been documented as well: restricted mobility, time poverty from unpaid care work, unsafe public spaces, poor access to finance, information and markets and gaps in the quality, distance and cost of training. Indian schemes targeting women focus almost entirely on domestic cooking, reinforcing the stereotype that a woman's place with energy is in the kitchen.

Research done by TERI and SEWA has found inadequate purchasing power and low social status, which often limit womens' access to energy-sector livelihoods. Women gain optimal traction only when wider socially progressive policies are in place (Baruah 2015). Credit systems compound this, since rigid assessment criteria exclude women disproportionately (Coldrey et al 2026).

Insights and arguments

What stands out here is that the economics works when the model is complete. Under WESE's solar dryer initiative, women received hardware, training and guaranteed buyers. Their incomes tripled.

What surprised this writer was how little of WESEs success depended on hardware, and how much on there being a buyer at the end.

Maanya Thatte
BSc Hons student, Environmental Studies, TERI School of Advanced Studies

An analysis of dried chilli harvests found open-sun drying destroys 34 per cent of the potential revenue; a drying-only solar dryer does not reach cumulative income parity with open-sun drying for three to seven years even with 22 per cent quality gains. By adding a second season of seedling-growing and service-based operation can cut this payback time to about one year, reducing the adoption barrier by up to 85 per cent (Machala et al 2022).

What surprised this writer was how little of WESEs success depended on hardware, and how much on there being a buyer at the end.

Policy engagement is where the programme was the weakest. Its main political achievement was a seat on a Madhya Pradesh Urja Vikas Nigam task force on cooking solutions.

Scale is another limitation. Sixty dryers and 185 rooftop trainees are gains, but India's need runs into the hundreds of millions. ENERGIAs Women's Economic Empowerment programme, running since 2014

with five partners, has supported more than 4,000 women in clean energy businesses across seven countries (Dutta 2020). In India, community renewable energy projects have built networks of women "Solar Sakhis", with the aims of empowering women and build awareness on clean energy. But these remain as models, not a national strategy.

The way forward

Market linkages should be mandatory in womens' energy entrepreneurship schemes. Schemes should also move past cooking into uses. India's 2022 policy framework for decentralised renewable energy livelihood applications already targets rural women and youth with solar dryers, cold storages, solar charkha and solar rice hullers alongside end-use finance and capacity building (Ingole 2023).

Training through state skill missions should be tied to employers: it is recommended that training institutes be connected with power companies so that the trained workers are placed in viable jobs (J & Majid 2020). Women need authority -- Indian researchers have argued for over a decade that more women should be inducted into the decision-making bodies of financial institutions, utilities and government energy agencies (Reddy & Nathan 2012).

None of this is exotic. The ingredients are known; what has been missing is scale and political will. India will spend the next two decades building its clean energy system, and who will build it is still an open question: one that policy can answer.

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Mannya is a BSc Hons student in Environmental Studies at the TERI School of Advanced Studies.



GENDER AND ENERGY

Women in the Lead

Arya Dixit

Can expanding women's access to and their leadership in clean energy systems address two concerns at once: the disproportionate health toll that polluting fuels place on women, and their continued exclusion from the economic opportunities that energy transition is creating? I would like to argue that treating women only as beneficiaries of clean energy schemes, rather than as producers, entrepreneurs and decision-makers as well, is a policy blind spot that limits both public health gains and inclusive growth.

Across India and much of the Global South, energy poverty is experienced differently by men and women. Cooking and other domestic energy tasks remain overwhelmingly a woman's responsibility, and a large share of households, particularly in rural India, still rely on firewood, dung cakes and other solid biomass for cooking. This dependence has direct, gendered health consequences: women and children spend a substantial time near indoor stoves and are exposed to the highest



concentrations of household air pollution.

At the same time, India's renewable energy sector is expanding rapidly, creating new jobs in solar installation, maintenance, micro-enterprise and distributed energy services. But women hold a very small share of these emerging livelihoods. Growth and health are not separate issues for women in energy-poor communities -- the same structural exclusion that keeps them locked into rooms filled with emissions from polluting fuels also keeps them out of the paid roles being created by the clean energy transition. Addressing one without the other misses an opportunity for compounding gains.

Government efforts such as the Pradhan Mantri Ujjwala Yojana (PMUY) have expanded LPG access to millions of women-headed households, pushing national LPG coverage above 90 per cent. However, many beneficiary households "stack" fuels — reverting to firewood when refills are unaffordable — showing that a connection alone does not guarantee sustained clean-fuel use, particularly when women lack independent income.

Barefoot College in Rajasthan offers a counter-example. Since the 1990s, it has trained large numbers of rural women, including many who are illiterate, as solar engineers who electrify their own and neighbouring villages — showing that technical capacity in energy is a matter of access and opportunity, not formal education.

Three insights emerge from this evidence. First, clean energy access functions as a public health intervention for women specifically, not a general household upgrade — so schemes that measure success only through connection or cylinder-distribution numbers, without tracking continued use by women, understate the health gap that remains.

Second, sustained adoption of clean fuels is closely tied to women's own economic agency: households where women have independent or supplementary income are better able to maintain LPG or other clean-fuel use. This suggests that clean cooking and women's livelihood programmes should not be designed as separate policy tracks.

Third, the renewable energy sector's own workforce gap represents an underused lever. Models like Barefoot College show that when women are trained as solar engineers, installers or micro-entrepreneurs, the benefits multiply: households gain electricity, women gain income and respect in their communities, and the diffusion of clean technology accelerates because women often reach other women more effectively than external agencies. Treating women as passive recipients of energy access, rather than as a workforce for delivering it, therefore leaves both health and growth gains on the table.

So what should be the way ahead? Clean cooking and livelihood schemes should be explicitly linked, for instance by routing LPG refill subsidies or clean-cookstove financing through women's self-help groups (SHGs), so that affordability and continued use are reinforced by parallel income support rather than left to household budgeting alone.

Energy access programmes should build in women-led delivery models, following the Barefoot College template of training rural women, rather than treating technical energy roles as gender-neutral by default -- when in practice they remain male-dominated.

Clean cooking and women's livelihood programmes should not be designed as separate policy tracks.

Arya Dixit
Master's student, Zoology, DBS College Govind Nagar, Kanpur

Monitoring and evaluation of schemes like PMUY should track continued clean fuel use by women beneficiaries, not just initial connections, so that fuel-stacking and reversion to biomass are visible to policymakers and can be corrected.

Finally, women should be represented in local energy planning -- panchayat energy committees, electricity distribution consultations and state renewable energy missions -- so that programme design reflects their lived experience of both the health burden and the economic opportunity.

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Arya is a student of the Master's Programme in Zoology at DBS College Govind Nagar, Kanpur.

GENDER AND ENERGY



Eshita Jain

Bridging the Data Gap

Gender-responsive energy evidence for rural India: How can ground-level, gender-disaggregated energy data become decision-ready evidence for rural energy planning and climate- and CSR-related proposals in India?

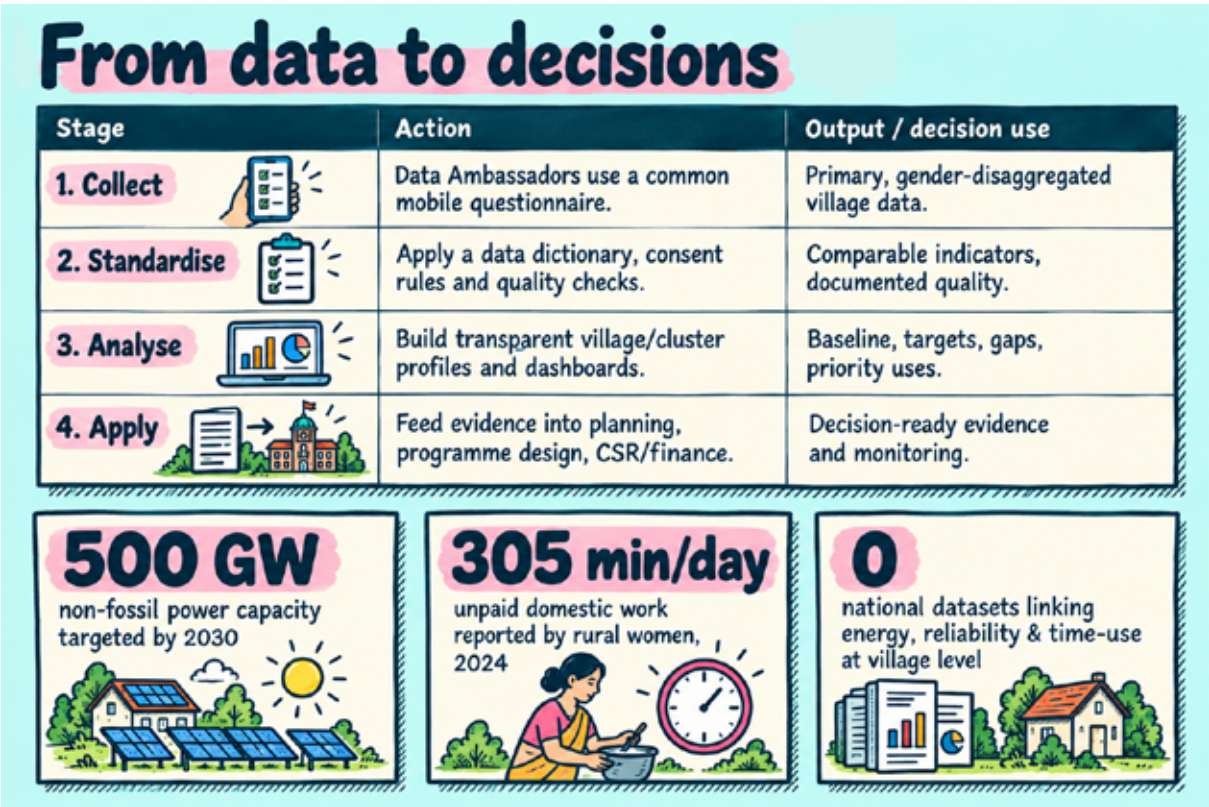
India's energy transition is accelerating, with the government targeting 500 GW of non-fossil-fuel capacity by 2030.1 Yet, electricity access is not fully captured by connections or aggregate supply alone — CEEW's ACCESS research shows duration, quality, reliability and affordability matter just as much, and its clean-cooking work distinguishes access to a fuel from its sustained use.3

These distinctions carry gendered weight. India's 2024 Time Use Survey found women aged 15-59 spend roughly 305 minutes a day on unpaid domestic work, far more than men.2 Energy-related tasks sit inside this load, but national statistics do not reveal the village-level causes, reliability gaps or productive-use opportunities behind the numbers.

The evidence gap

National surveys such as NFHS and NSO answer macro questions well, but rarely combine energy





use, reliability, affordability and women's time burden at the village level, where local planning actually happens. The proposed dataset would capture time burden, unpaid energy work, reliability, affordability, productive electricity demand, women-led enterprise needs, seasonality and household decision-making in one place. The gap isn't missing gender data — it's the lack of integrated, local evidence.

Existing narratives and evidence

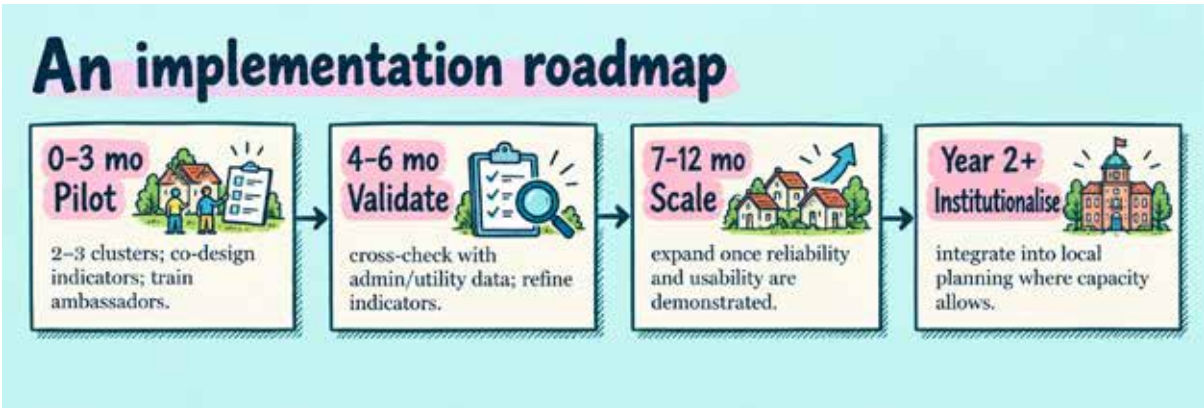
Three strands of evidence support this approach. Energy access is multidimensional: CEEW's ACCESS work found wide variation among rural households in supply duration, evening availability and reliability.3 Decentralised renewable energy can lift women's livelihoods — CEEW's 2023 study links clean-energy-powered equipment such as sewing machines and milk chillers to higher productivity and less drudgery.4 And gender-responsive climate finance increasingly runs on measurable indicators: the UNFCCC Gender Action Plan calls for sex-disaggregated data5, while the Green Climate Fund requires gender assessments and disaggregated targets in funding proposals [6]. Better data doesn't guarantee finance — but it makes problem definition, baselines and monitoring more specific and auditable.

The original contribution

The core contribution is a Grassroots → Data → Analytics → Policy pipeline. Community Data Ambassadors — trained women from self-help groups — would collect structured village data on who faces a constraint, when, how reliable or affordable the service is, and whether energy is used productively. This is standardised, quality-checked and turned into village or cluster profiles that inform local planning and strengthen CSR and climate-finance baselines. Better data doesn't automatically unlock funding — it makes the evidence behind funding requests sharper and harder to dismiss. Women's energy realities → Standardised indicators → Analytics / dashboard → Planning & finance → Monitoring & evaluation.

Moving ahead: The data-to-decision framework

Pilot test: women surveyed →



evidence flags a problem → an institution reviews it → a planning or programme priority changes. Even a non-change is useful evidence about the model's limits.

Indicators

Time: Hours/week on energy-related tasks; unpaid energy work; seasonal variation.

Energy: Reliability; cooking-fuel use; estimated productive-use and peak-hour demand.

Economic: Household expenditure; enterprise activity; opportunity cost of time released (clearly labelled as an estimate, not income).

Accountability: Baseline; target; beneficiaries; data quality; monitoring frequency.

