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MINISTRY OF
NEW AND RENEWABLE ENERGY

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Renewable Energy

Akshay Urja

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Renewable Energy
Akshay Urja

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From the Editor's Desk...

Dear readers,

Welcome to the July 2025 edition of *Akshay Urja*! Over time, India has made substantial advancements in the renewable energy sector, positioning itself as a global frontrunner in clean energy initiatives. Our commitment to achieving 175 GW of renewable energy capacity by 2022, with plans to scale this up to 500 GW by 2030, exemplifies our dedication to fostering a green energy ecosystem. These ambitious targets are not just a testament to our resolve but also a crucial step towards fulfilling our obligations under the Paris Agreement.

Akshay Urja has featured updates on renewable energy developments across the country in every edition, which you are aware of.

The article on BIPV details how the new technology offers an edge over traditional solar PVs. A holistic and efficient solution for sustainable urban infrastructure, BIPV promise to deliver energy performance while maintaining architectural quality and design integrity. Another report on Anaerobic Gas Lift Reactor technology details how the technology offers a golden opportunity amid what is otherwise overlooked as waste. The piece advocates for the early adoption of technology and calls for mass awareness programmes. Another article talks about the current status of hydrogen in the transportation sector. It bats for hydrogen as a great alternative for long-distance freight and commercial transportation at a time when electric mobility has started picking up pace. Yet another piece details how solar cold storage is becoming an exemplar to provide cold storage solutions at the first mile itself. Serving remote, underserved parts of rural India, how the technology is aiding small and marginal farmers by avoiding spoilage and extending shelf life of fresh produce is being described in the article.

Keep sending your stories and ideas. We take pleasure in sharing them with the world at large. Thank you for your continued support.

Best wishes

Arun K Tripathi

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RENEWABLE ENERGY NEWS

SECI's Landmark Green Ammonia Tender set to Decarbonize India's Fertilizer Sector

The Solar Energy Corporation of India Limited (SECI), a 'navratna' Central Public Sector Undertaking under the aegis of Ministry of New and Renewable Energy (MNRE), has issued a landmark tender for offtake of Green Ammonia, aimed at decarbonizing India's fertilizer sector. The tender calls for the production and supply of 7,24,000 tonnes of green ammonia annually across 13 fertilizer plants, under the Strategic Interventions for Green Hydrogen Transition (SIGHT) Scheme - Mode 2A, Tranche I.

SECI will anchor demand aggregation and sign long-term offtake agreements, providing producers with market certainty over a 10-year contract period. The tender was issued on June 07, 2025 and the last date for bid submission was extended to June 30, 2025.

Ammonia, an essential component in urea and other nitrogen-based fertilizers, is currently produced using fossil fuels, leading to high greenhouse gas emissions. SECI's tender leverages renewable energy to produce green hydrogen and ammonia, promoting low-emission, domestic fertilizer production.

Launch of the City Accelerator Programme to Boost Rooftop Solar Adoption in Indian Cities

Shri Santosh Kumar Sarangi (IAS), Secretary, Ministry of New and Renewable Energy (MNRE), launched the City Accelerator Programme during the National Conference on Skill Development for Renewable Energy Workforce held at Atal Akshay Urja Bhawan, New Delhi. The programme is being implemented in collaboration with Shakti Sustainable Energy Foundation (SSEF).

The programme is a key initiative under the PM Surya Ghar: Muft Bijli Yojana (PMSGMBY), the world's largest domestic rooftop solar (RTS) scheme, and aims to drive faster adoption of RTS across Indian cities. The programme is designed to provide:

- Technical assistance to urban local bodies (ULBs) and DISCOMs
- Capacity building and institutional strengthening
- Support in designing enabling city-level policy and regulatory frameworks

A dedicated cell has been set up at MNRE, and teams will be deployed with implementation agencies in each city to ensure effective on-ground support and monitoring. By building solar-ready cities and creating replicable models, the City Accelerator Programme aims to transform India's urban energy landscape and contribute meaningfully towards clean energy transition.

MNRE Launches ₹2.3 crore Innovative Projects Start-Up Challenge to Accelerate Rooftop Solar and Distributed Renewable Energy Innovations

The Ministry of New and Renewable Energy (MNRE), Government of India, launched the Innovative Projects Start-Up Challenge on Rooftop Solar (RTS) and Distributed Renewable Energy (DRE) Technologies, during the National Conference on Skill Development for the Renewable Energy Workforce at Atal Akshay Urja Bhawan, New Delhi.

This unique national innovation challenge aims to identify and support breakthrough solutions for India's rooftop solar and distributed energy ecosystem. It is being implemented under the aegis of MNRE with support from the National Institute of Solar Energy (NISE), and in coordination with StartUp India, DPIIT.

The startup challenge seeks applications from innovators and startups in India, focusing on four key categories to boost renewable energy adoption:

1. Affordability – Making rooftop solar affordable for low and middle-income households using innovative financing, modular systems, and circular economy strategies.
2. Resilience – Enhancing climate resilience, grid stability, and cybersecurity in solar infrastructure, especially for vulnerable and remote areas.
3. Inclusivity – Expanding access to underserved communities through community solar, virtual net metering, and inclusive financing models.

4. Environmental Sustainability– Promoting eco-friendly technologies such as solar panel recycling, land-neutral solar deployment, and hybrid clean energy models.

The challenge welcomes a wide range of startups in green tech, IoT, AI, blockchain, construction, energy hardware, fintech, and waste management.

IREDA Successfully Raises ₹2,005.90 crore via QIP to Boost Green Financing

Indian Renewable Energy Development Agency Ltd (IREDA) has successfully raised ₹2,005.90 crore through a Qualified Institutions Placement (QIP). The capital was mobilized by issuing 12.15 crore equity shares at a price of ₹165.14 per share, which includes a premium of ₹155.14 per share over a face value of ₹10.

The issue price of ₹165.14 reflects a discount of 5.00% to the floor price of ₹173.83 per equity share. Launched on June 5, 2025, the QIP issue closed on June 10, 2025, receiving an encouraging response from a diverse set of both domestic and foreign qualified institutional buyers (QIBs) including insurance companies, scheduled commercial banks and foreign portfolio investors. The Board has approved allotment of equity shares to eligible qualified institutional buyers in its meeting held today, i.e., June 11, 2025.

The QIP was oversubscribed with bids amounting to ₹2,005.90 crore against the base issue size of ₹1,500 crore, achieving a subscription of 1.34 times. The capital raised through

this successful issue will further strengthen IREDA's Tier-I capital and overall capital adequacy ratio (CAR), enhancing the company's capacity to support the expanding renewable energy sector in India.

Diu is a National Example in Renewable Energy: Union Minister Pralhad Joshi

Union Minister for New and Renewable Energy, Shri Pralhad Joshi, said that Diu is a national example in renewable energy adoption, with its entire daytime electricity demand being met through solar energy. The minister also congratulated Diu's exceptional milestone as the first district in India to meet its entire power demand with solar energy, achieving 11.88 MW (9 MW ground-mounted + 2.88 MW rooftop) capacity. He was visiting Diu to review its remarkable progress in solar energy adoption and assess the implementation of the PM Surya Ghar: Muft Bijli Yojana.

World Hydrogen Summit 2025: India's Vision and Capabilities

Secretary, Ministry of New & Renewable Energy, Shri Santosh Kumar Sarangi addressed the World Hydrogen Summit 2025 in Rotterdam. During his keynote address, he highlighted India's strategic vision and capabilities in the domain of renewable energy and green hydrogen production. He underscored India's transformative potential of Green Hydrogen to become a global leader in this space. This ambition relies largely on India's strength in the renewable energy domain.

The Secretary highlighted that India has already installed over 223 GW of renewable energy that includes 108 GW from solar and 51 GW from wind—placing India among the fastest-growing renewable energy markets globally. He also reiterated India's vision to achieve energy independence by 2047 and reach net zero emissions by 2070.

To drive this transition, the National Green Hydrogen Mission was launched by the Government in 2023, with an initial allocation of $2.4 billion. It lays out a comprehensive roadmap to:

- Identify and create demand in potential sectors
- Provide production incentives for setting up domestic capacity
- Achieve 5 million metric tonnes of green hydrogen production by 2030
- Averting nearly 50 MMT of CO_2 emissions annually
- Attract investments of about $100 billion
- Generate over 6,00,000 jobs

All news items courtesy Ministry of New and Renewable Energy, Government of India

AMENDED

GUIDELINES FOR BIOMASS PROGRAMME

TO BOOST BIOENERGY AND EASE OF DOING BUSINESS

The Ministry of New and Renewable Energy (MNRE) has issued revised guidelines for the Biomass Programme under Phase-I of the National Bioenergy Programme, applicable for the period FY 2021–22 to 2025–26. These amendments aim to promote cleaner energy solutions, ease of doing business, and accelerate the adoption of biomass technologies across India.

Under the new framework, the Ministry has simplified several processes, such as cutting down paperwork and easing approval requirements, which will enable the industry, especially MSMEs, to enhance their production. These changes align well with the improvement of stubble management and India's broader goal of reaching net-zero emissions by 2070.

A total of 118 biomass projects, including biomass pellet/briquette and non-bagasse cogeneration, have been sanctioned with a total Central Financial Assistance (CFA) of ₹124.13 crore. Out of this, ₹23.75 crore has been disbursed so far. These projects have cumulatively developed a capacity of approximately 400 metric tonnes per hour (MTPH) of biomass briquettes and pellets, and 69 MW of biomass power, providing green power and steam to industries.

One of the major highlights of the revision is technological integration by enabling the use of IoT-based monitoring solutions or quarterly data submissions instead of expensive, high-tech systems like SCADA. This cost-effective step promotes digital monitoring and accountability, especially for smaller business operators.

The guidelines also encourage significant simplification of documentation requirements. Developers of briquette and pellet manufacturing plants will no longer be required to submit a number of documents related to clearance matters. The transition will save time as well as promote ease of doing business.

Biomass-based pellets

Non-bagasse-based biomass power generation project

In a move to enhance operational flexibility, the earlier requirement for a two-year briquette or pellet sale contract has been replaced with a general sale agreement. This change will allow project developers to respond more dynamically to market conditions without being constrained by long-term contracts. The amended guidelines allow flexible selling of biomass products, meaning businesses no longer need long-term contracts to get started.

Furthermore, the subsidy disbursement mechanism under the CFA component has been made performance-based and transparent. Projects that run efficiently, above 80%, will receive full financial assistance, while below 80% will receive the same on pro-rata basis.

The performance inspection period has been simplified. Earlier, it had to be done within a period of 18 months from the date of commission, but now, it can be carried out within 18 months period either from the commissioning date or from the date of in-principle approval, whichever is later. Additionally, to cater on-ground operational challenges of developers, Secretary, MNRE may extend the time period.

During inspection, performance report was made on the basis of operation plant at an average of 80% of rated capacity measured over a period of three consecutive days, taking an average of 16 hours per day. However, now it has been reduced to just 10 hours, as the inspection process primarily aims to verify the claimed and operational capacities and inspection for 10 hours continuous operation would suffice this purpose.

Recognizing the urgent need to address air pollution, especially from stubble burning in northern India, the new guidelines include a provision allowing biomass pellet producers in Delhi, Punjab, Haryana, and NCR districts of Rajasthan and Uttar Pradesh to choose the most beneficial support scheme, either from MNRE or CPCB.

These revisions will not only support smooth implementation of the biomass programme and timely delivery of approved financial support to commissioned plants but also encourage the sector to establish more biomass-based plants. This would ultimately help in addressing the menace of crop residue burning and ensure sustainable management of agricultural waste.

Overall, the updated guidelines will make it easier for businesses to adopt biomass technologies, provide financial incentives for efficient operations, and support India's clean energy efforts, all while promoting practical, business-friendly solutions to waste management and pollution reduction.

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WASTE-TO-ENERGY: AMENDED FRAMEWORK

EASES COMPLIANCE, SPEEDS UP FINANCIAL SUPPORT

The Ministry of New and Renewable Energy (MNRE) has issued revised guidelines for the Waste-to-Energy (WtE) Programme under the National Bioenergy Programme (NBP). These revisions aim to foster a more efficient, transparent, and performance-oriented ecosystem for bio-waste to energy deployment in India. By simplifying procedures, expediting financial assistance, and aligning support with plant performance, the updated guidelines are designed to significantly enhance the ease of doing business for private as well as public sector.

MSW-based CBG plant

Under the new framework, the Ministry has simplified several processes, such as cutting down on paperwork and easing approval requirements, which will enable the industries, especially MSMEs, to enhance their production of CBG, biogas & power. These changes align well with the improvement in waste management including stubble, industrial waste, and India’s broader goal of reaching net-zero emissions by 2070.

Since the start of NBP scheme, 78 WtE projects have been supported financially and ₹374.32 crore of Central Financial Assistance (CFA) have been sanctioned till date. Whereas around ₹92 crore have been disbursed for 27 WtE projects. To address the challenges faced by the developers, the revision in WtE guidelines was proposed.

A key highlight of the revised guidelines is the improved system for releasing CFA. Considering the challenges faced by the developers to achieve 80% generation, flexible provisions have been made in the scheme for release of CFA-based on plant performance. Previously, companies

Layout of CBG plant

Biogas cascading and dispensing system

had to wait until the entire WtE project attains 80% generation to receive support. Moreover, as per the revised guidelines, there is a provision to release the CFA in two stages. Based on the performance of projects, 50% of total CFA will be released after obtaining the consent to operate certificate from state pollution control board, against the bank guarantee, while the remaining half of the CFA would be released after achieving 80% of the rated capacity or the maximum CFA eligible capacity, whichever is lesser.

Notably, even if a plant does not achieve 80% generation for both conditions mentioned above during performance inspection, provision is made for pro-rata based disbursement based on the percentage output. However, no CFA will be given if the PLF is less than 50%.

This change acknowledges real-world challenges and supports developers by offering financial flexibility and viability during operations.

Fermented Organic Manure (FOM)

The inspection process has also been refined to ensure greater credibility, transparency and accountability. The revised norms mandate joint inspections led by National Institute of Bio-Energy (SSS-NIBE), an autonomous institute of MNRE, along with any one agency among the respective State Nodal Agencies (SNAs), Biogas Technology Development Centres (BTDCs), or any agency empanelled by MNRE. For developers not opting for advance CFA, only a single performance inspection is required, reducing procedural delays.

The introduced revision provides flexibility to the project developers in claiming CFA either within 18 months from the date of commissioning, or from the date of in-principle approval of CFA, whichever is later.

Overall, these revised guidelines represent a proactive step by the government to support clean energy in industries. By aligning financial support with actual performance, simplifying compliance, and making funding more accessible, MNRE is fostering a more business-friendly environment. This initiative not only helps private players in the WtE space but also strengthens India's progress towards sustainable waste management and renewable energy goals.

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India's Critical Mineral Self-Reliance

A Journey Towards Green Energy Transformation

When one talks about renewable energy, the term evokes solar panels, windmills and electric vehicles in public imagination. However, it is the critical minerals that drive the sustainable energy revolution and are the real actors behind the scenes. This article by **Dr Pipasa Layak** details India's critical mineral profile, its approach towards critical mineral security reflecting a balanced and forward-looking strategy.

As the nation advances towards its ambitious targets of 500 GW of non-fossil fuel power by 2030 and net-zero emissions by 2070, critical minerals emerge as invisible enablers powering this green transition.While solar panels, wind turbines, and electric vehicles capture public attention, it is the sophisticated interplay of specialized minerals that truly drives our sustainable energy revolution.

Critical Minerals: The Building Blocks of Clean Technologies

Critical minerals serve as the essential components that make modern clean energy systems possible. These materials are integral to every aspect of our renewable energy infrastructure, from the photovoltaic cells that convert sunlight into electricity to the permanent magnets that harness wind power and the advanced batteries that store clean energy for round-the-clock availability.

India's clean energy infrastructure relies on an intricate network of specialized materials across various technologies:

Clean Energy Technology	Key Critical Minerals	Applications
Solar PV	Silicon, Gallium, Tellurium, Indium, Copper	Solar cells and thin-film PV
Wind Turbines	Neodymium, Dysprosium, Copper	Permanent magnets for turbines
Battery Storage	Lithium, Cobalt, Nickel, Manganese, Graphite, Copper	Li-ion batteries and chemistries
Electric Vehicles (EVs)	Lithium, Cobalt, Nickel, Neodymium, Dysprosium, Graphite, Copper	Batteries and magnets for EV motors
Hydrogen/Electrolyzers	Platinum, Iridium, Ruthenium	PEM electrolyzers
Smart Grids & Transmission	Copper, Silicon	Grid infrastructure and semiconductors
Hydropower	Copper, Nickel, Manganese	Supporting infrastructure
Fuel Cells	Platinum, Palladium, Other PGEs	Catalysts for fuel cell systems
Energy-Efficient Electronics	Gallium, Germanium, Silicon	Semiconductors and efficient electronics
Geothermal	Copper, Nickel, Manganese	Power generation infrastructure
Concentrated Solar Power (CSP)	Copper, Manganese	Heat transfer and power generation
Grid-Level Energy Storage	Lithium, Cobalt, Nickel, Manganese, Graphite	Large-scale battery systems

Expert Committee under Ministry of Mines (2023) has identified a set of 30 critical minerals for India. These are Antimony, Beryllium, Bismuth, Cobalt, Copper, Gallium, Germanium, Graphite, Hafnium, Indium, Lithium, Molybdenum, Niobium, Nickel, PGE, Phosphorous, Potash, REE, Rhenium, Silicon, Strontium, Tantalum, Tellurium, Tin, Titanium, Tungsten, Vanadium, Zirconium, Selenium and Cadmium.

Understanding India's Current Mineral Profile

The nation maintains a strong foundation in traditional minerals, ranking among the world's leading aluminium producers while holding substantial reserves of iron ore, bauxite, and coal. The transition to clean energy technologies has expanded our mineral requirements, creating opportunities for diversified sourcing and value chain development. The International Energy Agency (IEA) estimates that achieving global climate goals will require a six-fold increase in critical mineral inputs for clean energy technologies by 2040.[1] Demand for critical minerals continues to rise across all sectors, driven by the rapid deployment of energy technologies. This dramatic surge underscores the strategic importance of securing reliable access to these materials.

Currently, India participates actively in global mineral markets, sourcing key materials through established international partnerships.

No	Critical Mineral	Major Supply Partners
1	Lithium	Chile, Russia, China, Ireland, Belgium
2	Cobalt	China, Belgium, Netherlands, US, Japan
3	Nickel	Sweden, China, Indonesia, Japan, Philippines
4	Vanadium	Kuwait, Germany, South Africa, Brazil, Thailand
5	Niobium	Brazil, Australia, Canada, South Africa, Indonesia
6	Germanium	China, South Africa, Australia, France, US
7	Rhenium	Russia, UK, Netherlands, South Africa, China
8	Beryllium	Russia, UK, Netherlands, South Africa, China
9	Tantalum	Australia, Indonesia, South Africa, Malaysia, US
10	Strontium	China, US, Russia, Estonia, Slovenia
11	Zirconium (zircon)	Australia, Indonesia, South Africa, Malaysia, US
12	Graphite (natural)	China, Madagascar, Mozambique, Vietnam, Tanzania
13	Manganese	South Africa, Gabon, Australia, Brazil, China

Source: Ministry of Mines, 2021[2]

This diversified sourcing approach reflects the country's growing engagement with the global mineral economy while highlighting opportunities for enhanced domestic production and processing capabilities.

Recent Developments in Mineral Ecosystem

- **Domestic Resource Discovery:** Recent geological surveys have identified promising lithium deposits in Salal-Haimana area of Reasi District of Jammu & Kashmir (UT), and Karnataka's Mandya and Yadgiri districts, opening exciting possibilities for domestic production.[3,4] The Geological Survey continues intensive exploration across these regions, with preliminary assessments indicating reserves that could significantly contribute to our battery manufacturing objectives.
- **Strategic Asset Acquisition:** Through Khanij Bidesh Limited (KABIL), India is actively securing

[1] *International Energy Agency, "The Role of Critical Minerals in Clean Energy Transitions", (2021)*

[2] *Ministry of Mines, "Critical Minerals for India", (2023)*

[3] *Geological Survey of India finds lithium and gold deposits, PIB (2023).*

[4] *Discovery of Lithium Resources in Mandya and Yadgiri districts Karnataka by Atomic Minerals Directorate for Exploration and Research, PIB (2024).*

Integrated Green green energy ecosystem and circular economy showing the interconnected network of renewable energy sources, sustainable transportation, smart cities, and recycling systems that depend on critical minerals

overseas mineral assets in lithium-rich regions of South America, cobalt resources in Africa, and rare earth projects in Australia and other strategic locations.[5] This proactive approach ensures long-term supply security while building valuable international partnerships.