Recommendations

Community Data Ambassadors: Trained local women collect data, with fair pay, informed consent and privacy safeguards, funded through existing mechanisms such as DAY-NRLM rather than a new budget line.

Standard Rural Gender-Energy Dataset: A common questionnaire and data dictionary covering time burden, reliability, affordability, cooking energy, productive use and decision-making.

Decision-Ready Dashboards: Transparent village/cluster profiles with baseline, target, beneficiary and monitoring fields.

Integrate Evidence into Planning: Pilot village profiles within Gram Panchayat Development Plans, and explore use by State Rural Livelihood Missions for targeted interventions.

Data Governance and Ethics: Define anonymisation, access rights, community oversight and reuse rules aligned with the Digital Personal Data Protection Act, 2023, before scale-up.

> **The gap isn't missing gender data — it's the lack of integrated, local evidence.**
>
> Eshita Jain
> MBA student, IMS Unison University, Dehradun

Limitations, safeguards and conclusion

Self-reported data carries recall bias; monetary estimates depend on assumptions and shouldn't be read as guaranteed income; dashboards can create false precision; and data collection risks becoming extractive without community control over how it's used. Institutional dynamics and capacity — not data alone — will determine whether evidence changes decisions; stronger evidence can strengthen proposals, but it cannot guarantee approval or finance.

Rural energy policy needs to measure more than whether infrastructure exists. A gender-responsive evidence chain — from lived experience to evidence, analytics, planning and finance — can make rural energy decisions more responsive to women's realities, without overstating what data alone can achieve.

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Eshita is doing her MBA from IMS Unison University in Dehradun, Uttarakhand.

TRACK

4

DECENTRALISED RENEWABLE ENERGY AND LOCAL SOLUTIONS



DECENTRALISED RENEWABLE ENERGY AND LOCAL SOLUTIONS



Soumya Gurung

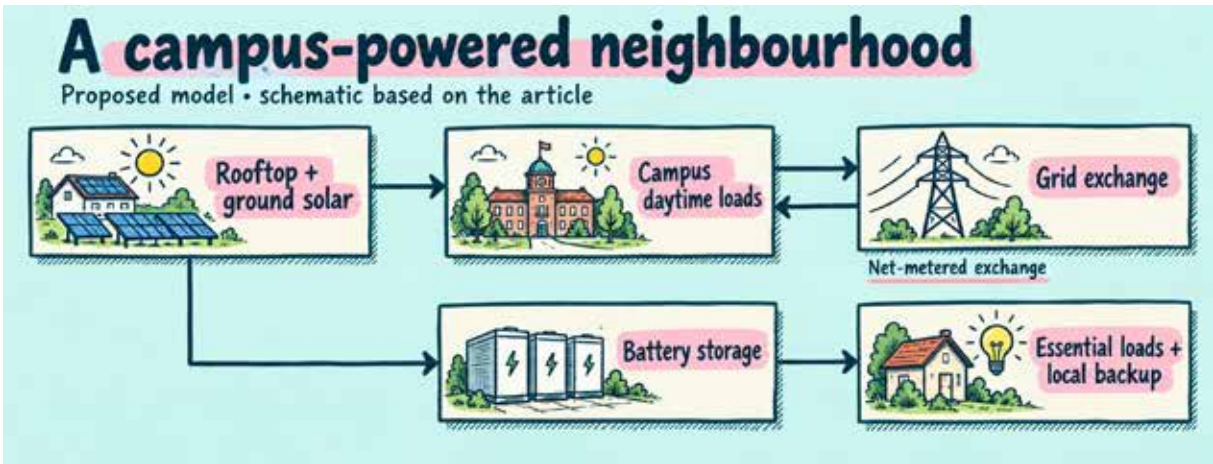
Powering from Within

A campus-scale model for decentralised solar – the case of IMS Unison University

Can a mid-sized educational campus in a small Indian town design and operate its own decentralised solar-based energy system, one that reduces grid dependence, lowers electricity costs, and extends a measure of energy resilience to the neighbourhood around it? This article examines what a campus-anchored, locally governed energy model could look like in practice, and why campuses are unusually well positioned to lead this shift, using IMS Unison University in Dehradun as a working example.

India's power system still runs largely on a centralised model: electricity is generated far from where it is consumed and carried over long transmission lines that bleed energy, money and reliability along the way. Small towns and peri-urban neighbourhoods feel this most acutely, through frequent outages, voltage fluctuations and tariffs inflated by transmission and distribution losses -- even as India's climate pledges commit it





to expanding non-fossil generation to 40 per cent of its power mix; this is a target that utility-scale solar parks alone cannot meet.

Educational campuses sit at an unusual intersection of this problem. They hold large, often under-used rooftop and open-ground areas; predictable, daytime-heavy electricity demand that closely tracks the solar generation curve; a captive population that can be trained and mobilised; and an institutional mandate to model responsible behaviour for the community around them. IMS Unison University, spread across roughly 10-12 acres at Makkawala Greens, Dehradun, illustrates this well: a self-contained, multi-block campus with hostels, academic blocks and a sports complex — precisely the scale and layout where a phased rooftop-and-ground-mounted solar system could be piloted and, in time, shared with the neighbourhoods around it.

A campus that generates and manages its own power is not merely cutting its own electricity bill; it becomes a visible, replicable proof of concept for the neighbourhood, the local distribution company (DISCOM) and nearby institutions — a meaningful entry point into the larger question of decentralised, community-owned energy transition in a hill state like Uttarakhand.

The promise and the pitfalls

India's rooftop solar story shows both promise and a persistent implementation gap. The Jawaharlal Nehru National Solar Mission set an early target of 40 GW of rooftop capacity out of a 100-GW solar goal, yet by 2019 rooftop systems made up under 7 per cent of installed solar capacity. The trajectory since then has been steep: cumulative rooftop solar capacity climbed from roughly 2.5 GW in FY2018 to about 10.2 GW in FY2022, 16.9 GW in FY2024, and 25.7 GW by March 2026 — a roughly 10-fold increase in under a decade, accelerated recently by the PM Surya Ghar Muft Bijli Yojana household subsidy scheme, which alone has connected over 3.2 million households since its 2024 launch.

Even so, the ceiling remains far higher than the floor. A CEEW analysis estimates India's rooftops could technically host over 600 GW of solar capacity, enough to meet close to a third of residential electricity demand nationally. A widely cited feasibility study of the MANIT Bhopal campus modelled a 5-MW rooftop-and-ground-mounted solar plant sized to the institute's annual consumption, using satellite mapping and simulation software to identify usable area, and found it financially and environmentally viable. A similar exercise, scaled down, applies directly to a campus the size of IMS Unison University. Other Indian case studies confirm that institutional and commercial rooftops are commercially attractive for solar precisely because of their high, steady daytime load, even where residential uptake continues to lag. Three barriers recur across this literature: high upfront capital cost, uncertainty in net-metering approvals, and a shortage of in-house technical capacity to maintain a system once installed.

Some insights

Two things follow from this evidence. First, a campus need not treat solar energy purely as a cost-saving retrofit; it can treat it

as shared local infrastructure. At a campus of IMS Unison's size, a modest rooftop-and-open-ground array across the academic blocks, hostels and sports complex — sized to daytime academic-hour load rather than theoretical maximum capacity — would avoid over-investment while still displacing a large share of grid draw during peak sunshine hours, precisely when DISCOM supply is often most strained in small towns and hilly terrains.

Second, ownership and financing structure matter as much as the technology itself. Many institutions stall between feasibility study and installed capacity purely on upfront cost. A Renewable Energy Service Company (RESCO) or 'solar-as-a-service' model — where a third-party developer installs and owns the system and the campus simply buys the power at a pre-agreed rate — removes this barrier and shifts technical risk away from the institution. Pairing this with a modest battery buffer lets a campus like IMS Unison University keep essential loads (water pumping, security lighting, a health room, a public charging point) running through outages, turning it from a pure consumer into a limited backup source for its neighbourhood in an emergency.

The Figure here sketches how these pieces — generation, storage, campus load and the grid — might fit together on a campus of this scale.

This is the same logic of local generation, storage and use that India's rural mini-grid programmes have already validated at village scale.

A third insight is about people, not just panels: systems that survive past their first year tend to have a designated maintenance owner, often a student energy club, because DISCOM paperwork, inverter faults, and cleaning schedules are exactly where feasibility studies elsewhere have stalled after commissioning.

A way forward

Audit first. Map hourly electricity consumption against usable rooftop and open-ground area across academic blocks and hostels, so the plant matches real demand rather than an assumed one.

Phase the rollout. Pilot a high-daytime-load building (library, labs, admin block), validate for two to three semesters, then scale across the rest of the campus.

Choose a RESCO or CAPEX-light financing model to avoid the upfront-cost barrier that has stalled many Indian institutional projects, and secure net-metering approval from the local DISCOM early.

Add a small battery buffer for essential loads, with a simple community-sharing protocol so the campus can support critical neighbourhood needs during outages.

Institutionalise maintenance through a student-run energy club, with a public dashboard of generation and savings — turning the installation into a teaching tool as well as a power source.

Document and share the model. A well-monitored pilot, with real cost and generation data, is exactly the kind of case study that can persuade neighbouring institutions to replicate it.

Designing local energy is ultimately less about the panels than about building an institution's capacity to generate, govern, and share power responsibly — a small but concrete step toward the kind of distributed, resilient energy system India will need at much larger scale.

> **Ownership and financing structure matter as much as the technology itself.**
>
> Soumya Gurung
> MBA student, IMS Unison University, Dehradun

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Soumya is an MBA student at the IMS Unison University in Dehradun, Uttarakhand.

DECENTRALISED RENEWABLE ENERGY AND LOCAL SOLUTIONS



Riti Bhuva

From Energy Consumers to Energy Partners

Operationalising DRE for productive use of renewable energy for rural wellbeing and local resilience in India

Can decentralised renewable energy (DRE) systems become a resilient and locally suitable foundation to boost basic health care and rural employment as well as stabilise the grid in India? The writer argues that DRE systems are essential for addressing India's electricity demand, and can be a vital tool for fulfilling the energy needs of rural communities.

The decisive decade

Climate change is real. Human activities have raised global temperatures by 0.18°C every decade since 1981. The Paris Agreement seeks to limit warming to under 1.5°C by the century's end. By March 2026, Nationally Determined Contributions aim for a 47 per cent reduction in greenhouse emissions intensity by 2035; they have also called for generating 60 per cent of electricity from non-fossil fuel sources.

According to available statistics, clean energy is on the rise. India has reportedly achieved its target of 50 per cent of non-fossil energy five years ahead of time. But despite this, critical structural imbalances persist:

Fossil fuel-based grid curtailment: Coal remains a significant part of India's energy mix, accounting for 79 per cent of its energy usage and 42 per cent of power production (2025). The grid struggles to balance this, since non-fossil sources contribute only 29 per cent of the electricity. Grid managers have to trim terawatts of power due to the inflexibility of coal-based thermal plants. Additionally, India relies on oil imports 89 per cent of the time, increasing its vulnerability to global oil price fluctuations.

Regional vulnerabilities: Vulnerabilities arising from the coal phase-out are significant in Jharkhand, where 18 of 24 districts rely on coal for 80-90 per cent of their incomes. A zero-emission goal can lead to a loss of employment. Climate funding to tide over the transition remains inadequate. An estimated US $8 trillion will be required for climate projects from 2025 to 2050, with US $5 trillion allocated to the power sector. Current annual financial support for





climate initiatives is only US $300 billion.

Resilience, productivity and social equity

Solarizing Primary Health Centres enhances vaccine preservation and maternal care, showcasing the advantages of localized energy solutions. Research indicates that 90% of micro-enterprises using decentralized renewable energy see annual income increases of INR 40,000, shifting communities to active energy participants. Initiatives such as Telangana's Self-Help Groups bolster trust and maintenance in renewable energy by employing trained women.

A roadmap for the way ahead

There are seven actionable local solutions that could be explored:

Shared community solar
Solar livelihood hubs
Community energy storage
Women-led solar enterprises
Local youth energy fellows
Solar health and pharma hubs
Integrated local energy hubs

'Local' is, according to me, what we must stress on. We need to listen to the local needs -- conduct energy audits and prioritise critical loads. Community participation must be encouraged and organised. This will promote transparent governance with local stakeholders for effective oversight. Develop solar health and pharma hubs alongside livelihood hubs for essential services. Make access to inclusive ownership and finance seamless -- utilise public schemes and funds to remove the cost barriers. And last but not the least, localise maintenance and accountability -- train local youth for service and repairs to ensure system reliability.

India does not need a single uniform renewable energy model. Reaching net-zero by 2070 requires the institutional and financial capacity to deploy customised, resilient and gender-inclusive local energy solutions across every district.

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Riti is doing her Bachelor's in Pharmacy from the KB Institute of Pharmaceutical Education and Research in Gandhinagar, Gujarat.

DECENTRALISED RENEWABLE ENERGY AND LOCAL SOLUTIONS



Prabhav Kumar

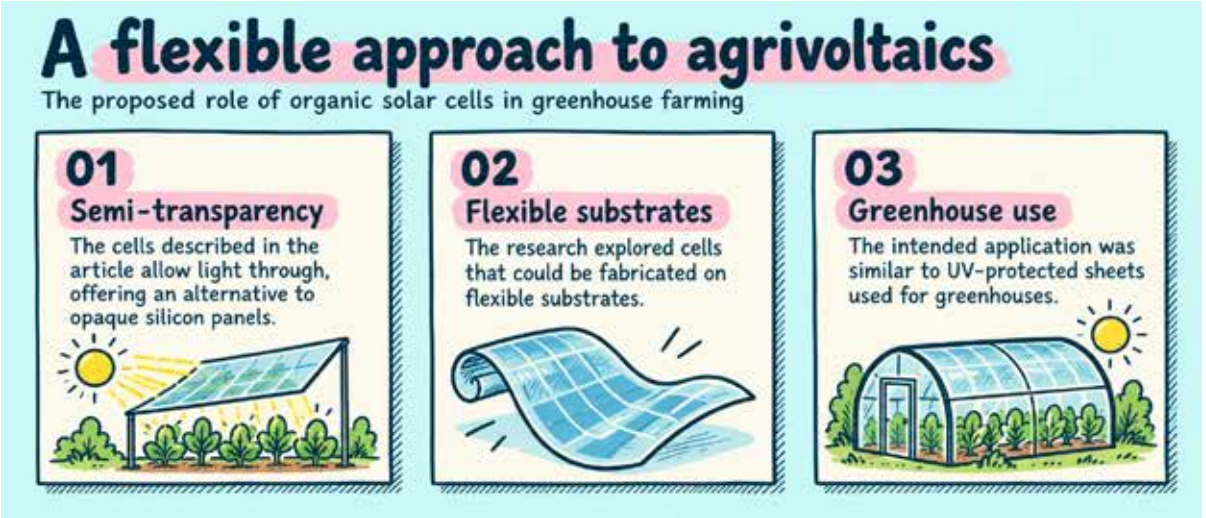
Towards Climate-resilient Agrivoltaics in India

Are semi-transparent solar cells the answer?