- **Progressive Regulatory Framework:** The amended Mines and Minerals (Development and Regulation) Act has revolutionized the mining sector by enabling private sector participation.[6] Six critical minerals including, lithium, titanium, beryllium, niobium, tantalum and zirconium have been removed from the atomic minerals list, enabling private sector participation in their exploration and mining. The Centre now has exclusive authority to auction mineral concessions for critical minerals, while revenue continues to flow to state governments. The introduction of exploration licences for deep-seated and critical minerals through competitive bidding is attracting specialized expertise and foreign investment to the sector.
- **Technology-enabled Exploration:** Advanced exploration technologies including drone surveys, satellite mapping and artificial intelligence-powered geological analyses are accelerating the discovery and assessment of new mineral deposits across the country.

Building Comprehensive Value Chains

- **Advanced Processing Infrastructure:** The country's first battery-grade lithium refinery has been announced in Gujarat with 1,000 metric tonnes annual capacity, achieving recovery rates of 90%+ against an industry average of 60–70%.[7] A major lithium hydroxide refinery project with ₹2,200 crores investment is under development in Gujarat, planned to produce 20,000 LCE (lithium carbonate equivalent) and create thousands of direct and indirect jobs.[8] Existing aluminium and copper refineries are upgrading to produce battery-grade materials, while IREL's rare earth processing facilities in Odisha and Kerala, along with their permanent magnet manufacturing plants in Visakhapatnam, Andhra Pradesh, are creating significant downstream value addition opportunities.
- **Integrated Manufacturing Ecosystem:** Major investments in gigafactory projects across multiple states are establishing a comprehensive battery manufacturing hub. Gujarat is set to host the country's first lithium-ion cell manufacturing gigafactory with an investment of ₹13,000 crores and 20 GWh production capacity, creating direct and indirect employment for over 13,000 people.[9] Leading automotive and energy companies are developing integrated production lines spanning cell manufacturing, pack assembly, and recycling operations. The permanent magnet manufacturing sector is expanding rapidly with new facilities producing

[5] *KABIL is exploring opportunities for acquisition of overseas critical minerals assets in Argentina, Australia and Chile, PIB (2024).*

[6] *Parliament passes Mines and Minerals (Development & Regulation) Amendment Bill, PIB (2023).*

[7] *Gupta, U., Lohum announces India's first battery-grade lithium refinery, PV Magazine India (March 5, 2025)*

[8] *Lithium-ion Battery Manufacturing in India - Current Scenario, EV reporter, (April 8, 2024)*

[9] *India's first Lithium-ion Cell manufacturing gigafactory to be established in Gujarat, CMO Gujarat (2023).*

rare earth-based magnets for wind turbines and electric vehicle motors. Solar PV component manufacturing has achieved substantial scale, with domestic production of solar cells, modules, and specialized semiconductors growing significantly. The country's first lithium-ion cell manufacturing facility has been inaugurated in Bengaluru with 50MWh initial capacity, expanding to 1 GWh cell and 2 GWh battery pack capacity by 2025.[10]

- **Circular Economy and Policy Framework:** The government has implemented the Battery Waste Management Rules, 2022, mandating extended producer responsibility (EPR) for battery manufacturers, which requires producers to collect and recycle/refurbish waste batteries and use recovered materials in the production of new batteries.[11] The rules cover all battery types including electric vehicle, portable, automotive and industrial batteries, prohibiting disposal in landfills and mandating minimum percentage recovery of materials from waste batteries. Import duty structures have been revised to encourage domestic value addition in critical mineral processing.
- **Innovation and Research Leadership:** Public-private partnerships continue to establish specialized R&D facilities focusing on critical mineral processing technologies and alternative battery chemistries.

Critical mineral extraction and processing operations

Premier institutions and national laboratories are driving innovation in material science and extraction techniques, supporting the development of indigenous technologies for lithium processing and advanced battery manufacturing.

A Vision for Sustainable Mineral Independence

India's approach to critical mineral security reflects a balanced and forward-looking strategy—combining domestic exploration, strategic international partnerships, technological innovation, and circular economy principles. With diverse geological potential, evolving policy frameworks, and growing technical capabilities, the country is steadily strengthening its position in the global clean energy transition.

As renewable energy deployment accelerates, critical minerals will remain central to the technologies driving this transformation. Sustained investment in domestic value chains, supported by research and responsible sourcing, will be key to building long-term resilience. By aligning our mineral strategy with broader energy and climate goals, we are laying a strong foundation for a cleaner, more self-reliant future.

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10 *Press Trust of India & Business Standard. Log9 commissions country's first commercial Li-ion cell manufacturing line (April 21, 2023)*

11 *E-Waste management, PIB (2023)*

From Walls to Watts

Unlocking the Potential of BIPV in India

Building-Integrated Photovoltaics, the updated version of traditional solar PVs, are an edge above the widely prevalent solar panels currently in application. **Rashi Srivastava** and **Dr Aravindh MA** while describing BIPV not as a mere technology, look at it as a transformative opportunity to reimagine urban India as a self-powered, climate-resilient powerhouse.

Overview

Since the 1990s, photovoltaic technologies have increasingly been integrated into building structures to manage electricity demand and enhance energy efficiency. These systems, collectively known as Building-Integrated Photovoltaics (BIPV), include roofs, façades, windows, and shading elements. With India's rapidly evolving urban infrastructure and growing focus on sustainable development, the country offers a promising landscape for the adoption of BIPV. This article delves into the concept of BIPV, examines its current status in India, highlights its advantages and challenges, and outlines key measures needed to scale up its adoption nationwide.

South-facing vertical façade of Atal Akshay Urja Bhawan featuring integrated solar panels

What is BIPV?

As India moves towards its goal of becoming a global leader in clean energy, its cities are expected to play a central role in this transition. Urban populations are projected to reach 600 million by 2031 and 850 million by 2051, marking a significant rise in urbanization. This growth will naturally lead to increased energy demand, particularly in the residential and commercial building sector. At present, buildings account for nearly one-fourth of India's total electricity consumption. With rapid expansion underway, the sector is expected to add more than 3 billion square metres of built space by the end of this decade, further intensifying energy needs.

This expansion presents both a challenge and an opportunity. On one hand, the sector's growing reliance on air conditioners, lighting, and other appliances is expected to push its share in electricity demand to nearly 38% by 2047. On the other, it provides fertile ground for innovative, clean energy solutions that can help India meet its goal of 500 GW of non-fossil capacity by 2030, including 365 GW from solar energy alone.

One of the most promising solutions in the shift towards sustainable urban energy systems is Building-Integrated Photovoltaics (BIPV). This technology combines design and function by embedding solar power generation directly into the structural elements of buildings. Unlike traditional rooftop solar systems, which are added onto existing structures, BIPV replaces conventional building materials, such as windows, façades, and roofs with materials that generate solar energy. In doing so, buildings become self-sustaining sources of clean electricity, while maintaining their aesthetic appeal and architectural flexibility.

The potential for applying BIPV in India is immense. Based on the current building stock alone, the estimated BIPV capacity exceeds 300 GW. In addition to generating clean energy, BIPV systems offer several added benefits.

It is important to understand that generating electricity alone does not qualify a photovoltaic system as 'integrated'. For a system to be considered BIPV, it must also take the place of conventional building materials and perform standard building functions, such as providing shelter, insulation, or structural support. This dual purpose makes BIPV a holistic and efficient solution for sustainable urban infrastructure, as it delivers energy performance while maintaining architectural quality and design integrity.

Status of BIPV in India

India's rapid urbanization brings with it a growing demand for reliable and clean energy. Traditional rooftop solar (RTS) systems, while valuable, face practical limitations in densely built environments. A typical RTS setup requires approximately 300 square feet of shadow-free roof space for just a 3-kilowatt (kW) system, something many high-rise buildings and compact urban homes simply cannot provide.

For example, a 16-storey residential building may only accommodate around 40 kWp of RTS capacity on its rooftop. In contrast, if the building's façade is integrated with photovoltaic panels, it could potentially generate up to 150 kWp, more than three times the output, without occupying any additional space.

India initially set a target of achieving 40 GW of rooftop solar capacity by 2022 as part of its broader goal of 100 GW of solar energy. However, progress has been slower than expected due to challenges such as limited rooftop space, delays in installation, and low consumer awareness. As a result, the deadline has been extended to 2026. Despite this extension, relying solely on rooftop and ground-mounted systems may not be sufficient to achieve India's ambitious target of 300 GW of solar capacity by 2030.

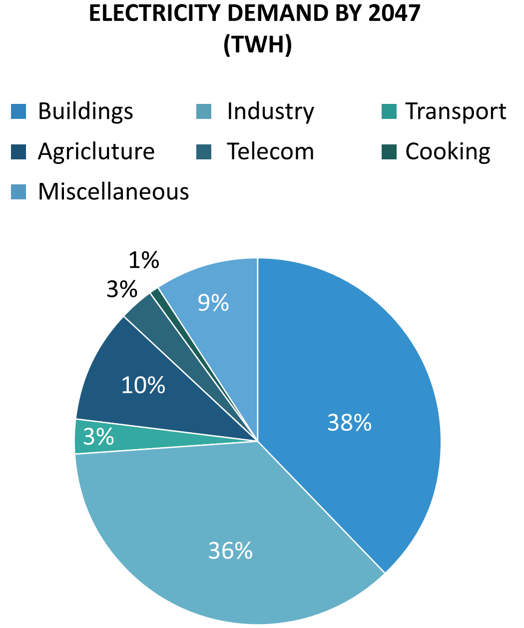

Figure 1: Electricity demand by 2047 (TWH)[1]

In this context, BIPV offer a promising alternative. Government policies are increasingly supporting BIPV adoption. The updated Energy Conservation and Sustainable Building Code (2022) encourages the integration of renewable energy and energy-efficient design, making BIPV a strong fit within current regulations. At the same time, the declining cost of solar technologies and growing demand for environmentally sustainable buildings are accelerating interest in BIPV across various sectors. A few pioneering projects stand out:

- CtrlS Datacenters in Navi Mumbai

[1] *Whitepaper on Scaling up Building Integrated Photovoltaics (BIPV) in India. Accessible at https://teriin.org/sites/default/files/2025-03/Whitepaper_BIPV_GIZ.pdf*

Rooftop solar installation at Atal Akshay Urja Bhawan harnessing clean energy at scale

installed an 863-kWp BIPV system, demonstrating the feasibility of large-scale commercial use.

- The Renewable Energy Museum in Kolkata features an innovative solar dome, showcasing how BIPV can be artistically and functionally integrated.
- Indian Railways has led by example with significant BIPV installations at Vijayawada and Sahibabad stations, leveraging public infrastructure for energy self-sufficiency.

Advantages of BIPV

India's growing prominence in global green building certification also strengthens this momentum. In 2022, India ranked second globally in LEED-certified projects, while its own GRIHA system has certified over 1700 projects nationwide. As sustainable design becomes the norm, integrating energy solutions like BIPV will be critical to achieve both climate targets and urban resilience. By turning buildings into power generators, BIPV offers a host of advantages tailored to India's urban landscape.

- **Improved Energy Efficiency:** BIPV systems help moderate indoor temperatures by reducing solar heat gain, particularly through semi-transparent panels that allow light but block excess heat. This reduces the load on air conditioning systems and supports passive cooling.

  Example: BIPV façades have been shown to cut indoor heat load significantly in pilot installations.
- **Optimal Use of Space:** In cities where land and rooftop areas are limited, BIPV enables solar generation from façades, balconies, railings, and windows. This makes it especially effective for high-rise buildings.
- **Architectural Integration:** Unlike conventional panels that sit atop buildings, BIPV systems are seamlessly embedded into the building's design. They are available in various shapes, colours, and transparencies, maintaining the structure's aesthetic appeal.
- **Dual-Function Materials:** BIPV replaces traditional construction materials, such as glass or tiles while performing their usual functions and simultaneously generating solar power. This multi-functionality reduces material use and enhances sustainability.
- **Long-Term Economic Benefits:** While the initial investment in BIPV

may be higher than traditional systems, the savings on electricity bills over time can make up for the cost.

Example: In Germany, households using balcony BIPV panels have reported up to 30% savings in energy bills.

- **Empowering Urban Sustainability:** With urbanization expected to touch 850 million people by 2051, BIPV supports sustainable infrastructure by:
  - Unlocking 309 GW solar potential on existing building stock as per the World Bank estimate.
  - Enabling clean, decentralized energy generation in crowded cities.
  - Reducing emissions in line with India's climate commitments under the Paris Agreement.
  - Enhancing public infrastructure (e.g., metros, airports) under missions like Smart Cities and AMRUT.
  - Opening new markets for green jobs, solar architecture, and domestic BIPV manufacturing.

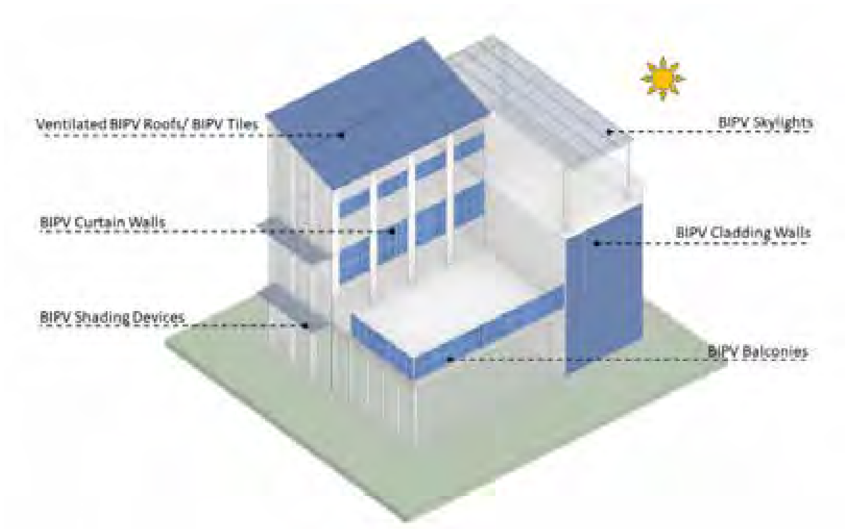

Figure 2: Different system categories of BIPV

Challenges Associated with BIPV Adoption

While Building-Integrated Photovoltaics (BIPV) offer a promising route to sustainable urban development, their adoption in India faces several practical and systemic hurdles. Understanding these challenges is crucial for unlocking the full potential of this innovative technology.

- **High Initial Investment:** BIPV systems are more expensive than traditional rooftop solar setups due to the need for specialized materials, design adaptations, and structural integration. This higher upfront costs often discourage developers and homeowners from exploring BIPV options.
- **Limited Awareness and Technical Know-how:** A major barrier is the low level of awareness among architects, builders, and urban planners about BIPV's benefits and integration techniques. Without adequate exposure or training, BIPV often remains absent from early design and planning stages, limiting its feasibility.
- **Policy and Regulatory Gaps:** India currently lacks dedicated policies, incentives, or building codes that actively promote BIPV adoption. In contrast to regions like the European Union, where clear directives guide energy-efficient building design, India's policy framework remains largely silent on BIPV applications.
- **Dependence on Imports:** Many BIPV components, such as semi-transparent glass panels and flexible solar laminates, are imported due to limited domestic manufacturing capacity. This dependence raises project costs and introduces supply chain vulnerabilities.
- **Lack of Standardization and Performance Benchmarks:** The absence of clearly defined technical standards or safety guidelines for BIPV modules adds uncertainty for both developers and regulatory bodies. Without benchmarks for efficiency, durability, and integration, approvals and installations tend to be delayed or avoided altogether.

Potential of Scaling BIPV in India

To accelerate the adoption of BIPV and address India's growing urban energy demands, a multi-pronged and inclusive approach is essential. The following steps can guide the way forward:

- **Introduce Targeted Incentives and Subsidies:** BIPV needs dedicated financial support, particularly in urban areas with limited rooftop space. Building on recent steps, such as its inclusion under the PM Surya Ghar Muft Bijli Yojana, which offers subsidies of up to ₹78,000 for a 3-kW residential BIPV system, similar provisions should be extended to commercial and industrial sectors.

- **Integrate BIPV into Building and Energy Codes:** To make BIPV mainstream, its inclusion in key regulatory frameworks such as the National Building Code, Energy Conservation Building Code, and Eco Niwas Samhita is crucial. India can draw lessons from the European Union, where BIPV is encouraged through clear standards under the Energy Performance of Buildings Directive.
- **Boost Domestic Manufacturing and Demonstration Projects:** Supporting indigenous BIPV production through initiatives like the Production-Linked Incentive (PLI) scheme can reduce costs and supply risks. Pilot installations in public infrastructure, such as metro stations, airports, and government schools will enhance visibility and public trust in the technology.
- **Develop Innovative Financing Models:** Introducing models like Renewable Energy Service Companies (RESCO) and long-term Power Purchase Agreements (PPAs) can improve project bankability and attract private investment in BIPV.
- **Strengthen Awareness and Capacity Building:** Awareness campaigns and technical training for architects, builders, and urban planners are key to incorporating BIPV into early-stage designs. Demonstration projects such as those at Atal Akshay Urja Bhawan, and CtrlS Datacenters show how innovation and aesthetics can go hand-in-hand.

Atal Akshay Urja Bhawan: A Living Example of BIPV in Practice

Standing tall in New Delhi's CGO Complex, the Atal Akshay Urja Bhawan (AAUB) is more than just a government office. It is a pioneering model of how renewable energy can be seamlessly woven into urban architecture. What makes AAUB particularly remarkable is its 1-megawatt solar power plant that follows a BIPV design.

Unlike conventional solar installations, the photovoltaic components here are integrated directly into the building's structure, allowing the building envelope itself to generate electricity. Constructed on a 2.76-acre plot, the building embodies the concept of energy-positive architecture, producing more energy than it consumes, while also meeting high environmental and aesthetic standards. As the capital city faces mounting pressure from air pollution, rising energy demand, and climate change, AAUB offers a real-world example of how institutional buildings can turn into energy hubs. Beyond its technical achievements, it acts as a symbol of leadership, encouraging public and private sector actors to invest in similar clean energy transitions. AAUB's integration of BIPV showcases the untapped potential of solar innovation in shaping India's low-carbon urban future.

Conclusion

With nearly 70% of the infrastructure needed by 2047 yet to be built, India stands at a pivotal moment. The decisions taken today will shape the energy and environmental landscape of tomorrow. In this context, BIPV is not just a technology, it is a transformative opportunity to reimagine urban India as a self-powered, climate-resilient powerhouse. In short, BIPV is more than just a solar solution, it is a future-ready approach to urban energy security, environmental responsibility, and architectural innovation. As India builds the cities of tomorrow, BIPV offers a way to make every square foot count.

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India's Pioneering Move in Agriculture

Solar cooling, a pathbreaking technology in the field of agriculture and aquaculture is proving to be a robust infrastructure for cold storage of perishable items. In this article, **Dr Nitin Goel** writes how, with favourable policy environment and growing interest of manufacturers, the technology is poised for rapid growth and adoption.

Overview

India is a global leader in agriculture, ranking 1st in milk production, 2nd in both aquaculture and fruit and vegetable production, and 3rd in fish production. These perishable commodities demand robust cold storage infrastructure, preferably situated at the farm gate.

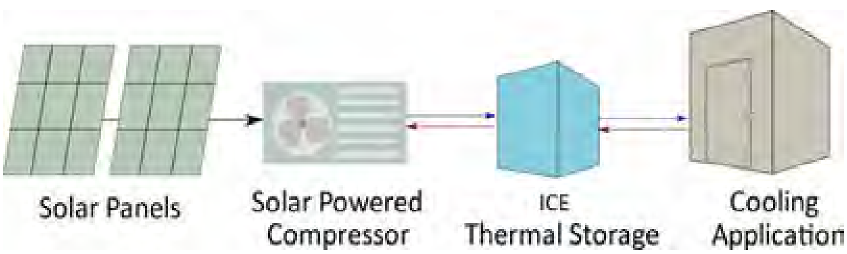

Figure 1: Working principle of solar cold storage

While expanding cold storage capacity across the country could increase pressure on fossil fuel resources, reducing post-harvest losses offers significant benefits too. It not only boosts farmer incomes and helps curb migration to urban areas but also conserves valuable inputs used in production—such as fertilizers, pesticides, irrigation, field preparation, harvesting, and transportation—that otherwise go to waste.