As the global average temperature continues to rise, one of the first effects that is already being seen and felt is in agriculture. Erratic and extreme weather takes a heavy toll.[1] Crops suffer due to stronger solar radiation – in India, most of the agriculture is practised in open cropfields; the privilege of greenhouse-based farming is held by a very small minority of its farmers.[2] Even as we talk about climate-resilient agriculture, it is worth noting that most of India's farmers still rely online connections or diesel generators for their day-to-day use.[3]

The government is putting its best foot forward to educate farmers about using renewable energy in their fields (agrivoltaics), but the practice is still not widespread due to high installation





and maintenance costs of silicon solar cells, besides the problem of having sufficient space to install the opaque silicon solar panels. The PM KUSUM scheme has enabled farmers to procure solar panels in a risk-averse manner[4]; however, the government needs to also prioritise the needs of marginal farmers by allowing them to access solutions that are more affordable and can be easily retrofitted to their existing systems.

In the past couple of years, there has been progress in the quest for more efficient solar cells. Far more advances have happened in making these solar cells fit various other parameters such as flexibility and semi-transparency. One such innovation can be seen in a new type of solar cells known as 'organic solar cells' that I had the privilege to witness. During my time as a researcher at the Indian Institute of Science (IISc), we had developed these cells that were semi-transparent and could be set up for fabrication on flexible substrates. The idea was to eventually allow farmers to use these solar cells in way that was similar to UV-protected sheets for their greenhouses.

The government has set a target of reaching carbon neutrality by the year 2070[5] -- reducing carbon emissions in agriculture would be a key step in that direction. I hope to see our nation committed to this goal: home-grown innovations like the semi-transparent cells would certainly help in reaching the target.

Home-grown innovations like the semi-transparent cells would certainly help in reaching the target.

Prabhav Kumar
MBA student, IIM Bangalore

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India is committed to achieve the Net Zero emissions target by 2070 as announced by PM Modi, says Dr. Jitendra Singh. Pib.gov.in. https://www.pib.gov.in/pressreleaseiframepage.aspx?prid=1961797&reg=48&lang=2

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Prabhav is doing his MBA from IIM Bangalore.

DECENTRALISED RENEWABLE ENERGY AND LOCAL SOLUTIONS



Nitin Bisht

DRE and Local Solutions

Overcoming geographical constraints in Himalayan villages



As global temperatures and environmental pressures rise, remote mountain communities face severe vulnerabilities, particularly due to their complex and rugged topography. In Himalayan hamlets, the terrain creates massive barriers to traditional energy distribution, and during harsh winters with sub-zero temperatures, residents are forced to rely on burning wood and biomass for survival. Due to blocked terrain, recurring landslides, and high transportation costs, regular supplies of liquefied petroleum gas (LPG) remain erratic and out of reach for marginal households, plunging these communities into deep energy poverty, economic strain and severe health hazards. Furthermore, the physical isolation and steep slopes make the extension of central power grids and high-voltage transmission lines technically and economically impossible.

What has been the existing policy on this

While the government has introduced overarching frameworks such as India's commitment to achieving a net-zero carbon emission target by 2070 and schemes such as PM-KUSUM scheme, which provides enhanced Central Financial Assistance (CFA) and higher subsidies for hill states like Uttarakhand and Himachal Pradesh, the ground realities of remote Himalayan villages require targeted micro-level interventions. State-level bodies like the Uttarakhand Renewable Energy Development Agency (UREDA) actively execute Decentralised Distribution Generation (DDG) initiatives, installing solar micro-grids and remote power plants, while schemes like the Mukhyamantri Saur Swarozgar Yojana (MSSY) encourage rural youth and women to adopt solar installations to create self-sustaining 'solar villages'.

However, more focus is needed to bypass heavy infrastructure, which scientific bodies like the Wadia Institute of Himalayan Geology (WIHG) warn against due to the risk of destabilising the already fragile hill slopes and increasing disaster vulnerability.

My perspectives

Drawing from my understanding of high-altitude and decentralised energy challenges, my focus has been on exploring low-impact, decentralised systems that align with the fragile geomorphology of the region. During my assessment of mountain energy needs, I examined how autonomous community-scale micro-grids, passive solar architecture and solar-thermal storage units can be seamlessly integrated to withstand extreme winters.

By avoiding heavy infrastructure like large hydro-dams or long transmission lines, my approach centers on utilising localised, low-impact clean energy solutions that protect high-altitude ecosystems while providing reliable, grid-independent electricity for daily household needs. Additionally, my framework incorporates the distribution of high-efficiency, chimney-fitted smokeless improved cookstoves as a vital transitionary measure, alongside providing technical training to local youth and women for hardware upkeep to generate grassroots green employment.

> **The nation must prioritise decentralised and locally tailored innovations.**
>
> Nitin Bisht
> Student, Uttarakhand Open University

To permanently resolve energy poverty and enhance climate resilience in Himalayan communities, the nation must prioritise decentralised and locally tailored innovations. By integrating community solar micro-grids, passive solar space heating, and clean cooking technologies under state and national frameworks (such as UREDA and the 2070 net-zero target), isolated mountain settlements can successfully transition into self-sustaining, resilient eco-villages without disrupting the fragile Himalayan ecology.

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Nitin is studying at the Uttarakhand Open University for his Bachelor's degree in Library and Information Science.

DECENTRALISED RENEWABLE ENERGY AND LOCAL SOLUTIONS



Moumita Guin

Whispering Watts

Piezoelectric micro-power from urban tree canopies as a conservation incentive

There is a spatial contradiction in Indian cities: it is this, on one hand the space required to install utility-scale solar and wind plants is exactly the space that urban clusters do not have, on the other rooftop solar runs into shading problems, structural limitations and ownership challenges. This spatial contradiction is evident in almost all Indian million-plus cities where competing uses of land for residential purposes, transportation and parks mean that there is no space available for ground-mounting renewable power generation capacity.

At the same time, trees -- which could act as natural cooling devices in cities -- are being cut down faster than they mature and are cleared for construction of roads, metro corridors and buildings without considering their ecological worth. The case of Bengaluru, which was once called



the Garden City of India, is one example of how intense this battle has become. Over the period from 2023 to 2026, more than 19,000 trees have been cut down in the city, almost 7,700 of them because of metro rail, flyover and road widening construction. Computer simulations done in other Indian cities demonstrate that just small amounts of tree cover can cool down the local environment by six to eight degrees, meaning that the cutting down of trees is directly contributing to increased energy use.

This article seeks to explore a smaller question in the context of such a paradoxical situation: can the trees be viewed as energy infrastructure themselves rather than as an obstruction to infrastructure in urban spaces and produce decentralised power by harnessing the energy from wind in their canopies?

Is this a workable option?

A biomechanical basis for this proposal exists and is quite well developed. Trees subjected to wind load act as tapered dynamic beams, absorbing energy of the gust by low frequency, high amplitude sway of the trunk and the branches. Piezoelectric cylinders configured like a group of tree trunks have been found by engineers at the Georgia Institute of Technology to produce measurable amounts of micro-watt levels of energy from wind-induced vibrations that could be modulated by cylinder spacing and wind velocity.

A separate experiment using wind tunnel found that attaching a piezoelectric harvester to a live palm branch and measuring its performance showed a near-linear voltage increase with wind velocity. Researchers at the Laboratory of Sound and Vibration Research at Ohio State University have shown that miniaturised tree structures covered by PVDF piezoelectric film can convert random flutter of leaves and branches into a stored low frequency energy signal.

From the biological perspective and decades of thigmomorphogenesis research, Morton Arboretum's Tree Biomechanics white paper shows that trees perceive mechanical stress from wind loads and respond positively, strengthening the base of branches and trunk tapering.

The science and logic of it

The environmental science involved is based on separating two different signals that are carried by the same swaying motion: the tree's own adaptive growth response to wind stress and a small portion of the vibrational energy which can be caught without interfering with that response. Thigmomorphogenesis demonstrates that trees are already capable of converting wind-induced strain into a physiological signal which strengthens their structure.

A piezoelectric harvesting collar is designed to be fitted non-invasively around a branch rather than being drilled or bolted into the tree, and it is intended to flex with the branch's normal swaying movement rather than restrict it. Since piezoelectric material produces an electric charge from just a few millimetres of bending, the device will take in a small amount of the energy that would otherwise be lost as heat and sound within the wood, leaving the branch's amplitude, the root anchorage and transpiration essentially unchanged.

> **Implementation should start small, and stay community-led.**
>
> Moumita Guin
> Environmental sciences student,
> Central University of Jammu

Although each collar on its own produces only a power output in the order of milliwatts, which is in line with the figures reported in studies on wind-induced piezoelectric energy harvesting, a single mature tree has dozens of load-bearing branches and a row of trees has hundreds of trees, so the total output over a street network can meaningfully cover small, continuous municipal loads. This is in contrast to guying or staking, which biomechanics research has shown can weaken a tree by damping its natural swaying movement. A mature neem or rain tree swaying in the monsoon winds could therefore act as a micro-power source, avoiding the land-use conflict that both solar farms and rooftop panels encounter in densely populated Indian cities.

Implementation

Implementation should start small, and stay community-led. Resident welfare associations and ward committees could pilot 10 to 15 collars on mature street trees along one avenue feeding a shared battery bank that powers streetlights, water-ATMs or neighborhood wi-fi nodes giving residents a visible everyday benefit. Municipal forest departments should be involved early to certify tree health and set strain limits, turning tree preservation from a

compliance burden into a metered energy asset during road-widening and metro projects.

A modest per-tree canopy-energy credit, offset against electricity bills, would reward residents for protecting rather than removing mature trees. Over time, this creates a feedback loop: greater canopy cover means more generation capacity giving neighborhoods reason to expand plantation drives such as Bengaluru's Nagar Van efforts as an energy strategy rather than a separate environmental gesture. School and college volunteers in the spirit of youth-led action could take on the low-cost role of logging output and flagging tree-health concerns during device checks, turning maintenance itself into an environmental-science learning exercise. Piloted carefully, piezoelectric canopy harvesting could turn India's recurring contest between grey infrastructure and green cover into a shared solution.

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Moumita is studying environmental sciences through an integrated BSc Hons-MSc course at Central University of Jammu.



DECENTRALISED RENEWABLE ENERGY AND LOCAL SOLUTIONS



Manoj Kumar

Beyond the Pellet

The case for making compressed biogas (not coal co-firing) India's first answer to the problem of managing paddy straw

India has two state-backed answers to the issue of 90-100 million tonne of paddy straw burned across Punjab, Haryana and western UP every harvest season: mandatory coal co-firing with biomass pellets, and compressed biogas (CBG) under GOBARdhan. Both claim to be able to put a stop to the burning.

This article explores which of these answers actually gives farmers and local economies a viable reason to stop burning, and which of these can be a community-owned enterprise and can be scaled up.

Burning costs a farmer nothing and clears a field in a day – the alternatives to it cost money and time in the narrow window between paddy harvest and wheat sowing. Policy has tried to close that gap from the demand side by mandating power plants to buy pelletised straw; more recently, after supply disruptions due to US-Iran war, from the supply side as well by building a national CBG ecosystem. In August 2026, the Union Cabinet approved a restructured GOBARdhan scheme with a Rs 23,731 crore outlay (FY27-FY36), targeting a near-tenfold rise in CBG production, an administered price floor of Rs 2,110/MMBtu, 85 per cent MSME credit guarantees, and 1.5 lakh new jobs in collection, transport, plant operation and manure production – this is a far larger, more community-facing commitment than co-firing ever received.

The current scenario

Co-firing's record is weak. CSE's audit of Delhi-NCR plants has found in Dadri, the pilot site had displaced only 0.537 per cent of its coal with biomass by December



2022; all 11 NCR plants combined managed only 0.744 per cent. With pellet manufacturing capacity (~7,000 TPD) set against a 7 per cent mandate (~95,000 TPD demand), no way to verify feedstock, and prices doubling in 18 months have meant the farmer's income stayed indirect and unreliable, mediated by aggregators. The storage of straw is also becoming a big challenge for plant operators.

CBG's evidence is more direct. Rathore et al (Frontiers in Sustainable Food Systems, 2026) show a CBG plant sells two products from the same straw: BIS-standard compressed biogas and fermented organic manure (FOM) benchmarked to ICAR's crop-wise application norms. India operates about 97 functional plants today: this number is projected to reach 5,000-5,500 by 2047, displacing up to 30 per cent of gas imports and 50 per cent of chemical fertiliser use.

Bengaluru shows community anchored CBG in practice. Carbon Masters built its plants through a joint venture with Hasiru Dala Innovations, a waste-pickers' cooperative giving an informal workforce direct equity in a formal energy business. Its Harohalli plant (30 TPD) sells biomethane to restaurants at LPG competitive rates. The Kannahalli waste park is designed as a replicable green-jobs template, which not only reduces pollution but provides effective employment to the local community, thus helping in just transition.

The global record reinforces the ownership argument. In Denmark, this sector runs on farmer cooperatives. Biogas processes 930,000 t/yr from 120 farms, with municipalities and citizens co-investing. Germany, the EU's largest producer (232 plants), supports ~105,000 direct bioenergy jobs. No coal co-firing parallel exists; pellet chains create jobs at a few large manufacturing units, not distributed ownership in feedstock supplying communities.

Some insights

Jobs are structurally larger and more local under CBG, and are spread across collection, transport, plant operation and manure production near the villages supplying straw; compared to it, co-firing offers centralised manufacturing unit jobs.

Community ownership is a built-in design feature of CBG. GOBARdhan's 85 per cent MSME credit guarantee is structured for farmer cooperatives and SHGs to become plant owners. It mirrors Denmark and Carbon Masters' waste-picker JV. Co-firing offers no equivalent advantage: a farmer can sell straw but cannot own a share of NTPC's boiler.