Barely one in ten of India's perishable harvests ever see a cold room—and those facilities sit almost exclusively on the urban fringe, serving the last mile instead of the first. Closing this gap demands cold storage that is rural-ready—affordable, modular, and independent of an unreliable grid. Solar power supplies daytime energy, while low-cost phase-change materials (PCMs) 'bank that cooling' for night-time operations, delivering 24-hour refrigeration without any diesel or batteries. Deploying such farm gate cold storage not only lifts farmer incomes and unlocks higher-value processing options but also slashes CO_2 emissions tied to both food spoilage and wasted fertilizer, water, and labour embedded in every lost kilogram of produce.

Solar PV powers a traditional vapour compressor-based refrigeration system which stores the cooling in PCMs. This enables fast cooling, stores cooling without need of hazardous batteries and provides storage temperature in the range of -20 to 20°C. The system includes remote monitoring to track key parameters, report errors and operate fully automatically without user intervention. Another critical feature is

Figure 2: Typical layout for a multi-chamber solar cold storage

multiple temperature zones allowing simultaneous storage of different products at different temperatures.

The solution has demonstrated a positive impact in rural areas with unreliable or no grid access. Its application extends beyond storage of milk, fruits, vegetables, eggs, meat, fish but also cover ripening, mushroom cultivation and preservation of vital vaccines. Globally, the capacity of installed solar cold storage systems ranges from 2 to 100 metric tonnes, with more than 2,000 units deployed worldwide by over 10 manufacturers.

Indian manufacturers have made significant progress in establishing themselves as key players in this sector. They have installations in over 20 countries overseas, mainly across Africa and Southeast Asia. The strength of Indian companies lies in delivering the lowest cost solutions with the highest performance. Inficold India Private Limited, a leader in solar cooling solutions, has collaborated closely with the United States Department of Agriculture along with scientists from North Carolina State University and International Potato Center to support Kenya Agricultural and Livestock Research Organization in long-term storage of sweet potatoes and onions. These installations demonstrate the technological leadership of Indian companies, positioning them as global leaders in providing cost-effective solar cold chain solutions. This achievement aligns perfectly with India's vision of *Make in India, Make for the World*.

Clearing the Fog: Why Standards Matter

When a brand-new product class arrives, early buyers face a guessing game—Which vendor's claims are real? What does 'good' performance even look like? In solar cold storage, this uncertainty has cramped demand, eroded trust, and slowed R&D investment. Recognizing the risk, the Government of India stepped in with a farmer and climate-centric playbook.

1. **Policy - Set the rules of the game**

   The Ministry of New and Renewable Energy (MNRE) published the world's first design & testing guidelines for solar cold storage with thermal energy storage. These guidelines spell out (down to sensor accuracy and pull-down rate) how every unit must be built, tested, and installed, covering material specifications, safety, efficiency metrics, and maintenance access.

2. **Innovation - Compete on verified excellence**

   Because compliance is now measurable, manufacturers race to outdo one another on kWh-per-tonne-per-day, autonomy hours, and multi-chamber flexibility rather than on marketing hype. Field data feeds directly into the next design cycle, accelerating technical progress.

3. **Adoption - Confidence unlocks scale**

   Farmers, financiers, and state agencies finally have a common yard stick, so subsidies (e.g., MIDH), loans, and carbon-credit schemes can flow to proven units. Higher

Installation at National Centre for Cold-chain Development, Ministry of Agriculture and Farmers' Welfare, Government of India

volumes cut costs, making the technology accessible to even the smallest producer.

As installations report real-world performance through mandatory remote monitoring, MNRE gains data to refine the standards, tightening efficiency targets and expanding the scope to reefers and pack-house precoolers. The loop restarts, each turn driving greater reliability and lower costs.

India's Unique Move to Turn Standards into a Growth Flywheel

India is the first nation to put this kind of standards-driven flywheel in motion for solar cold storage, and countries across Africa and Southeast Asia are already modelling their own guidelines on MNRE's blueprint. The result—faster technology diffusion, stronger farmer economics, and a tangible dent in food-system emissions worldwide.

Additionally, the Ministry of Agriculture & Farmers' Welfare has recently incorporated solar cold storage under the Mission for Integrated Development of Horticulture (MIDH) for capital subsidy support. This inclusion plays a vital role in enhancing farmer incomes, promoting sustainable agricultural practices, and reinforcing the cold chain infrastructure thereby, helping ensure timely market access for perishables while minimizing post-harvest losses.

India is charting a transformative path in agricultural sustainability by championing solar cold storage as a scalable, cost-effective, and climate-resilient solution. By integrating renewable energy with thermal storage, these systems offer round-the-clock refrigeration without reliance on the power grid or harmful batteries—perfectly suited for rural and remote settings. With strong policy support, pioneering technical standards, and a growing base of successful deployments, India is not only addressing its own post-harvest challenges but also emerging as a global leader in solar cold chain innovation. This holistic approach—combining technology, policy, and entrepreneurship—is paving the way for a more equitable, sustainable, and food-secure future for farmers worldwide.

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Biochar: The Carbon Negative Powerhouse

Complementing India's 2070 vision for net-zero emissions, biochar has emerged as a global favourite when it comes to carbon negative biofuel systems. From renewable energy production to industrial carbon sequestration, biochar finds many applications to offset carbon footprint, **Sunil Dhingra** details.

Introduction

Rising industrialization and population growth have drastically increased energy demand and fossil fuel dependency, leading to alarming greenhouse gas emissions. The atmospheric CO_2 levels rose from 315 ppm in 1958 to around 417 ppm in 2023, intensifying global warming through enhanced heat absorption and re-radiation. At the same time, open burning of agricultural residues especially in Punjab, Haryana and Uttar Pradesh continues to pollute the air.

Biochar—a carbon-rich by-product of biomass pyrolysis—is gaining global traction as a powerful enabler of renewable energy and carbon negative biofuel systems. In India, with its vast agricultural residues and climate challenges, biochar offers a sustainable path to convert waste into clean energy and long-term carbon storage. According to *Global Biochar Market Report 2025*, the industry is set to grow from $3.1 billion in 2025 to $6.5 billion by 2030 at a 13.8% CAGR, with over 6,00,000 tonnes/year produced globally. Its rising demand spans energy generation, bio-oil production, carbon credit markets, and sustainable agriculture—positioning biochar at the heart of the circular, low-carbon economy.

Pyrolysis unit to convert agricultural residues into biochar

Biochar is produced by heating organic biomass—such as crop residues, wood waste, or other agro-waste—in a low-oxygen environment through a process known as pyrolysis. Typically conducted at temperatures ranging from 300°C to 700°C, pyrolysis breaks down the biomass into three main outputs—biochar, syngas, and bio-oil. Among the different pyrolysis methods, slow pyrolysis—which operates at lower temperatures and longer residence times—is specifically optimized for maximizing biochar yield, often achieving 35–50 wt% depending on feedstock and conditions (Multidisciplinary Digital Publishing Institute). Biochar finds its utility in renewable energy production, industrial carbon sequestration as well as soil health enhancement.

Biochar as a Fuel

Beyond its carbon sequestration potential (1 tonne biochar = up to 3 tonnes CO_2e stored), biochar is a high-energy solid fuel, with a calorific value of 22–30 MJ/kg and fixed carbon content of 65–85%, comparable to sub-bituminous coal.

Its low moisture (<5%) and volatile matter (10–25%) enable efficient combustion with fewer sulphur and nitrogen emissions. While combustion releases stored carbon, biochar can be used for energy in hard-to-abate sectors like cement or biomass power, especially when it is not suitable for soil use.

Co-firing biochar with coal in thermal power plants offers a practical emission-reduction strategy. A 10–20% blend can reduce CO_2 emissions by 8–27%, and even a 5% global coal substitution could save 300 million tonnes of CO_2 annually. Similarly, bio-oil, a pyrolysis by-product, when blended at 35–60%, can cut GHG emissions by 60–75% per kWh, offering further decarbonization potential.

Biochar: Feedstock Enhancer in Biofuels

Biochar significantly improves the efficiency of biofuel systems. In biogas plants, adding 5% biochar to mustard straw feedstock increased biogas yield by 40.5% and methane yield by 188.8% under mesophilic conditions (Chen *et al*., Bioresource Technology, 2020).

In biodiesel production, biochar works as an effective catalyst and filter. Yields of 92.4–95.2% have been reported using biochar derived from seed residues and wood under optimal conditions (Energy Conversion and Management, 2020). Overall, biochar boosts process efficiency and supports cleaner, high-yield biofuel production.

Carbon credits incentive as tool to promote biochar in industries

Carbon Credits from Biochar

In 2024, both the Intergovernmental Panel on Climate Change (IPCC) and the United Nations Framework Convention on Climate Change (UNFCCC) officially acknowledged biochar as a viable method for permanent carbon sequestration, making it eligible for carbon credits.

On voluntary carbon markets, biochar-based carbon credits are currently valued at $100–$180 per tonne of CO_2e, depending on project certification, feedstock type, and methodology used.

India, under the National Bio-Energy Mission and aligned with global standards like Verra's VM0044 methodology, is exploring frameworks to scale up biochar credit generation, especially from decentralized agro-residue management projects. With the country generating over 728 million tonnes of agro-residue annually, India holds immense potential to become a major hub for biochar-based carbon finance while tackling residue burning.

Biochar and India's Net Zero Goal

India has pledged to achieve net-zero emissions by 2070, and biochar can play a strategic role in accelerating this transition. Large-scale biochar deployment in industries can help sequester millions of tonnes of CO_2 annually, reducing methane emissions from decomposing organic waste, which is over 80 times more potent than CO_2 in the short term.

If India were to convert just 5% of its crop residue (~35 million tonnes/year) into biochar, it could prevent the release of 75–90 million tonnes of CO_2 equivalent annually. This industrial-scale production would not only contribute significantly to India's net-zero targets but also support green manufacturing, reducing industrial emissions, and boosting sustainable agriculture.