The income stack is deeper: a straw-selling farmer can also buy back subsidised FOM to cut fertiliser costs and earn Rs 700-800 per carbon credit under the CCTS revenue streams; co-firing's supply chain does not offer this. Alongside, CBG assures soil fertility along with supporting the mission for natural farming.

What should be the way forward

Redirect a larger share of central subsidy from co-firing infrastructure to GOBARdhan's MSME credit guarantee window, ring-fenced for FPOs and women's SHGs in the paddy belt.

Require CBG plants in new paddy belt to offer a minimum equity or profit share stake to a local FPO or cooperative – this should become a national norm, not a one-off case. It is essential to gain the confidence of the community, both for supplying the feedstock and buying back the manure/slurry produced.

> **Community ownership is a built-in design feature of CBG.**
>
> Manoj Kumar
> Master's in Law student, Delhi University

Publish a district-wise CBG jobs and ownership dashboard, so that farmers can compare direct CBG incomes against the historically unreliable co-firing route. It will help in better monitoring of the scheme along with a strong development of a resilient community both for fuel and feed for farms.

Use Carbon Masters' Kannahalli model – with co-located production, packaging and farmer-facing sales -- as the design reference for paddy belt CBG parks.

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Manoj is doing his Master's in Law from Delhi University's Campus Law Centre.

DECENTRALISED RENEWABLE ENERGY AND LOCAL SOLUTIONS



Kuhelika Bisht

Challenges of DRE in Remote Mountain Villages

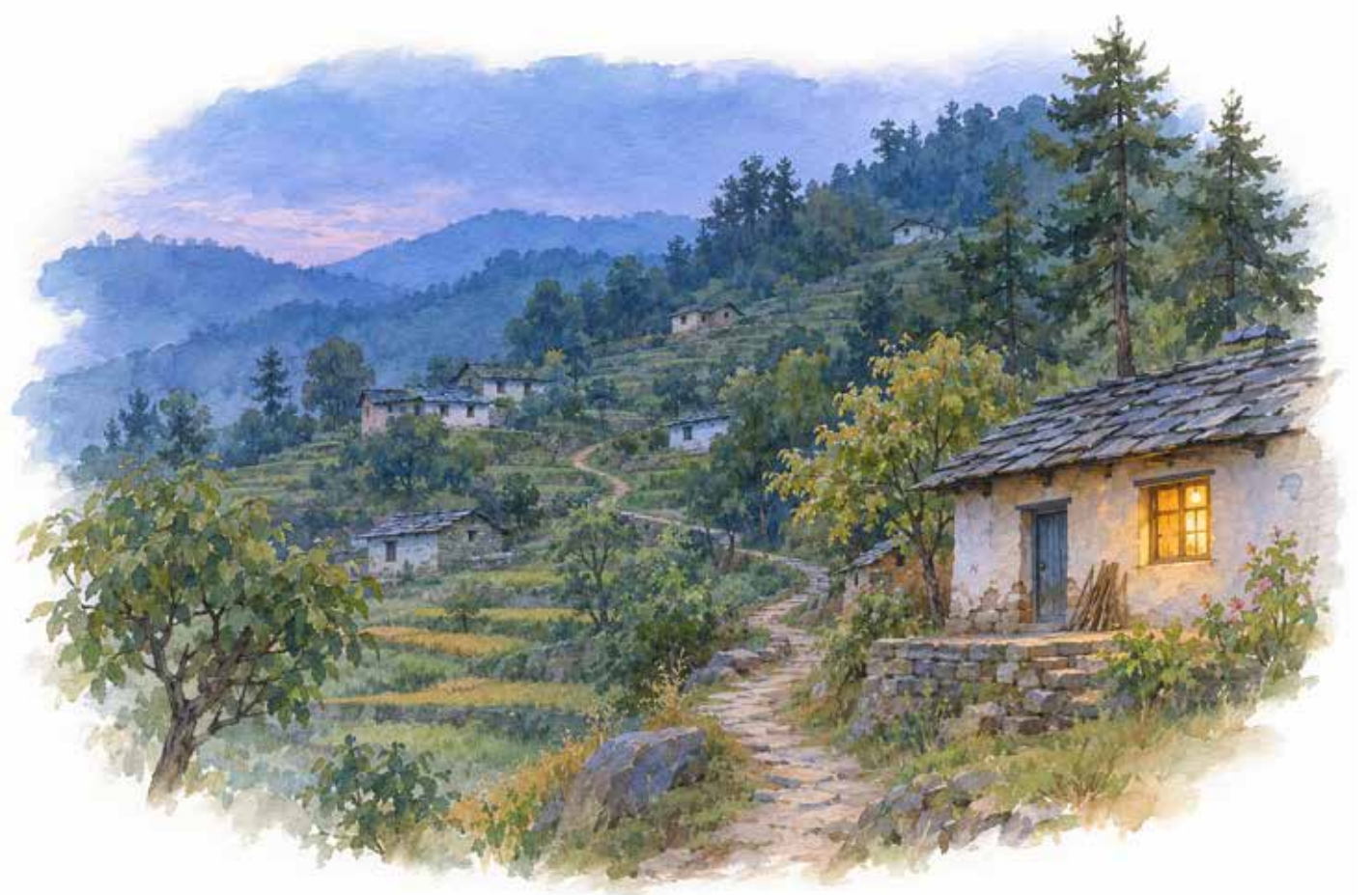
A Case study of Barangal Gram Panchayat, Almora district

When I arrived in Barangal Gram Panchayat, I could not see the village. After an arduous 15-hour journey from Delhi to this remote hamlet in west Almora district, I was really looking forward to reaching Barangal. As we moved up the seasonal road, all mud and stone from the rains, our host, the former Pradhan of the village, declared that we had finally arrived. The light from his house shone alone like a lighthouse on a dark shore.

"Where is the rest of the village?" I asked him. He replied: "You cannot see it right now because they choose to keep their lights off at night, but it's there!"

What village that has electricity and is surrounded by forests where leopards and wild boars roam, chooses not to use it? Why does a state like Uttarakhand -- with an installed hydropower capacity of roughly 3,855 MW – have villages that cannot afford to keep their lights on at night? Following my conversations with residents, I understood that the answer lay in this village's challenges with decentralised renewable energy (DRE).

Uttarakhand exports about 46 per cent of its energy to



neighbouring states (Asian Development Bank, 2023). But the state itself faces severe challenges in transmission: its terrain makes setting up infrastructure for energy distribution in remote areas difficult. There is a stark contrast in transmission systems in the plains of Dehradun and Haridwar compared to the hill districts of Almora and Uttarkashi (Open Access Exchange, 2026). Decentralised renewable energy shifts the reliance for energy from the main power grids to localised renewable energy generation alternatives.

Uncertain connection to the grid

Transmission lines reached one village in the Barangal gram panchayat in 1990, but extended to the remaining six villages only in 2003. It was primarily solar energy that powered Barangal as a result of the Remote Village Electrification Programme (RVEP) in 2003, which was implemented by the Uttarakhand Renewable Energy Development Agency (UREDA). Chanda Devi, a resident, recounted that houses would have only two bulbs, one to light outside the house and one for inside. Despite transmission lines having reached their village in 2003, people continued with solar energy as it met their demand and was affordable. A connection to the grid cost Rs 2,000-3,000 in 2003, which was beyond their purchasing power.

Schemes like Deendayal Upadhyaya Gram Jyoti Yojana launched in 2014 and Saubhagya-Pradhan Mantri Sahaj Bijli Har Ghar Yojana launched in 2017 provided subsidised meter connections and incentivised the village to transition from solar to a metered connection. Our host, who had served as Pradhan from 2019 to 2024, shared that currently homes with subsidised meters receive an electricity bill of Rs 70 to Rs 80 per month. There have been anomalies with some households receiving very high bills. Some, who had families and could manage to question the authorities, were able to challenge this and get the bills rectified; those who lived alone were not able to. This resulted in residents minimising their usage of electricity, thus explaining the dark village we arrived at.

While this transition from solar allowed them to increase their demand and usage from two bulbs to an LED in every room, it increased their dependence on an unreliable energy source. The Saubhagya Scheme increased domestic power demand by 20.7 per cent and added to the congestion in the power evacuation facilities; it has also led to frequent power cuts (Asian Development Bank, 2023). Recently, when Barangal's transformer, located 400 metre higher than the area, went down, two villages in Barangal Gram Panchayat were without electricity for eight days. Procuring labour that was willing to accept the logistical hassle of repairing a transformer at that height and terrain caused the delay in restoring electricity. With no electricity back-up, people had to walk to neighbouring villages during the day to charge their phones and torches and fetch them back before sunset. Ultimately, a new transformer was set up closer to the village.

Viability of solar power

The compound annual growth rate of electricity demand in Uttarakhand in 2023-2027 is estimated at 5.5 per cent (Asian Development Bank, 2023). Diversification of energy sources can distribute the load on the power grid to meet this growing demand.

> **Solar can be brought back to the village.**
>
> Kuhelika Bisht
> MA student, Sustainable Development Practice, TERI School for Advanced Studies

Barangal is situated at 1,400 m and receives an average daily solar radiation of 5.0 kWh/m2/day (Yaqoot et al, 2016) and 4.8 hours of average peak sun hours per day (Mission, nd). This, along with the existing solar panel infrastructure, should make solar the obvious back-up option. However, I was wrong in assuming that the infrastructure still existed: it had been 12 years since it had been abandoned. Pradhan ji shared that when metered connections came, residents thought that the batteries for solar were obsolete and therefore, sold them.

Solar can be brought back to the village. Despite the PM-Surya Ghar: Muft Bijli Yojana, which subsidises rooftop solar installations, the initial installation cost remains a daunting figure for the village. With the scheme, they could receive up to ₹78,000 in subsidy and sell the surplus power generated back to the grid. But Pradhan ji has been interested in a third option: a microhydel project.

Moving towards microhydel and biomass gasification

Microhydel projects are designed to harness the kinetic energy from small rivers and streams and do not require a reservoir (Nasir, 2014b). The water flows back into

The shortest path to net zero

In 1995, Arun III -- a 210-MW hydroelectricity project on the Arun river in Nepal -- was brought to a halt because a public movement began demanding the prioritisation of rural electrification in Nepal before exporting power. This movement brought DRE to the remote villages and boosted local economies and education (Khan, 2026). I envision a similar future for Uttarakhand. Uttarakhand's Vision 2030 states that the state government intends to focus on mini, micro and small hydro plants and harness solar energy through the private sector and community participation to provide energy security in remote areas (Asian Development Bank, 2023). According to Dr Debajit Palit, the Centre Head for the Centre for Climate Change and Energy Transition at Chintan Research Foundation, a development-led climate agenda where reliable and clean energy is accessible and affordable to all is the shortest path to India achieving its net zero emissions target (D Palit, personal communication, September 16, 2026).

the river system with minimal environmental impact on the aquatic ecosystem. The appeal of microhydel projects over solar is attributed to the fact that it can provide uninterrupted and reliable electricity through the night, unlike solar, and thus encourage micro-enterprises (Poudel et al, 2021).

Pradhan ji says they have a perennial river with a suitable head for such a project. Setting it up in proximity to the village, he intends to use the energy produced from the plant (up to 100 kW) to power biomass briquette machines (requiring up to 17 kW). The presence of abundant biomass in the form of lantana and pine leaves (pirul) makes it a viable option for Barangal. It is interesting to observe that despite the heavy incentivisation for solar by the government, there may be a preference towards a project that is community-owned and has a longer lifetime, even if it is capital intensive.

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Kuhelika is doing her MA in Sustainable Development Practice from the TERI School for Advanced Studies.

DECENTRALISED RENEWABLE ENERGY AND LOCAL SOLUTIONS



Amulya Yadav

PM-KUSUM, PM Surya Ghar and China's Distributed Renewable Energy Model

A comparative study: How effectively can decentralised solar energy policies promote rural livelihoods, energy security and community participation in India, and what lessons can India draw from China's experience?

India's solar energy transition is no longer limited to solar parks. The government and civil society are also focusing on decentralised solar energy, where local communities, farmers and households can directly participate in electricity generation. This is important because it affects the livelihood opportunities of farmers and local communities, energy security, and food inflation caused by supply-side shocks.

In this, PM-KUSUM aims to connect agriculture with solar energy to help minimise the cost of diesel or electricity. Its components include solar pumps, feeder solarisation and solar power plants. PM Surya Ghar: Muft Bijli Yojana mainly focuses on residential rooftop solar panels.

Case Study 1: Alwar, Rajasthan (PM-KUSUM)

Alwar provides an interesting example because PM-KUSUM has been implemented in Rajasthan where agriculture faces both unreliable electricity supply and groundwater constraints. The state provides a 60 per cent subsidy for solar pumps under Component B, comprising 30 per cent Central financial assistance and 30 per cent state support. A 2024 field study by Centre for Science and Environment (CSE), based on interviews with 17 farmers in Jaipur, Dausa and Alwar, found that eight had adopted PM-KUSUM. Across the three districts, Alwar had 862 installed solar pumps, said the study, of which 771 were 7.5-HP pumps. Farmers' average landholding among the interviewed group was 4.7 acre. The study found that the strongest motivation was not simply saving money but being able to irrigate during the day rather than at night; farmers reported that conventional agricultural electricity was often scheduled for six hours at night, but could provide only about four hours of usable supply.

The Alwar case also shows how decentralised solar can become a source of livelihood diversification.



The Ministry of New and Renewable Energy documents the experience of Rewati Devi from Alwar, who installed a 2-MW solar plant in Sanoli village under PM-KUSUM Component A. She reported generation of around six units per kilowatt on clear sunny days and described the plant as a reliable source of income. At 6 kWh/kW, a 2-MW plant would imply roughly 12,000 kWh of generation on a clear day, although actual generation varies with weather and operating conditions.

Case Study 2: Surat, Gujarat (PM Surya Ghar)

Surat represents the household side of decentralised solar. Under PM Surya Ghar, rooftop panels enable households to generate electricity where it is consumed, reducing grid dependence and potentially lowering electricity bills. The scheme targets one crore households and provides central financial assistance of up to ₹78,000 for eligible rooftop systems. A 2025 analysis by Centre for Social and Economic Progress (CSEP) finds that the benefits depend on system size, household consumption, tariffs and net-metering. Lower-consuming households may face longer payback periods than higher-consuming ones.

Surat has emerged as a major example of this expansion, with 93,886 PM Surya Ghar installations reported in July 2026. The case shows how decentralised solar can turn consumers into "prosumers" who both produce and consume electricity. However, higher-consuming and financially stronger households may capture greater benefits, meaning that rising installation numbers do not necessarily ensure an equal distribution of benefits.

Case Study 3: Dezhou, Shandong, China

Dezhou illustrates how distributed RE can become part of a broader local development strategy. The city has a long history of promoting solar technology and was designated a "Solar City" in 2005. Its experience initially developed around solar water heaters and later expanded into photovoltaic generation. By May 2023, Dezhou had 7.608 million kW (7.608 GW) of RE capacity, equal to 68.7 per cent of total installed capacity. Renewable electricity generation was 67.9 billion kWh, accounting for 55.6 per cent of the city's total electricity consumption, the highest share in Shandong province at the time.

Research on Dezhou's solar development has identified close interaction between local government, private firms, manufacturers, households and financial institutions as an important reason for its earlier solar-water-heater success. More recent research on Dezhou's rooftop PV expansion, however, raises a more complicated question about participation. A 2026 study found that rural households can receive fixed rental payments for allowing rooftop PV development, but that local participation in decision-making and long-term ownership can remain limited. This suggests that economic participation is not necessarily the same as community participation (ScienceDirect).

Lessons for India

For India, the most relevant lesson is, therefore, not to reproduce China's model mechanically, but to strengthen the local institutional foundations of decentralised energy. PM-KUSUM could be combined more systematically with micro-irrigation and groundwater management, while PM Surya Ghar could place greater emphasis on affordable finance and access for lower-consuming households.

> **Economic participation is not necessarily the same as community participation.**
>
> Amulya Yadav
> Master's in Economics student, Galgotias University

Both programmes would benefit from stronger local monitoring of actual electricity generation rather than measuring success only through installed capacity. Also, another important initiative our government can take is to mandate that government buildings should use RE for day-to-day energy consumption. Another good thing about the Shandong project is that companies pay local households because they let them use their roofs for putting up solar panels -- we can directly copy this idea in India.

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2026 research on China's rural solar transition and Dezhou rooftop PV

Amulya is doing her Master's in Economics from Galgotias University in Uttar Pradesh.

DECENTRALISED RENEWABLE ENERGY AND LOCAL SOLUTIONS



Patoda's Quiet Transition

Amruta
Upendra Shukla

What a village of 2,400 built, how it paid for it, and why it worked there and not in the city just five km away

Patoda, a gram panchayat of roughly 2,400 people, is about five km from Chhatrapati Sambhajinagar, a city of over a million. It has won over 20 awards, including the Carbon Neutral Vishesh Panchayat Puraskar in 2023, and was mentioned by the Prime Minister in his 'Mann Ki Baat' show in June 2025.

The dominant narrative about Patoda is actually a cleanliness story; its energy record is not discussed much, but it is interesting (see Table). The sequence matters more than the list. Former sarpanch Bhaskar Pere, who was at the helm when it all started, did not begin with solar panels, but with discipline -- mandatory toilets, water meters, covered drains and segregated waste with services villagers could see and avail of, such as free flour mills, cheap water and a working anganwadi. The village's recovery reached 90-95 per cent, and the panchayat could then afford solar street lights, biogas and solar water heaters: this cut down the recurring power bill and released money for the next service.



Interventions at a glance in Patoda

Intervention	Scale and detail	How it was financed	What it displaced
Solar street lighting	About 15 lights across the village	Panchayat's own revenue	Grid street lighting and the panchayat's monthly power bill
Biogas	11 plants; 2 connected directly to toilets	Panchayat support plus household contribution	Firewood and LPG for cooking
Solar water heaters	Household level, promoted village-wide	Household contribution plus scheme support	Firewood burnt to heat water
RO drinking water	Purification plant with a water vending machine, sold at a nominal charge	Tax revenue plus a small user charge	Unsafe water; household spend on bottled water
Free flour mills	2 mills, free for households that pay tax on time	Panchayat revenue	Paid milling outside the village
Waste management	2 bins per household for wet and dry waste; plastic collected weekly and sold by the panchayat	Panchayat budget, part-recovered from recyclables	Open dumping and burning
Wastewater	Treated before release into the river	Panchayat budget	Untreated discharge
Cremation practice	Cow-dung cakes used for last rites; ashes used to plant a memorial tree	Community practice	Firewood pyres
Discipline and monitoring	Mandatory household toilets and water meters; around 100 CCTV cameras	Panchayat revenue	Unmetered water use; weak enforcement

Source: Compiled from Gram Panchayat Patoda records, Loksatta and Divya Marathi reporting, and Ecoideaz field documentation

Gram panchayats are constitutionally responsible for street lighting, but are always short of own-source revenue: a study of 5,212 panchayats in Karnataka found they cannot afford even to maintain street lights. Rural supply has improved from 12.5 hours a day in 2014 to about 21.9, yet 17.6 per cent of generated electricity is lost before reaching a village.

> **Patoda's achievement is fiscal, not technological.**
>
> Shukla Amruta Upendra
>
> BSc student, KTHM College, Nashik

Patoda's achievement is fiscal, not technological. Its engine is a loop: services build tax compliance, compliance builds own revenue, revenue buys energy assets, energy assets cut bills, and the savings fund the next service. Chhatrapati Sambhajinagar, five km away, cannot copy it though it has more capital, engineers and schemes. The reasons are structural, not moral (see Table).

A village and a city

Dimension	Village (Patoda)	City (Chhatrapati Sambhajinagar)
Decision-making	One gram sabha, one sarpanch, one budget; a decision can be taken and seen the same year	Multiple departments, contractors and ward politics; accountability is diffuse
Roof and land	Panchayat land and owner-occupied roofs, available and undisputed	Tenancy, apartments and contested roof rights make siting slow
Demand shape	Daytime-heavy irrigation, milling, water pumping which matches solar output directly	Sharp evening peak from lighting and cooling, which needs costly storage
Position on the grid	At the tail of a feeder where losses are highest, so local generation is worth more per unit	Close to substations; the marginal system gain from local generation is smaller
Waste stream	Largely organic and segregated at source, so it can feed biogas and compost	Mixed, high-volume and largely landfilled
Visibility of failure	A dead street light is noticed by everyone the same night	A failure can persist for months inside a complaint system
Cost of change	Building a system where none existed	Retrofitting, and often demolishing, systems already in place

Source: District-level household carbon footprint estimates reported in IndiaSpend, based on NSSO expenditure data linked to supply-chain emissions.

A solar rupee buys more welfare in a village. It displaces diesel in irrigation pumps, kerosene in lamps and firewood in kitchens; generates where network losses are the greatest -- a unit produced in Patoda is worth more than one from a distant solar park. Cities are where India's emissions concentrate; villages are where low-carbon systems are still cheap to build, because nothing has to be torn down first.

Policy has blind spots as well. PM Surya Ghar's Model Solar Village component offers ₹1 crore per district, but only revenue villages with over 5,000 population may compete. Patoda's population is 2,368; it is ineligible for the scheme.

Patoda's renewable energy still only saves money; it does not earn any. Tractors are big fuel guzzlers in India. CSIR-CMERI's compact electric tractor, the PRIMA ET11, targets farmers owning under two hectare (over 80 per cent of India's farmers); its electric tiller supports solar DC charging with swappable batteries. Patoda already runs a shared, panchayat-owned electric machine in its flour mill. The same model, applied to e-tillers hired by the hour, can turn a savings story into an income story.

How to move forward

Fix the population threshold. Add a small village category to the Model Solar Village component, or let adjacent panchayats apply as a cluster with grants scaled to population.

Mandate a Village Energy Fund. Ring-fence a share of measured savings from solar street lighting and rooftop solar into a maintenance corpus.

Contract for uptime, not installation. Make a five-year maintenance contract compulsory in publicly-funded rural DRE procurement, with vendor payment tied to verified functioning days.

Institutionalise. Create a statutory Village Energy Committee with written procedures, so the system survives an election.

Fund shared solar charging for farm machinery. Pair PM-KUSUM with a panchayat-owned charging point for e-tillers, on the flour-mill model: collectively owned, individually used.

Standardise the claim. Patoda's carbon neutrality is not independently audited, and no greenhouse gas protocol exists for a gram panchayat. A one-page annual energy template, scored within the panchayat climate awards, would make the claim measurable rather than reputational.

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Amruta is a First Year Bachelor of Science student at KTHM College in Nashik, Maharashtra.

TRACK

5 THE ELECTRIFICATION OF EVERYDAY LIFE



THE ELECTRIFICATION OF EVERYDAY LIFE



Yaikhombi Thounaojam

LPG to Electric Cooking

Household adaptation and affordability in Shillong, Meghalaya

Shillong is a hill station in northeast India and the capital of the state of Meghalaya. According to NFHS-5 (2019-2020), 91.9 per cent of Meghalaya's households had access to electricity, but only 33.7 per cent used clean cooking fuels. Research on household energy in India has found that the transition to modern and cleaner cooking energy can be impacted also by the cost of making the transition – and not only by whether the energy source is available.

With the recent war-induced crisis in access to LPG, there has been a move towards electric cooking – in Shillong, the transition has varied across households.

Middle- and higher-income households might have been able to respond to supply challenges more flexibly and adapt to the new circumstances. They would have purchased induction cookers, electric rice cookers and other necessary appliances without encountering a significant stress on their household budgets. But the transition to electric cooking would increase electricity consumption and power bills.





For lower-income households, the situation can be more challenging. Purchasing new appliances can be more difficult compared to the cost of an LPG refill. Moreover, even if a new induction cooker is purchased, the use of electricity will require continued and heavier bill payments.

When LPG becomes unavailable or unaffordable and an electric alternative is inaccessible in terms of cost, some families may be forced to rely on firewood or other solid fuels to meet their cooking needs. The use of solid fuels can bring additional challenges: it will generate smoke and indoor air pollution, particularly if these fuels are burned in an enclosed space. Affordability is a critical factor: a household may prefer a cleaner environment generated by an LPG or electric stove, but it would choose to continue using firewood which is a cheaper alternative.

This writer did a short comparative study among 15 households on the use of electrical appliances. It was found that people preferred using pressure cookers over an electric rice cooker – the main reason was frequent power cuts in Shillong; it rains a lot in Shillong, and long power cuts usually accompany every bout of rain.

On the other hand, people who cannot afford these expensive appliances use charcoal and firewood – fuels which lead to indoor air pollution and unhygienic cooking practices.

The writer recommends making electricity supply more reliable and affordable -- frequent power cuts can act as a key barrier to transitioning to cleaner energy solutions. For a majority of the households in Shillong, an effective transition would necessitate the availability of a consistent electricity supply and access to reasonably priced, energy-efficient appliances and electricity consumption knowledge.

Frequent power cuts can act as a key barrier to transitioning to cleaner energy solutions.

Yaikhombi Thounaojam

BSc Zoology student, St Edmund's College, Shillong

Yaikhombi is a Bachelor of Science student in Zoology at the Shillong-based St Edmund's College.

THE ELECTRIFICATION OF EVERYDAY LIFE



Shruti Sikder

The Cooling Paradox

How powering millions of air conditioners heats up Bengaluru's streets and overloads the grid

As Bengaluru gets hotter, air conditioning is becoming less of a luxury and more of a necessity for many households. But the problem is while an air conditioner cools the room by taking the heat out of it, this heat is then released outside into the atmosphere; to add to this, an AC also consumes a considerable amount of electricity. This raises a simple question: as Bengaluru becomes hotter and more densely built, could increasing our dependence on air conditioning also be making the outdoor environment warmer and putting more pressure on the power grid?

Bengaluru's changing urban environment

Over the past three decades, Bengaluru has undergone significant changes in its population, density, built form, electricity demand and natural environment. The following timeline brings these changes together to understand how the city's relationship with cooling and electricity has evolved.

The table shows a clear shift from a city that could rely more on natural ventilation and cooling towards one that increasingly depends on electricity-powered cooling.



Decadal evidence

Decade/year	1990-1995	2001-2005	2011-2015	2021-2025
Population and density (Census/Master Plan)	~4.1 million Density: ~6,200/km²	~5.7 million Density: ~7,800/km²	~8.4 million (2011 Census) Density: ~11,500/km²	~13.5-14.5 million Density: >14,000/km² (core >30,000/km²)
Master Plan iteration and density policy	CDP 1985 / CDP 1995 Revision: Low FAR (1.0-1.5), independent plots, low-rise concrete/tiled roofs with natural airflow	Pre-RMP 2015 studies: IT corridor boom begins; conversion of agricultural fringes into tech campuses	RMP 2015: FAR boosted to 2.5-3.25; rapid vertical multi-family apartments across Mahadevapura, Whitefield	Draft RMP 2031 framework: High-density transit corridors, deep floor plates, minimal ventilation setbacks
Summer peak power demand (BESCOM/KPTCL)	~650-850 MW (broadly industrial/lighting driven)	~1,400-1,850 MW	~3,200-4,000 MW	Surpassed 8,400 MW (approaching 8,800 MW in extreme heatwaves)
Ambient max temperature and AC role (IMD, BEE)	Average summer max: ~33.5°C; ACs were rare luxury goods; residential EPI: ~30-45 kWh/m²/yr.	Average summer max: ~34.2°C; Commercial AC use expands; residential AC penetration remains under 5%	Average summer max: ~35.4°C. Split AC adoption spreads rapidly across middle-class homes	Summer peak days exceed 38°C. Residential cooling drives 30%-42% of peak summer household draw; EPI: 110-160 kWh/m²/yr
Blue and green cover	Green cover: ~35%-40% of city area. Hundreds of active, interconnected lakes	Green cover: Dropped below 25%. Waterbodies: Shrinking and fragmenting due to peripheral layout development	Green cover: Fallen below 15%. Waterbodies: Loss of over 60% of original water spread area	Green cover: Down by ~88% since 1973. Waterbodies: Down by ~79%. Evaporative cooling is almost completely lost



The cooling paradox

An air conditioner does not actually make heat disappear. It takes heat from inside a room and releases it outside through the outdoor condenser. The compressor also produces waste heat while running. When thousands of AC units are operating across a dense neighbourhood, this heat is released directly into streets and spaces around buildings.

There is another side to the problem: electricity. When many households switch on their ACs at the same time, particularly between 10 PM and 2 AM, electricity demand rises sharply. This becomes especially challenging at night because solar power cannot meet this demand, putting additional pressure on the electricity system.