Biochar in Sustainable and Climate-Resilient Agriculture

Biochar exhibits properties that make it highly effective in enhancing soil health and agricultural resilience. Its composition varies with feedstock and production conditions, but typically contains up to 77% stable carbon, with low moisture (~4.7%) and volatile matter ranging from 5–30%, allowing it to persist in soils for centuries. With a porous structure, pH between 6.5–10, and Cation Exchange Capacity (CEC) reaching 150 Cmol/kg, biochar improves nutrient retention, soil aeration, and microbial diversity, especially in acidic or degraded soils.

It also features electrical conductivity (0.5–5 dS/m), impacting nutrient availability. Applied directly or blended with compost, biochar enhances moisture retention, plant health, and drought resistance. Moreover, by sequestering carbon and reducing fertilizer runoff, it serves as a key tool for climate-smart and regenerative agriculture, boosting both yield and resilience to climate extremes.

Challenges in Scaling Biochar

- **Scalability:** Decentralized models face financial and logistical challenges.
- **Standardization:** Need for standardized quality and carbon accounting protocols.
- **Awareness:** Farmers and industries still lack technical awareness of biochar's multiple benefits.

Conclusion

Biochar sits at the nexus of energy, environment, and agriculture—transforming agro-waste into renewable energy while sequestering carbon for centuries. As global carbon regulations tighten and ESG mandates grow stronger, biochar is poised to become a core enabler of energy sector, circular bioeconomy, and net-zero strategies. Its integration with biofuels, green financing, and climate-smart practices unlocks a scalable, carbon-negative solution for India and the world in the fight against climate change.

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We invite readers of *Akshay Urja* to share your stories about technology and innovations, as well as your perspectives on future advancements in the renewable energy sector. Submissions can be 400, 800, or 1600 words in length, and should include high-resolution photos that enhance your narrative. Please send your contributions to:

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Solar Dryers

Obscure Potential Ignored Too Long?

India's journey in the solar energy sector began with simple solar lanterns, gradually moving towards massive gigawatt-scale PV plants. However, solar dryers never received the attention they deserved, this article by **Amit Deotale** argues.

Installed 2 tonnes of solar tunnel dryer at Calderys

Introduction

As the global demand for energy continues to soar, industries and homes are evolving into complex ecosystems of energy consumption. From air conditioners to refrigerators, and from cooking gas to industrial boilers, every process now calls for a rethinking of how we generate, use, and conserve energy. While photovoltaic (PV) solar technology has rightly garnered attention and support over the past three decades, it is time we turned our focus towards an equally promising and underutilized solution—solar thermal drying systems.

Solar dryers are a critical piece in the 360-degree approach needed to build a sustainable future. With high solar irradiance available across India for over 300 days a year, solar drying offers a cost-effective, energy-efficient, and scalable alternative for industrial and domestic applications alike.

The Forgotten Pillar: Solar Thermal in India's Energy Evolution

India's journey in the solar energy sector began with simple solar lanterns, gradually moving towards massive gigawatt-scale PV plants. However, solar thermal applications, especially dryers, never received the attention they deserved. While solar water heaters gained some traction, drying systems lagged due to lack of awareness, limited policy support, and fragmented deployment models.

But the potential is enormous—not just for industries, but for agriculture, community infrastructure, and waste management. Solar dryers can significantly reduce electricity or LPG dependency, the associated operational costs, and carbon emissions.

Industrial Applications: Demonstrated Outcomes

1. Case Study – Solar Thermal Innovation at Calderys India Refractories Ltd

In a significant step towards sustainable industrial practices, Calderys India, a multinational company (MNC) in the refractory sector, has successfully installed a 1200 sq. ft solar dryer system at its manufacturing plant located at Butibori MIDC, Nagpur.

Inside view of solar tunnel dryer - storage area

Previously, the plant consumed over 0.5 MW of electricity daily for drying refractory powder — a key process in the production line. To reduce operational costs and shift towards green energy, Calderys searched for a customized solar thermal solution.

After intensive R&D trials, technical evaluations, and collaborative discussions, the solar dryer system was deployed. Designed for daily drying of up to 2 tonnes of powder material, the system has already demonstrated substantial energy savings and a payback period of less than 2 years.

This low-cost, polycarbonate-structured dryer not only cuts electricity usage but also aligns with Calderys' global commitment to carbon reduction and energy efficiency.

Every component of the dryer, from structure to thermal material, is completely made in India, with zero imports involved. It's a perfect example of Atmanirbhar Bharat, using local design, materials, and execution to solve global industrial challenges.

Encouraged by the success at Butibori, Calderys is now even exploring similar solar dryer installations across its international manufacturing facilities.

2. Hazardous Waste Management

Industries like galvanizing, textiles, and pharmaceuticals generate hazardous sludge with high moisture content. The cost of treating the sludge at common facilities is ₹40–50 per kg. A plant drying 100 kg of sludge daily can reduce the cost to just ₹17–18 per kg after solar treatment, cutting treatment costs by over 75%, with an RoI of just 12–18 months.

3. Effluent and Liquid Waste Evaporation

Effluent treatment plants (ETPs) often rely on membrane filters or electric evaporators, which are energy intensive. Solar dryers can evaporate high-TDS wastewater efficiently, significantly cutting operating costs. Additionally, government rules now mandate sludge from STPs to be treated at 45°C for 3 days or 75°C for 4 hours before landfilling. Solar dryers offer a scalable and eco-friendly alternative to electric chambers, which consume 3–4 MW for drying—a massive energy burden on municipalities.

4. Powder Coating and Metal Finishing Units

In several MSMEs like powder coating and cabinet manufacturing, components are dried in chambers heated by LPG to ~45°C. Solar dryers can achieve the same thermal output without recurring fuel costs. This is not only sustainable but commercially attractive.

Agricultural Applications: A Boon for Rural India

India is a leading exporter of agricultural products like dehydrated onions, moringa, turmeric, and tomatoes. Yet, the post-harvest losses due to improper drying and lack of storage are staggering.

A decentralized solar dryer in each village can empower farmers to preserve excess produce, reduce wastage, and access value-added markets.

Example: Tomatoes sold at ₹2 per kg during a price crash can be sun-dried and sold as dehydrated/dried tomatoes at ₹100–150 per kg.

Women self-help groups (SHGs) and youth can build cottage industries in food processing using solar drying.

Community and Urban Applications: Pilgrim Centres and Hostels

Places like Shegaon or Tirupati see millions of pilgrims. Daily laundry includes thousands of bed sheets and pillow covers, often sun-dried in open spaces. Solar dryers can provide a hygienic and UV-protected drying alternative thereby, saving electricity and preserving fabric quality.

Inauguration of solar tunnel dryer in the presence of Calderys team

Coastal and Fishery Sector

India's seafood export industry faces high refrigeration costs due to lack of drying alternatives. Coastal areas, with their flat terrain and sunlight abundance, are ideal for solar fish dryers. These can be used for small fish, prawns, and even algae drying, enabling income generation without grid dependency.

Technology vs Cost: A Smart Investment

- **1 kW solar PV system:** ~₹45,000; 80 sq. ft space
- **Solar thermal dryer:** ~₹16,000 for equivalent heat energy; 20 sq. ft space
- **Efficiency:** Up to 60% for low-temperature drying vs 20–22% in PV
- For low-temperature applications (40–75°C), solar thermal is vastly more cost-effective and space-efficient than PV systems

Policy Push: Need of the Hour

Just as the government has incentivized solar PV adoption through PM-KUSUM and Suryodaya Yojana, similar policy and financial support is needed for the adoption of solar dryers at a large scale. These may include the following:

- Capital subsidies for solar dryer deployment
- Inclusion in MSME energy-efficiency schemes
- Cluster-based solar drying units for rural areas
- R&D support for hybrid solar-electric drying models

Conclusion

Solar Drying – An Overlooked Giant of the Green Economy?

India stands at the cusp of energy transformation with solar thermal dryers not being just a substitute for conventional energy. They are catalysts for decentralization, job creation, and environmental responsibility. With the right support, the technology can be scaled from pilot projects to nationwide adoption—from Chandrapur to coastal Gujarat, from temples to textile clusters, from STPs to SHGs.

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Hydrogen in Transport

Current Status and Future Outlook

As India experiences a surge in electric mobility, hydrogen-based transportation is also gaining significant attention. With the government spearheading several initiatives, green mobility, particularly hydrogen, holds great potential and is poised to play a vital role in cutting emissions from long-distance transport, argue **Sharif Qamar** and **Dr Sujit Pillai** in this article.

Overview

Transportation is vital for any country's growth and economic development. It helps people access public spaces, essential services, and creates many job opportunities, both directly and indirectly. Even though there are cleaner fuel options like natural gas, electric and hybrid vehicles, and hydrogen, transport still depends mostly on petroleum products. One major reason is that these cleaner alternatives have been more expensive for a long period of time, leading to a huge rise in demand for fossil fuel-based service.

Under the Paris Agreement of 2015, many countries have set net-zero emission targets. To support these goals, several steps are being taken to reduce emissions from transport. These include promoting walking and cycling, encouraging the use of electric vehicles (EVs), exploring hydrogen as a fuel, blending biofuels with petrol and diesel, boosting rail transport, and investing in public transit systems.

National Green Hydrogen Mission

India's National Green Hydrogen Mission, initiated by the Ministry of New and Renewable Energy (MNRE) in 2023 has a production target of 5 MMT of green Hydrogen annually by 2030, with a potential of production of 10 MMT annually, and an associated renewable energy capacity addition of 125 GW.[1] Main components of production cost of green Hydrogen include cost of electrolysers and renewable energy sources, and the mission aims to adopt strategies to minimize these costs for end users.

Phase 1 (2022–23 to 2025–26) puts forward pilot projects for clean energy transition (fossil fuel replacement) through green hydrogen in steel production, long haul heavy-duty mobility, and shipping. The mission suggests that long haul mobility would require decentralization of green hydrogen production so that refuelling stations set up in cities and across highways can be connected to renewable energy plants for on-site production of green Hydrogen. The focus of Phase 1 was demand-creation and supply-enhancement by expanding domestic production capacity of electrolysers. Phase 2 (2026–27 to 2029–30) anticipates competitiveness of green hydrogen costs with that of fossil fuels in refinery and fertilizer sectors.