This creates a cycle: higher temperatures lead to more AC use, more AC use means more electricity consumption and more heat being released outdoors; at the same time, the loss of green and blue spaces makes the city increasingly dependent on mechanical cooling.

The way forward

The Bengaluru case makes it clear that simply producing more electricity is not enough. We also need to think about why the demand for cooling is increasing in the first place.

One possible approach is to manage peak electricity use through digital smart meters and higher tariffs during the 10 PM-2 AM period for households consuming more than 400 units per month. Encouraging people to set their ACs at around 24°C-26°C instead of very low temperatures could also help reduce unnecessary electricity consumption.

At the same time, the city needs to reduce its dependence on ACs by improving natural cooling. Protecting green spaces and waterbodies, improving ventilation in buildings and reducing heat build-up in dense neighbourhoods can all help.

Shruti is studying for her Bachelor's degree in planning at the School of Planning and Architecture in Delhi.

THE ELECTRIFICATION OF EVERYDAY LIFE



Elma Malik

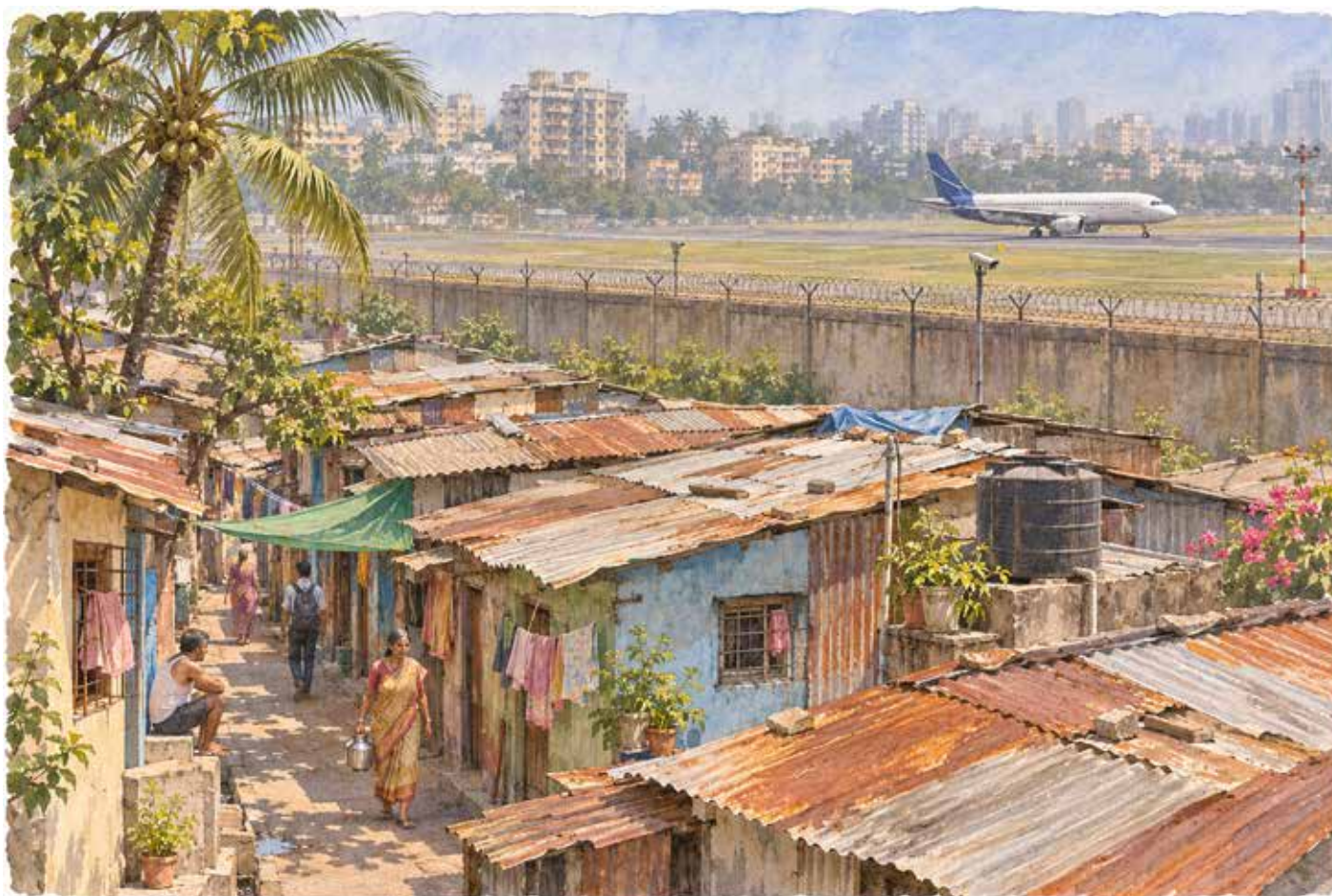
Localised concerns require multi-pronged solutions

Reconciling urban heat, equity in slum cooling and aviation safety in peri-airport Mumbai

It is easy to look at a busy airport runway and see only global travel, or to look at the crowded rooftops beside it and see only housing. We rarely realise that these two spaces form an interconnected urban crisis: standard urban city cooling methods like planting trees, expanding parks, or adding waterbodies are restricted around runway approach zones under aviation safety rules to prevent attracting birds into flight paths.

This article examines how Mumbai can reduce heat stress and cooling-energy demand in its peri-airport settlements using alternative infrastructure, good waste management practices, and policy solutions that align with strict aviation safety constraints.

Imagine a tin-sheet roofed house in Mumbai's Kurla, literally boiling inside at 40°C temperature; the air is thick enough to chew, and the measly ceiling fan is just stirring hot soup. Ask someone trying to survive that room whether they care about a mid-air bird strike, and the answer would be obvious: "I can't afford a flight, why do I care if a plane hits a bird?"



Mumbai's Chhatrapati Shivaji Maharaj International Airport (CSMIA) sits right at the heart of the city. While the airport has achieved notable sustainability milestones like sourcing its electricity from renewable power, the vast expanses of unbroken low-albedo asphalt and concrete required for its runways absorb and retain massive amounts of thermal energy, creating a prominent urban heat island (UHI) of its own, directly inside the urban core.

The Mumbai Climate Action Plan (MCAP, 2022) finds that land surface temperatures in Mumbai's slums run as high as at the airport itself: these are 5-8°C hotter than in the greener, lower-density neighbourhoods (about 42 per cent of the city's population lives in these slums). The same plan records a rising toll of extreme-heat days: caution-level days (26-32°C) and extreme-caution days (32-42°C) together now affect the city for over 360 days a year, a trend MCAP links to concretisation and vanishing green cover since 2007.

But, catch this… This heat has an energy cost on both sides of the boundary wall. CSMIA itself now sources 100 per cent of its electricity from renewable power and is targeting net-zero operations by 2029.

Directly abutting the airport boundary lie informal settlements such as Kurla, Jari Mari, Sakinaka and Asalpha. Without much access to active cooling like air conditioning, residents rely on basic electric fans that often just recirculate ambient, superheated air.

Studies and field surveys of indoor thermal comfort in Mumbai's informal settlements show that indoor temperatures under metal roofs frequently reach or exceed 40°C, often far hotter than the outdoor air temperature. Additionally, due to Mumbai's high coastal humidity, high indoor heat pushes indoor wet-bulb temperatures close to critical human physiological thresholds.

Add to this the aspect of soaring kites and other birds. Black kites and other birds of prey use thermal soaring to fly without burning much energy. As the sun bakes the airport's open asphalt runways and the surrounding metal roofs, the superheated surfaces warm the air directly above them. This warm air rises quickly, creating strong invisible columns of air called thermal updrafts. Kites ride these updrafts to lift themselves high into the sky and glide effortlessly without continuously flapping their wings. What is a problem is the presence of open garbage dumps and illegal meat shops in the surrounding neighborhoods. While these soaring birds are a visible effect of localised surface heat, the bird-strike risk to aircrafts is driven by what attracts birds into the flight path for their food.

The airport's heat island effect that is essentially a land-use and materials problem. Separately, the waste and illegal meat trade in the area is a waste-governance and enforcement problem. How are we solving this? An example is the Mahila Housing Trust's cool-roof programme in Ahmedabad's slums, where solar-reflective white paint has been applied to over 20,000 tin roofs; it has been reported that this has cut indoor temperatures by roughly 5-6°C.

The question that arises here is "would aviation regulators permit large-scale reflective white coatings directly adjacent to approach paths, or would the resulting solar glint create hazardous visual interference for pilots during critical phases of flight?"

Solving them requires addressing heat, roofing materials, and trash as one connected policy.

Elma Malik

MSc student, Environment Science and Disaster Management

Some recommendations

Pilot project of cool-roof retrofits for peri-airport slums: Deploy matte, non-glare, high solar-reflectance index white or lime colour coatings on tin roofs within the CSMIA perimeter wards, prioritising diffuse rather than glossy finishes so no glare is directed at approach or departure flight paths.

Closed-loop organic waste-to-energy: Route unsegregated fish, meat and vegetable-market waste from such areas into a decentralised closed biodigesters instead of open dumps; the biogas produced can displace LPG/electric cooking load in the local households.

Neither safety rules nor urban greening need to yield to each other. Mumbai simply needs to acknowledge that its hottest thermal hotspot and its highest-risk bird-strike zone share the same area. A resident's high electricity bill stems from extreme surface heat. A bird in a pilot's flight path stems from uncollected organic waste. They are two separate problems happening at the exact same fence line, and solving them requires addressing heat, roofing materials, and trash as one connected policy.



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Elma is doing her MSc in Environment Science and Disaster Management from the Ramniranjan Jhunjhunwala College in Maharashtra.

TRACK

6 DIGITAL INFRASTRUCTURE AND ENERGY



DIGITAL INFRASTRUCTURE AND ENERGY



A single image, a huge consequence

Shilpi Shukla

These days, everyone is engaged in making AI-based photos. Until some days ago, 80's style photographs were the rage -- a filter with vintage effect, retro styling etc. A similar thing was the Studio Ghibli trend in March 2025, with entire feeds turned into Miyazaki characters. People converted photographs of their weddings, pets and childhood into Ghibli art. OpenAI reported over 700 million images were generated in just a few days during that period.

We take this for granted because we think that AI is free. But a single AI image needs around 2.9 Watt-hour of electricity and 29 ml of water for cooling the server. On the face of it, this is a tiny amount -- until crores of people start using it.

The maths behind it

During the Ghibli trend, people did not create only one image or post. For the purposes of arriving at an estimate, let's assume one person created an average of 10 images. India's population is about 140 crore -- if only half of this population (70 crore) creates AI photos in this manner, there would be seven billion images.

Electricity needed: 2.9 x 7 billion = ~21 Twh

Water needed: 29 ml x 7 billion = ~211 billion litre

Compare with what is required in our cities. Mumbai's annual





electricity intake is around 20-22 Twh – thus, half of India making 10 AI images each is equal to powering the whole of Mumbai city for one whole year. In Bengaluru, the authorities supply around 1.45 billion litre per day of water -- 211 billion litres would be around 145 days of Bengaluru's whole water supply.

Our small AI-generated images have the power to empty the resources of big cities.

The inside story of data centres: Where is this cost going?

The electricity and water are not used by mobile phones; they are being used by data centres. For instance, Greater Noida is emerging as India's aspiring data hub. According to industry reports, India's data centre capacity was 1 GW in 2023 and will become 9 GW in 2030. About 30 per cent of it will be in Greater Noida. A hub with 2,700 MW IT load needs about 35 TWh electricity annually.

Right now, 60-70 per cent of that still comes from coal. During peak digital months, PM2.5 levels around these hubs go up to 90-120 μg/m3 in winters, while the safe limit is 40 μg/m3. Besides the obvious health impacts, this has a huge carbon footprint which is as yet invisible to our digitally-enabled existence.

Millions of people creating images over three-four days forces data centres to run in peak load, which is the least energy-efficient mode. To add to this, we never delete those images -- they remain in the cloud server forever needing back-up power for years. And this is how we generate permanent environmental damage while indulging in a temporary trend.

So, is AI bad?

Absolutely not. AI increases human efficiency and saves time. But there is a saying in Sanskrit "अति सर्वत्र वर्जयेत्" – this means anything that more than required is not good. So, it is up to us how we use it wisely.

We should adopt PUE<1.3 as a standard, which means less than 30 per cent extra energy for cooling. New methods like liquid cooling and AI-based load management can save 30 per cent energy. If a large hub shifts to 50 per cent solar and reuses waste heat, it can save around 15 million tonne of CO2 per year.

Some states have made green power purchase mandatory. Uttar Pradesh's Data Centre Policy 2023 only offers incentives -- it is not compulsory yet. We need stronger rules and better monitoring by regulatory agencies.

For people like you and me, we should think before we provide the prompts -- try to get it right in one or two attempts, not 15. Delete extra versions, do not keep everything on the cloud. We should ask ourselves: Is this image necessary or am I doing it because everyone is doing it? I know the pictures look beautiful, but behind them lie a hidden bill of huge loss of water and electricity, and health impacts.

Is this image necessary or am I doing it because everyone is doing it?

Shilpi Shukla

Master's student in Zoology, DBS College, Kanpur Nagar

Shilpi is pursuing her Master's in Zoology from DBS College in Kanpur Nagar, Uttar Pradesh.

DIGITAL INFRASTRUCTURE AND ENERGY



Drying oceans

The impact of data centres on Indian coastal ecosystems

Dewanshi Narayan

With growing demand for cloud-based services and generative AI, data centres that support these services have increased exponentially. Because of its geography and favourable policies like tax holidays for eligible foreign cloud service providers, global mega corporations like Amazon, Google and Meta are investing in India, making it an emerging market for digital infrastructure. According to the Press Information Bureau, approximately US $70 billion has already been invested in India's data centre sector.

While such investments are creating new opportunities for economic growth, this rapid expansion of digital infrastructure is putting a strain on natural resources and energy demand. The total data centre capacity in the country has increased from about 375 MW in 2020 to around 1,500 MW by 2025 and is projected to reach up to 13.56 GW by the year 2031-32. Such increasing demand for energy, land, connectivity and cooling infrastructure has compelled corporations to set up data centres in coastal areas.

Coastal regions bring a unique set of features favourable for data centres, like availability of efficient transport and connectivity, access to ocean water for cooling, etc. In India, coastal cities like Mumbai, Chennai and Visakhapatnam, amongst others, house a majority of data centres.

Mumbai: India's data-centre leader

The financial capital of India, Mumbai, along with Navi Mumbai, has the highest operational data-centre capacity at 790 MW. As per a report by Redseer Energy Consultants, Mumbai accounts for almost 50 per cent of India's installed data centre capacity. Owing to its strategic location, the city provides numerous advantages like



undersea cable connectivity and cooling facilities. Its proximity to companies provides excellent connectivity. The Government of Maharashtra has classified data centres as "essential services", thereby providing them enormous incentives like quick approvals, relaxation in taxes and compliance, and even permitting construction in green belts. However, this has put an enormous strain on the power grids, reinforcing coal dependency.

The conflict of Visakhapatnam

Tech giant Google's India data-centre hub, estimated at US $15 billion, has faced opposition from locals and environmentalists regarding growing concerns over water supplies, pollution and damage to wildlife. Concerns were also raised regarding noise pollution and other ecological impacts on the Kambalakonda Wildlife Sanctuary located just 860 metre away from the centre. A legal battle has been ongoing at the High Court of Andhra Pradesh to address the issues raised by protestors.

"Green" data centre in Nicobar

In August 2026, a proposal for a green data centre in Andaman and Nicobar Islands was put forth by the government. Claiming to be a greener alternative, it boasted several features like "renewable energy-powered operations", "seawater-based or other innovative cooling systems", etc. While such sustainable alternatives are required, not enough research has been done to find an effective substitute for freshwater cooling or a complete shift to renewables. The islands are endowed with rich biodiversity and home to endemic flora and fauna. Thus, any construction projects pose a great risk to the fragile ecosystem; priority, in the form of policy support and funding, should be given to conducting proper research and studies to develop practical and greener alternatives without disrupting the local biodiversity.

The project has since been scrapped due to administrative reasons. However, it should still stand as a reminder that sustainability and development should go hand-in-hand, and while island ecosystems provide numerous benefits for the installation of data centres, attention should be given to local communities, native wildlife, and long-term impacts.

Challenges

The biggest question is whether India can keep up with the demand without endangering the natural resources and livelihoods of people. The development in digital infrastructure stands in sharp contrast with the living conditions of the people. India's data centres consumed roughly 150 billion litre of water in 2024-25, while the country is still facing a water crisis, with over 600 million people facing high to extreme water stress. Other challenges include a lack of specific legal provisions; data centres do not require specific environmental clearances as per the Environmental Impact Assessment Notification, 2006, which leads to an inability to consider their specific impacts.

Inspiration can be taken from the UN guidelines on sustainable data centres, and India can implement standard guidelines for water management, and data centre operators can be directed to be more transparent with their water and energy consumption practices. Similarly, India can work on maintaining a comprehensive database that collects and publishes data relevant to the energy performance and water footprint of data centres with significant energy consumption, as is done in the European Union.

India must balance the growing demand for energy and infrastructure with conserving the environment.

Dewanshi Narayan
LLB student, University of Delhi

Establishment of data centres in or near oceans provides many benefits, making it a sustainable alternative; for instance, Japan is building data centres on floating platforms to reduce demand for land, powered by solar panels installed on floating platforms which cut down emissions and coal dependency. Coastal data centres cut down on freshwater consumption; however, they can disrupt the nearby marine life; also, maintenance in the ocean proves to be more difficult and costly.

The coming years are crucial as the impact of climate change worsens each day, and India must balance the growing demand for energy and infrastructure with conserving the environment. Prioritising awareness, education and training to make people aware of this new phenomenon is vital. India, especially the coastal states, can strive to develop while protecting the fragile coastal and marine ecosystem.

Dewanshi is in the LLB course in University of Delhi.

DIGITAL INFRASTRUCTURE AND ENERGY



Dimple Sharma

Rajasthan's AI Data Centre Boom

Can the desert state afford its energy and water footprint?

Rajasthan is on its way to becoming the next major data centre hub of India. In July 2026, chief minister Bhajan Lal Sharma met investors from the data centre industry in Jaipur, announcing that the state has received over Rs 43,000 crore in investment proposals; companies like STT GDC, HG Akaya, Nayo Bolt and Ztudium are either in operation or are in the process of evaluating projects.

The newly notified Rajasthan AI/ML Policy 2026 classifies 'AI' as a 'Sunrise Industry 4.0 sector' for which asset-creation subsidies are offered, and green incentives are provided, with an additional interest subvention for eligible data centres. There is also the Rajasthan Data Centre Policy 2025, which mandates an annual asset creation incentive, exemptions on power charges and up to Rs 12.5 crore for a green solution incentive. Rajasthan, thus, is emerging as a competitor to Karnataka, Maharashtra and Tamil Nadu.

The state has renewable energy capacity of nearly 30 GW and a tier-4 government data centre; the state government is committed to offering single-window clearance of land and power. But lurking beneath the investment figures is a fact that Rajasthan is one of the most water-stressed parts of India, and data centres are among the thirstiest forms of digital infrastructure ever constructed.

What a data centre drinks and burns

Cooling, not computing, is what makes data centres thirsty. The heat emitted by servers is enormous, and many Indian data centres still use evaporative or chilled-water cooling to prevent burnout. An analysis by Down To Earth found that a single data centre of 20 MW consumes around 1.4 million litre of water per day, which equates to the water consumed by 27,000 urban homes



in a day. India already consumes an estimated 150 billion litre of water per year for its data centres, a number which would double by 2030 as capacity increases from nearly 375 MW in 2020 to nearly 8-10 GW by 2030, and will continue to rise substantially after that.

Beyond power requirements of servers and networking equipment, cooling systems can consume 30 to 50 per cent of a data centre's electricity needs. Much of this electricity comes with an understated water cost. Thermal generation requires water, so if you're building a data centre, its actual water footprint goes much higher than the pipes you connect to the cooling towers.

This freshwater dimension poses the greatest threat to a desert state. The majority of Indian plants rely on either municipal supply or groundwater, which are also relied upon by towns, farmers and households. Bengaluru, Mumbai and Chennai, which together host the bulk of India's existing capacity, have already experienced its impacts. Karnataka alone has about 32 data centres, with 31 of them packed in Bengaluru, which has been plagued by water scarcity in recent years and a thousand or more dry wells. Mumbai and Chennai account for nearly 70 per cent of the country's capacity, yet both these cities have their own documented water stress. Rajasthan, where natural water reserves are thin on the ground to start with, would be stepping up to new levels of industrial demand on a scarce resource even as it already struggles to provide for drinking and irrigation purposes over much of the state.

The regulatory gap

Down To Earth's evaluation of state frameworks revealed there is currently no major state data centre policy that mandates water usage data to be reported to a centralised framework. Rajasthan's AI/ML Policy 2026 contains the following principles on paper for fair, private, and transparent AI systems in government service, to go along with a commitment to human oversight and independent audits. These principles are based on algorithmic responsibility, rather than the physical resource impact of the infrastructure supporting the algorithms. There is no mandatory requirement to disclose water use or to grade water-stress potential before siting a data centre; neither is there a standard metric for water-use efficiency equivalent to that already followed by the policy for energy-efficiency.

That gap is significant as data centres are long-term investments. The type of cooling technology, the water supply and the degree of reliance on the local water supply at the time of construction are also likely to persist over the decades. With the water issue a key constraint, selecting sustainable alternatives for an already operational facility is considerably more expensive than choosing these options for newer ones, and the government's choice will have an impact on the state's water security long after 2047.

How Rajasthan can still make it right

There is still time to infuse safeguards into its data centre footprint before they become permanent. There are a couple of things that stand out here.

First, mandatory disclosure. As the CoE-AI is intended to monitor and evaluate the use of AI, any operator receiving incentives under the AI/ML Policy and the Data Centre Policy should be mandated to report water discharge and withdrawals on a public dashboard.

Cooling, not computing, is what makes data centres thirsty.

Dimple Sharma
PhD scholar, Guru Gobind Singh Indraprastha University, Delhi

Second, a push for treated wastewater for cooling. Redirecting a share of treated wastewater to data centre cooling towers, rather than freshwater or groundwater, would substantially reduce the sector's demand on drinking water supplies. Several policy commentators following the Indian Data Centre boom have pointed to the use of recycled and treated wastewater as the immediate solution that does not require new sources to be found, but only old pipes and the adoption of new procurement practices.

Third, location and technology are very crucial. Locating new facilities away from already water-stressed districts, incentivising air cooling or immersion cooling where feasible, and tying green incentives explicitly to water-use efficiency, not just renewable power sourcing, would align Rajasthan's ambitions with its actual resource constraints.

Rajasthan's AI ambitions and environmental impact need not be in conflict. The change will require a course correction right now, when the sector is still small enough to be turned around.

Dimple is pursuing her PhD from the Guru Gobind Singh Indraprastha University in Delhi.

DIGITAL INFRASTRUCTURE AND ENERGY



Water Use in Data Centres

Kanak Singh

Data centres use up about 1.4 million litre of water every day in India (https://www.orfonline.org/expert-speak/the-cloud-runs-on-water] – with 305 listed data centres in India and over 12,000 across the world [https://www.datacentermap.com/india/), one can imagine the huge quantum of water that the sector uses. Data centre developers are increasingly tapping into freshwater resources to quench the thirst of these centers, which is



putting nearby communities at risk.

More than half of India's data centres are in regions already facing water stress -- and they are not spread evenly either. A staggering 75 per cent of the country's data centres are packed into just five states — Maharashtra, Tamil Nadu, Karnataka, Telangana and Uttar Pradesh — housing 278 of them in total. This concentration is a risk — not just for the industry, but for the communities and ecosystems sharing the water.

A data centre's water footprint is made up of three components:

The water consumed by power plants generating the electricity that runs the facility

The water used directly on-site for cooling and operations

The water used in manufacturing processor chips. That water can come from different sources — blue sources like surface water and groundwater, piped sources such as municipal supply, and gray sources like treated or reclaimed water.

Reuse and recycle

Using recycled or non-potable water for cooling is a well-established practice, especially in dry or drought-prone areas, helping conserve limited drinking water where it is needed the most.

Treated used water (TUW) is a reliable, low-TDS source that data centres can benefit from. There is a potential win-win in reusing treated municipal wastewater. Reuse of treated wastewater is encouraged by the National Water Policy and some state reuse policies, but not yet mandated for data centres. At present, data centres also do not have standard reporting of water-use efficiency, source mix, or reuse.

Closed loop cooling systems

Closed-loop systems recycle the same water in a sealed circuit instead of constantly pulling fresh supply. The water absorbs heat from servers, gets cooled back down, and goes around again. You only lose a little to evaporation or blowdown, cutting freshwater use by 80-95 per cent.

Some designs go further -- liquid cooling or immersion cooling uses almost no water at all. For a data centre in a water-stressed area, that is the difference between competing with a city for drinking water and barely touching it.

Less water use in the cooling tower

Cooling towers use a lot of water and lose much of it to evaporation. The most effective way to lower their water usage is to reduce the amount of blowdown water, which is the water drained from the cooling tower to remove mineral build-up. You can do this by chemically treating the water and regularly maintaining your cooling tower.

Other options

Alternative cooling systems: Some cooling systems, such as industrial fans, do not use water. Depending on your data center's layout and requirements, alternative cooling options may be an effective choice.

Invest in water treatment solutions: Higher-quality water increases the efficiency of equipment, which helps reduce data centre energy consumption. Industrial water treatment solutions include services like cooling tower water treatment, boiler feedwater treatment and closed loop water treatment. These

> **There is a potential win-win in reusing treated municipal wastewater.**
>
> Kanak Singh

treatment solutions can help ensure you use only the highest quality water for cooling.

Schedule regular maintenance

Try remote monitoring technologies: Tracking data on metrics like temperature and flow rates can help determine areas for improvement and develop strategies to optimise the relationship between data centres and water usage.

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Kanak is pursuing B.Com at Sri Aurobindo College, University of Delhi

DIGITAL INFRASTRUCTURE AND ENERGY



Powering the Cloud

Sustainable growth for India's data centres

Kanishk Kumar

How can India balance its exponential cloud and AI-driven data centre expansion with severe localised groundwater depletion and carbon-heavy electrical grid dependencies? As digital infrastructure accelerates across major corridors (Chennai, Navi Mumbai, Noida, Hyderabad, Visakhapatnam), data centres have transformed passive facilities into continuous, high-volume consumers of electricity and water. Can the country address this issue through a unified regulatory framework?

Energy transition constraints in data hubs

Driven by data localisation mandates under the Ministry of Electronics and Information Technology (MeitY), rapid cloud adoption and national initiatives like the ₹10,372 crore IndiaAI Mission, India's installed data centre power capacity has surged from approximately 375 megawatt (MW) in 2020 to 1.57 gigawatt (GW) in 2026. Official projections from the Central Electricity Authority (CEA) estimate capacity to reach nearly 8 GW by 2030, with long-term digital demand potentially requiring up to 17 GW



by 2031-32.

Unlike conventional commercial real estate, data centre computing operates on a continuous 24/7/365 baseload schedule. To maintain server rack temperatures within operational thresholds (20°C to 25°C), facilities rely heavily on evaporative cooling towers, creating significant localised resource stress:

Aquifer stress: Hyperscale hubs are frequently seen in rapidly urbanising peri-urban belts where municipal water infrastructure is constrained, leading to high-volume groundwater extraction or relying on commercial water tankers.

Energy intensity: Connected directly to state power discoms, facilities draw thermal power heavily during non-solar hours and utilise localised diesel generators (DG) during grid fluctuations.

Micro-climate impact: Industrial HVAC thermal discharge venting into ambient air elevates micro-ambient temperatures in surrounding residential zones, whether in Delhi-NCR's industrial sectors or in coastal peri-urban clusters like Siruseri along Chennai's Old Mahabalipuram Road (OMR) corridor.

Evaluating the resource footprint of digital infrastructure requires assessing two core efficiency metrics:

Power Usage Effectiveness (PUE) -- total facility power divided by IT equipment power

Water Usage Effectiveness (WUE) – total litre of water consumed annually per kWh of IT load

Credible government datasets and field assessments highlight systemic pressure across both resource streams:

Water consumption intensity: Industry data indicates that conventional wet evaporative cooling towers consume between 1.5 and 2.5 litre of freshwater per kWh of IT load. A 30-MW hyperscale facility operating at capacity requires 1.5 to 2.0 million litre per day (MLD) of make-up water, matching the daily domestic allowance of over 12,000 urban households.