MNRE has formulated guidelines for pilot projects for utilizing green hydrogen in road transport (buses, trucks, and four-wheelers) in phased manner with a budgetary outlay of ₹496 crore till 2025–26.[2] The objective is to develop hydrogen highways with supporting distribution infrastructure and refuelling stations.

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1 https://mnre.gov.in/en/national-green-Hydrogen-mission/

2 https://www.pib.gov.in/PressReleaseIframePage.aspx?PRID=2006052

For developing countries, including India, this shift is challenging. They face what is known as the Energy Trilemma: providing access to affordable energy to the citizens; ensuring energy security through secured supplies; and providing energy systems that are environmentally sustainable. Countries like India, which are focused on growth and development, need to carefully manage these three priorities. So far, petroleum products and natural gas have been the main sources of energy for transportation. Moving forward, finding a cleaner and more balanced energy mix is crucial for sustainable growth.

Notably, emissions from transport are rising rapidly, and urgent steps are needed to help India reach its target of net-zero by 2070, announced by the Hon'ble Prime Minister. In India, the transport sector accounts for about 14% of India's total greenhouse gas (GHG) emissions. Within this, freight transport uses over 40% of the sector's total energy.

Hydrogen: The Future of Clean Transport

Hydrogen fuel technology is also being discussed as a potential low carbon alternative technology for hard-to-abate sectors, like waterways and long-distance freight transport. For zero tailpipe emissions, hydrogen fuel cell vehicles (HFCVs) are one of the two alternatives, other being EVs. In case of HFCVs, electricity is generated from hydrogen in fuel cells that power the electric motor, leading to zero emissions. These are more energy efficient than internal combustion engine (ICE) vehicles. Pre-dominantly, three operational modes are popular: fuel cell vehicle (FCV) and hydrogen ICE vehicles.

Over the past decade, extremely rapid cost reductions in battery technologies have been observed, alongside significant improvements in vehicle performance and charging infrastructure capabilities. This has made battery electric vehicles (BEVs) lower cost, with greater range and faster recharging times, making them more attractive to consumers across a growing number of segments. FCVs must compete with the ever-improving BEV technologies to have an impact on transport decarbonization. Based on TERI's analysis, BEVs will dominate most of the smaller, shorter-range passenger vehicles, including two, three, and four- wheelers, as well as city buses and last-mile freight from the medium-term perspective. However, hydrogen-powered vehicles could still have an edge in larger, long-distance vehicles like trucks and inter-city buses. These heavier vehicles need more energy and take longer to recharge with batteries. Hydrogen vehicles can refuel quickly, more or less like diesel trucks, which could make them more suitable for the majority of operational requirement and use cases.

A number of other important criteria, alongside the total cost of ownership (TCO), all of which have an important bearing on the take-up of alternative drivetrain vehicles.[3] These include infrastructure requirements, user acceptability, weight penalty, and other risks. Whilst we can be confident that BEVs will compete from a cost perspective, other barriers including new charging networks, which will be especially challenging to deliver for India's rural population, will limit the pace of transition.

For the heavier-duty and longer-distance segments, such as trucks and inter-city buses, we have undertaken a similar assessment. Whilst the TCO analysis suggested close competition between BEVs and FCEVs over the longer term, the pace of adoption in these segments will depend on reducing recharging time, rolling out high-capacity charging, raising awareness with fleet operators, and reducing the weight penalty of batteries, via improving energy density. Aside from a new hydrogen refuelling network, FCEVs would be more competitive in these areas, due to faster refuelling times and the similar operation of an FCEV truck or bus versus a diesel equivalent.[4]

The overall impression that emerges from this analysis is that the heavier-duty and longer-distance vehicle segments will likely decarbonize through a mixture of direct electrification with BEVs and indirect electrification through FCEVs.

- BEVs are likely to be highly competitive in sectors where daily utilization rates are less than

[3] Note: TCO is a measure of cost of running a vehicle in INR per km terms, and includes factors such as upfront vehicle cost, insurance cost, maintenance cost, fuel cost, etc.

[4] https://www.teriin.org/sites/default/files/2021-07/Report_on_The_Potential_Role_of_%20Hydrogen_in_India.pdf

Table 1: Comparative Assessment of Fuel Technologies – HDVs

Particulars	Diesel	LNG	Electric	Hydrogen
Total Cost Ownership	Not competitive post 2030	Competitive with diesel	Competitive for shorter distances post 2030. Potentially competitive across all relevant distances by 2050.	Competitive over longer distances
Refuel/charging time	15–20 mins	15–20 mins	45 mins – 2 hours (fast-charging only)	15–20 mins
Infrastructure requirement	In place	New LNG refilling stations required	New high-capacity charging network	New hydrogen refilling stations required
User acceptability	No change	No change in operations	Change to fleet operation required	Change required
Weight penalty of drivetrain + storage	No change	Minimal change	Significant for long distance	Minimal change
Risks	Crude oil price fluctuation and fuel taxes	Gas price fluctuation	Battery cost reduction. Uncertainty about pace of improvement in battery energy density. Secondary market price discovery.	Dependent on cost declines in fuel cells, tanks, and electrolysers. Secondary market price discovery.

Source: TERI

500 km, and routes are highly predictable to allow programming of lengthy charging periods. These include waste disposal, commuter bus routes, service vehicles, etc.

- FCEV trucks may be a preferred option for routes above 500 km, although competitiveness of FCEVs is dependent on reduction in overall costs of green hydrogen production technologies and very low landing costs of hydrogen.

  Likewise, for net emission reductions to be achieved, either open access low carbon sources of generation are required, or the electricity grid emissions must reduce by roughly a factor of three from today's level.

- CNG trucks appear useful as a potential bridging option, but care must be taken about locking in investment and infrastructure.

Storage of hydrogen requires high pressures of 350–700 bar.[5] Pilots with guaranteed hydrogen supply and long-term fixed prices are needed for performance checks under different conditions. Early establishment of regional hubs for hydrogen in high density passenger and freight routes would ease the refuelling needs at later stages. OEMs are working on developing fuel cell and H-ICE vehicle models.

In terms of mobility, hydrogen emerges as the primary contender to electricity, providing comparable advantages. Hydrogen possesses gravimetric energy content of 143 MJ/kg (compressed, 700 bar), which is 2.7 times the calorific value of petrol.[6] Additionally, it is environment-friendly, causing zero tail-pipe emissions, i.e., water vapour at the point of use. It is to be stressed that with respect to scale of operations and the use case for long-distance transport, FCVs stand out as a feasible option.

On a Mission Mode

In a major push towards clean transportation, the Ministry of New and Renewable Energy (MNRE), Government of India launched five pioneering pilot projects aimed at introducing hydrogen-powered buses and trucks on Indian roads. The flag-off ceremony was held on March 4, 2025, in the august presence of Union Ministers Shri Nitin Gadkari, MoRTH and Shri Prahlad Joshi, MNRE who emphasized the importance of hydrogen in achieving a sustainable and low-carbon transport future. This initiative, under the National Green

5 https://www.sciencedirect.com/science/article/abs/pii/S0360319922047644

6 https://www.researchgate.net/figure/olumetric-and-gravimetric-energy-densities-of-common-fuels_tbl2_235777492

Table 2: Hydrogen in transport – applications and policy focus

Vehicle Category	Best Technology (Long-Term)	Practical Transition Fuel	Hydrogen Colour Pathway	Policy Focus
Intracity Buses	FCEV (Green H_2)	FCEV (Blue H_2)	Blue → Green	Mandate ESG-driven targets for municipal fleets; prioritize green H_2 procurement
Intercity Buses	FCEV (Green H_2)	H_2 ICE (Blue → Green H_2)	Grey → Blue → Green	Support retrofits, hydrogen blending, and green H_2 cost-reduction measures
Intercity Trucks	FCEV (Green H_2)	H_2 ICE (Grey → Blue H_2)	Grey → Blue → Green	Use grey to kickstart demand; incentivize long-term shift to green supply

Hydrogen Mission, follows MNRE's commitment to foster Hydrogen use in the transport sector.

Following a rigorous evaluation process, MNRE approved these projects with financial backing of approximately ₹208 crores from the Government of India. The projects have been awarded to prominent government agencies and private sector players.

The shortlisted pilot projects will deploy a total of 37 vehicles, comprising 15 hydrogen FCVs and 22 hydrogen internal combustion engine (ICE) vehicles, across 10 key routes.[7] These routes span major corridors including Greater Noida-Delhi-Agra in Delhi/Uttar Pradesh, Bhubaneshwar-Konark-Puri in Odisha, Ahmedabad-Vadodara-Surat in Gujarat, Sahibabad-Faridabad-Delhi in Haryana/Uttar Pradesh, Pune-Mumbai in Maharashtra, Jamshedpur-Kalinga Nagar in Jharkhand/Odisha, Thiruvananthapuram-Kochi and Kochi-Edappally in Kerala, Jamnagar-Ahmedabad in Gujarat, and Visakhapatnam-Bayyavaram in Andhra Pradesh. Supporting infrastructure will be bolstered with nine Hydrogen refuelling stations, making this a significant step toward future-ready transport systems.

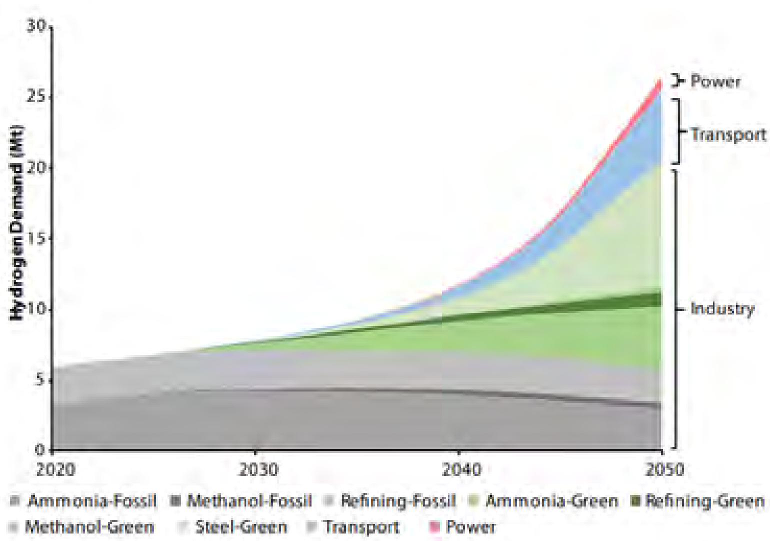

Figure 1: Hydrogen demand projection in the low-carbon scenario, 2020–2050

Source: TERI[8]

One of the key objectives of this pilot initiative is to develop and validate commercially viable hydrogen technologies for heavy transport. It aims to assess technical performance, operational safety, and economic feasibility of hydrogen-powered vehicles and refuelling infrastructure in real-world conditions. These learnings will help pave the way for large-scale deployment of hydrogen mobility solutions across the country.