Groundwater vulnerability: The Central Ground Water Board's (CGWB) Dynamic Ground Water Resources Assessment reports that India's groundwater extraction stands at 60.47 per cent with 11.1 per cent of all assessment units classified as 'Over-Exploited'. Major data centre hubs in Thiruporur block (serving Siruseri), Gautam Buddha Nagar (UP) and Visakhapatnam operate directly within or adjacent to severely depleted aquifers.

Wastewater supply disconnect: While municipal bodies operate Tertiary Treated Reverse Osmosis (TTRO) plants (such as Chennai's 90-MLD unit), reclaimed water pipelines are predominantly allocated to heavy manufacturing, leaving data centres dependent on secondary freshwater suppliers.

Grid load and standards: To address efficiency, the Bureau of Indian Standards (BIS) and the Energy Conservation and Sustainable Building Code 2024 have established benchmarks for PUE, WUE, and Carbon Usage Effectiveness (CUE). However, CEA data confirms that non-solar baseload demand continues to rely on coal-heavy grid supply.

Insights and arguments

The fallacy of annual renewable offsets: Annual Renewable Energy Certificates (RECs) create a false impression of sustainability. A facility operating 24/7 cannot be considered zero-carbon if its night-time compute load is sustained by thermal grid power while off-setting emissions through midday solar credits.

Can the country address this issue through a unified regulatory framework?

Kanishk Kumar

Trade-off of water and energy: Switching from evaporative water cooling to dry air-cooling reduces water consumption but significantly increases electrical energy draw (raising PUE). In coal-dependent power grids, saving water through air-cooling can inadvertently increase net operational carbon emissions.

Absence of spatial resource audits: Policy frameworks currently treat data centres primarily as real estate or IT investments rather than heavy industrial utility consumers. Development of hyperscale facilities in water-stressed urban hubs creates ecological competition between digital servers and surrounding communities.

Policy recommendations: A three-phase framework

To align India's digital infrastructure expansion with environmental sustainability, a three-phased regulatory framework is proposed:

Regulatory framework and EIA clearance standards (Enforcing Authority: Ministry of Environment, Forest and Climate Change MoEFCC)

EIA notification inclusion: Amend the Environment (Protection) Act, 1986, to bring data centers exceeding 10 MW capacity under mandatory Environmental Impact Assessment (EIA) notifications, requiring public resource audits before development.



Mandatory performance benchmarks: Enforce Bureau of Indian Standards (BIS) metrics across state data center policies, establishing maximum operational ceilings: PUE < 1.30 and WUE ≤ 0.2 L/kWh.

Mandatory circular water integration (Enforcing Authority: Central Ground Water Authority & State Water Boards, CMWSSB)

Reclaimed wastewater mandates: Prohibit the extraction of fresh groundwater or potable water for facility cooling in CGWB-designated over-exploited or critical blocks. Mandate dedicated dual-piping infrastructure connecting facilities directly to municipal TTRO wastewater plants.

Advanced cooling transition: Require state policy incentives to be contingent on adopting closed-loop dry cooling, direct-to-chip liquid cooling, immersion cooling, or seawater cooling in coastal hubs.

Grid and spatial planning reforms (Enforcing Authority: Ministry of Power & State Electricity Regulatory Commissions, SERCs)

24/7 hourly clean energy matching: Transition state incentives from annual RECs to hourly real-time clean energy matching, requiring operators to integrate Battery Energy Storage Systems (BESS) or round-the-clock hybrid solar-wind Power Purchase Agreements (PPAs).

Resource-informed siting incentives: Direct future hyperscale growth toward regions rich in renewable energy and non-potable water resources, preventing excessive infrastructure density in metropolitan coastal belts.

Kanishk is doing his BTech in Civil Engineering from the Vellore Institute of Technology in Chennai.

DIGITAL INFRASTRUCTURE AND ENERGY



The Green Paradox

Can AI truly be sustainable?

Resha Negi

AI is fundamentally dependent on electricity-intensive data centres (DC) which require uninterrupted power supply and Battery Energy Storage Systems (BESS) for power back-up. Due to the rapid acceleration of digitisation and demand for AI in almost every sector, investments in data centres have grown manifold. The International Energy Agency (IEA) reports that global investment in data centres reached around US $500 billion in 2024,



having nearly doubled since 2022.

The environmental performance data of tech companies – as revealed in their annual reports – is often insufficient to determine the performance of their data centres; often, whatever data is provided lacks authenticity.

According to the IEA report Energy and AI 2025, global power demand of data centres stood at approximately 415 TWh in 2024 (~1.5 per cent of global electricity consumption) and is projected to expand to roughly 945 TWh by 2030. In India, data centre capacity -- which reached 1.5 GW in 2025 -- is undergoing rapid expansion, with AI-linked infrastructure projected to demand an additional 40 to 45 TWh of electricity by 2030.

Many data centres face delays from electricity grid constraints; AI growth must be planned on localised grid capacity rather than land or power availability alone. Tackling this requires strategic management, including renewable energy deployment at appropriate location, battery storage and the required load shifting.

AI can enhance solar, wind, and storage technologies by utilising predictive machine learning to continuously analyse real-time sensor and weather data, optimising generation forecasts, dynamic charging, wake alignment, and automated maintenance schedules. Smart grids use real-time data loops to balance fluctuating renewable energy and smoothen out power demand, but sustaining this growth requires addressing AI's huge physical resource demands and adapting regulatory policies.

But, renewable energy-powered AI does not necessarily mean sustainable AI.

What is the environmental cost of AI and is it distributed fairly across the globe?

With global data centre water consumption projected by the International Energy Agency (IEA) to nearly double from 560 billion litre annually to over 1.2 trillion litre by 2030, site selection can no longer be driven solely by electricity costs. The majority of AI's water footprint is blue water extracted from rivers, lakes or groundwater, which is increasingly getting more limited in availability. The IEA reported about 140 billion litre of direct water consumption on a total data centre electricity consumption of 360 TWh in 2023. Also, emissions from data centre electricity use are projected to rise to 300 Mt by 2035 in the IEA base case.

According to the study Making AI Less 'Thirsty' published in 2025, the training phase of large-scale models represents a significant initial energy footprint. For example, training GPT-3 consumed 1,287 MWh of electricity and directly evaporated an estimated 700,000 litre of high-purity freshwater for onsite thermal management (consumption). Meta is the only company reporting 'water consumption embedded in purchased electricity' while also highlighting that this value is significantly higher than Meta's direct water consumption. Meta's self-reported scope-2 water consumption for its global datacentre fleet was 3.7L/kWh (that is, 55.475 billion litre) in 2023.

When examining the metrics in

> **Green AI must be evaluated across its entire life cycle, not only at the point of electricity consumption.**
>
> Resha Negi

for many data centre infrastructure in India, offsite scope-2 water consumption -- which is the water evaporated during electricity generation to power the data centre -- is estimated at 3.445 L/kWh (using the regional Electricity Water Intensity Factor, EWIF). This results in a total scope-2 offsite water consumption of approximately 6.340 million litre for model training. When evaluating user requests, processing a single medium-sized conversation prompt in India uses roughly 19.704 mL of offsite water, or approximately 25.4 user requests per 500 mL of water consumed.

There is a new digital divide in energy transition across developing economies like India, where, despite housing a large portion of the world's internet users, it houses small fraction of global data-centre capacity when compared to countries like the US, China and Germany. Major data centre hubs in India (such as Mumbai, Chennai, and Bengaluru) operate in regions with high local water stress. Operating direct evaporative cooling towers in these locations creates direct competition with municipal water requirements.

This necessitates regulatory shifts toward mandating closed-loop systems, dry-cooling

technologies, and zero-liquid-discharge (ZLD) plants using treated tertiary wastewater. Google's Carbon-Intelligent Computing System demonstrates sustainable load management using predictive models to shift delayed queries and increase flexibility of AI tasks until renewable power peaks reappear. The aim is to use carbon-free energy—reducing carbon intensity without extra hardware or performance lag.

Another challenge in a country like India arises in the form of increased coal dependency for baseload stability, creating a hindrance to net-zero path, renewable energy and decarbonisation targets. According to IRENA's report in 2026 the amount of annual end-of-life solar PV panels in India will reach half a million tonne by 2039. From 2035 to 2050, India is expected to handle an average of 1.2 Mt of end-of-life solar PV panels every year. Even if we use battery storage systems and renewable energy, India still needs to develop recycling and material recovery industrial units that help to tackle future waste problems.

What is the Green AI Paradox?

Green energy-powered AI paradox: The phenomenon represents the rebound effect or Jevons' Paradox, where making a resource more efficient lowers its cost, paradoxically driving an explosion in demand that increases total consumption. So, efficiency increase leads to demand of more data centres, servers, semiconductor production, electricity infrastructure and cooling infrastructure. The IEA warns that making AI cheaper and faster won't automatically cut power usage -- instead it can trigger higher AI integration, lower cost of deployment that ultimately push overall energy demand higher. Thus, measuring "energy efficiency per AI query" is an inadequate sustainability metric because volume growth might skyrocket, causing overall electricity and resource demand to rise. Efficiency is not equivalent to sustainability.

The carbon paradox: This is the contradiction where AI accelerates global greenhouse gas emissions while also serving as a tool to fight climate change. According to the IEA, emissions linked to electricity consumption in data centres are projected to rise from approximately 180 $MtCO_2$ to around 300 Mt by 2035 in its base case. The ongoing widespread deployment of existing AI technologies across key industrial sectors could cut energy-related emissions to support net-zero -- that might be more than the direct carbon output of data centres themselves. However, while these efficiency gains make AI a vital decarbonisation accelerator, they remain insufficient on their own to address systemic climate change, proving that technology alone cannot replace structural energy transition policy.

Green AI must be evaluated across its entire life cycle, not only at the point of electricity consumption.

Where do we go from here?

To truly achieve so called green AI, we must target both structural compute inefficiencies and industrial governance gaps. To achieve true sustainability, AI and data centre operations must minimise AI's environmental footprints across energy efficiency, closed-loop water cooling, implement air-cooling penalty, dark data sink risk elimination, dynamic load shifting, circular hardware lifecycles (like sustainable critical mineral extraction), grid decarbonisation, reduce cumulative carbon multipliers or emissions multiplier, prevent AI assistants from outputting energy-wasteful code, replacing inefficient air management, and destruction of native ecosystems, directly supporting SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation, and Infrastructure), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action).

In all levels of governance -- the legislature, judiciary and executive -- policy frameworks must evolve beyond legacy point-source pollution models like the Environment (Protection) Act, 1986. Moving forward requires resolving EIA ambiguity to specific subjects and environmental impact protocols, updating the E-Waste (Management) Rules, 2022 and Extended Producer Responsibility (EPR) frameworks to responsibly manage for AI hardware replacement cycles, and expanding privacy-focused rules like the Digital Personal Data Protection (DPDP) Act, 2023.

Resha is pursuing M.Tech at TERI School of Advanced Studies, Delhi

DIGITAL INFRASTRUCTURE AND ENERGY



Ritanshi Singh

Powering Ahead, Regulating Behind

India's data centre boom and the rules left catching up

India is targeting 10-12 gigawatt (GW) of data centre capacity by 2030. States are racing to attract investments through tax breaks, land subsidies and cheap power. This investment-centered approach is now raising concerns regarding its environmental and social costs, such as massive electricity and water consumption, strains on local grids, and site selection in ecologically sensitive of water-stressed regions.

To add to this, environmental obligations of data centre companies remain patchy, mostly voluntary, and lag far behind the provided incentives.

What is happening in the states

States are falling over themselves to offer these incentives. Maharashtra is offering permanent electricity duty exemptions and single-window clearance via the 'MAHITI' portal. Telangana provides power at cost of generation, dual power grids, land cost rebates and 100 per cent reimbursement of stamp duty and transfer fees.

Tamil Nadu has a 100 per cent electricity duty subsidy for five years, district-wise stamp duty



concessions, and land cost subsidies. Karnataka provides concessional industrial power tariffs, green energy tariff reimbursements and capital and land subsidies.

West Bengal has come up with electricity duty waivers, dual power grids, and uninterrupted water supply commitments. Gujarat offers electricity duty and SGST reimbursements and a 20-year power tariff subsidy; the state also mandates that at least 51 per cent of the core power consumption must come from renewable sources.

Rajasthan focuses on uninterrupted power, dedicated data centre parks, capital/asset creation incentives, mandatory wastewater recycling, and zero liquid discharge requirements for specific classes. Andhra Pradesh promotes seawater cooling for coastal data centres and offers SGST reimbursement or capital subsidies.

Odisha provides a 30 per cent power bill subsidy, land at concessional rates and 100 per cent stamp duty exemption. Uttar Pradesh superseded its 2021 policy with another policy in 2026, which targets over 20,000 MW capacity and offers land subsidies and interest/capital subsidies.

Haryana grants electricity suty exemptions, net SGST reimbursements of up to 75 per cent and stamp duty reimbursements. Chhattisgarh has offered electricity duty exemptions up to 12 years, seamless land allocation and extended duration fixed capital investment subsidies.

The gaps in the picture

Most states compete on the same four levers – subsidised power, land and stamp duty concessions, tax reimbursements and fast approvals. They are not matching these with environmental accountability. AI data centres usually do not require standalone environmental clearances unless they trigger large-building thresholds.

The 'Green Data Centre' guidelines issued by the Ministry of Electronics and Information Technology (MeitY) of the Government of India are advisory in nature and carry no legal penalties. Rajasthan is the only state which has tied incentives directly to environmental conditions like zero-liquid discharge.

What then is the way forward

This article proposes the following:

States must evaluate long-term impacts on land, water tables and power grids rather than solely competing on tax holidays.

Make the efficiency guidelines of MeitY legally enforceable.

Mandate water and energy disclosures at the state level.

Integrate community consultations before land and water allocations.

> **States must evaluate long-term impacts on land, water tables and power grids rather than solely competing on tax holidays.**
>
> Ritanshi Singh

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Ritanshi is pursuing an MBA at TERI School of Advanced Studies, Delhi



Centre for Science and Environment
41, Tughlakabad Institutional Area, New Delhi 110 062
Phone: 91-11-40616000 Fax: 91-11-29955879
E-mail: cse@cseindia.org Website: www.cseindia.org