Policy Recommendations

To unlock the full potential of hydrogen in India's mobility sector, a robust and coordinated policy framework is essential. Launching a "National Hydrogen Mobility Mission

7 https://sansad.in/getFile/loksabhaquestions/annex/184/AU5278_ccyEJc.pdf?source=pqals

8 https://www.teriin.org/sites/default/files/2021-07/Report_on_The_Potential_Role_of_%20Hydrogen_in_India.pdf

(NHMM)" can provide the strategic direction needed to scale hydrogen adoption across transport modes. Under this, developing hydrogen corridors as part of the PM Gati Shakti multi-modal infrastructure plan will ensure reliable supply and refuelling networks for long-haul and freight transport. These corridors could be selected based on the industrial hubs enroute, coastal roads connecting ports and terminals, among others. Aligning with this would be establishing cluster-based hydrogen valleys that can drive localized production and consumption, while encouraging innovation and lower logistical costs. These hubs would integrate industry and transport sector, thereby, accelerating hydrogen ecosystem development.

Introducing freight incentives for hydrogen-powered transport, particularly exemption of toll payment, lower taxes, or green freight credits, would be essential to make hydrogen trucks competitive with diesel during the initial few years of deployment. In parallel, retrofit programmes for existing heavy-duty fleets will allow faster transition without full fleet replacement, reducing costs for logistics operators. Of course, overall cost of retrofitting would play critical role in the adoption of retrofit technology and indicate the additional support required to make the intervention worthwhile.

Finally, indigenization and skill development initiatives would be critical to build a domestic hydrogen capacity. Promoting local manufacturing of components and training a skilled workforce will boost Atmanirbhar Bharat (self-reliance), create jobs, and ensure long-term sustainability. Together, these policy actions will provide the foundation for a clean, competitive, and future-ready hydrogen mobility ecosystem in India.

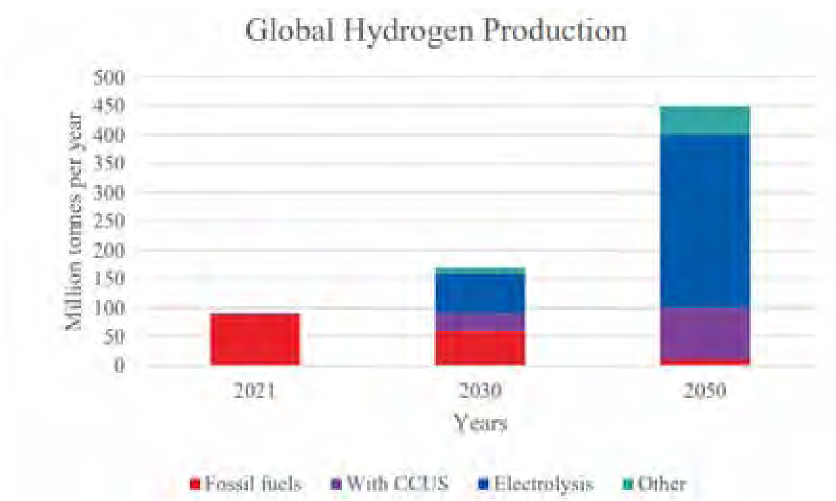

Figure 2: Global hydrogen production

Conclusion

In the upcoming decades, the road transport sector is anticipated to expand steadily. The dependency on oil imports is predicted to increase from 88% in 2025 to 93% by 2031, with more expansion foreseen in the future. This highlights the need for a mix of old, new and innovative strategies towards reducing the country's dependency on imported fuel to meet the growing road transport demand, particularly the freight segment. Government efforts such as the pilot projects for green hydrogen-based transport solutions under the National Green Hydrogen Mission are a vital boost to the production capacity as well as ecosystem augmentation—refuelling infrastructure, vehicle manufacturing and operations capabilities.

As highlighted in the recent White Paper on Hydrogen in Mobility released by Hydrogen Association of India in May 2025, India stands at a decisive moment to position hydrogen mobility as the strongest catalyst for its clean energy transition. India's colour-neutral approach, leveraging grey and blue hydrogen in the short term while ramping up green hydrogen infrastructure, would ensure faster market adoption. This pragmatic transition allows India to address current mobility needs without waiting for green hydrogen scale-up, while still aligning with long-term sustainability goals. Together, these factors position hydrogen as a pivotal enabler of clean, efficient, and inclusive mobility for India's future.

Hydrogen offers a transformative solution for mobility, especially in hard-to-abate sectors like freight, heavy-duty transport, railways, and shipping. These sectors demand high utilization rates, quick refuelling, and long driving ranges, areas where hydrogen fuel cells outperform EVs. Unlike EVs, hydrogen vehicles face lower payload penalties, making them ideal for long-haul and heavy-load applications.

Hydrogen also eases the pressure on critical battery minerals such as lithium, cobalt, and nickel, reducing geopolitical and supply chain

Table 3: Hydrogen-based sustainable technologies for multiple mobility segments

Segment	Hydrogen Intervention	Technology	India-Specific Considerations
Heavy-duty trucks	Grey/Blue/Green H_2	H_2 ICE, Fuel Cells	India has 3.5M+ trucks[9]; over 70% logistics by road[10]; BEVs may not be viable due to terrain, payload loss, and refuelling time; domestic OEMs testing H_2-ICE
Rail	e-Diesel / H_2 ICE / Fuel cells	Drop-in e-fuels, H_2 combustion / electrochemical conversion	Electrification is not possible on all routes hydrogen trains already operational in Germany; India has low axle-load branch lines ideal for hybrid engines
Shipping	e-Methanol	Solid Oxide fuel cells, dual-fuel engines	India has 13 major and 200+ minor ports; methanol bunkering is feasible at scale[11]
Aviation	SAF / e-Kerosene	Jet A1-compatible engines	India among fastest growing aviation markets; hydrogen-derived SAF can help Indian airlines meet CORSIA/ICAO targets
Last mile	Batteries (grid-linked) / Range extender for niche applications	BEVs (2W/3W) / fuel cells	>75% of India's mobility is 2W/3W[12]; short-range, low payload; well-suited for Li-ion/Na-ion; electricity cost is dominant driver

Source:
9. Estimates by MoRTH (2023)
10. NITI Aayog – India Transport Sector Assessment (2021)
11. Annual Report 2023: Ministry of Ports, Shipping and Waterways
12. SIAM

vulnerabilities. This is particularly vital for India, which aims to strengthen its energy independence. By enabling decentralized hydrogen production, especially through small-scale units in rural and industrial regions, hydrogen supports local economies and ensures energy access across logistic hubs.

Hydrogen mobility offers not only environmental benefits but also economic opportunities—from domestic manufacturing, job creation, supply chain development, to global leadership in hydrogen-powered transport. As countries ramp up their climate commitments, the mode of hydrogen production is undergoing a fundamental transformation. Figure 1 illustrates this shift, showing how global hydrogen production currently dominated by fossil fuels is expected to transition significantly towards low-carbon routes like electrolysis and fossil fuels with CCUS by 2050, supporting a more sustainable energy future.

Figure 2 shows global hydrogen production, while the globe has understood that hydrogen isn't just a climate solution, it's a techno-industrial revolution waiting to be unlocked, India is positioning itself as a major player in the global hydrogen economy, targeting a 10% share of the projected $700–800 billion annual market by 2050. Domestic hydrogen demand is expected to surge nearly ~30 million tonnes per annum (MMTPA) by 2050, driven by decarbonization in industry, transport, and energy storage. To meet this vision, an estimated $300 billion investment will be required across the hydrogen value chain spanning production, storage, distribution, and infrastructure. India aims to manufacture 60 GW of electrolysers annually by 2030, enabling around 5 MMTPA of green hydrogen capacity. Thus, scale-up of grey hydrogen is not only a climate and energy imperative but also a socio-economic opportunity, with the potential to create direct and indirect jobs in manufacturing, EPC, logistics, and operations underscoring hydrogen's role as a catalyst for sustainable industrial growth. Buoyed by the developments in China, Japan and South Korea, mobility has the potential to emerge as a demand engine in India as well.

The success of hydrogen in India depends on identifying sectors where adoption can scale rapidly, deliver visible impact, and unlock economic value in the near term. Among the various use cases, mobility particularly through hydrogen internal combustion engines (H_2-ICEs) and fuel cell electric vehicles offers the most compelling starting point. Unlike industrial sectors such as refineries and fertilizers, which require ultra-low hydrogen prices and long infrastructure transitions, the mobility sector benefits from shorter adoption timelines, policy visibility, retrofit-friendly technologies, and strong job creation potential.

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Waste to Wealth!

Anaerobic Gas Lift Reactor, a technology developed to turn organic waste into biogas, is making silent waves by helping sustainably manage municipal waste. In this article, **Soujanya Padikkal** traces the development of the technology, which has a potential for nationwide adoption.

Overview

Anaerobic Gas Lift Reactor (AGR) is a bio-methanation technology designed to convert organic waste into biogas and biomanure. Developed by CSIR-IICT, this technology offers a sustainable solution for managing municipal solid waste (MSW).

The waste generated by the population ends up in a landfill leading to large heaps of trash. Communities living near landfills face serious health risks and environmental hazards like groundwater pollution. The waste generated is also highly rich in organic carbon and is biodegradable. It can be purposefully utilized to generate bioenergy. With natural resources depleting quickly, clean and green energy is the new talk in town with biogas witnessing significant growth as governments seek alternatives for natural gas.

History traces the use of biogas to as far as 10th century by the Assyrians, who used it to heat bathing water. The first modern biogas plant was built in Leper Colony, Bombay, India in 1859. As of October 2024, India has 4.31 million installed biogas plants.

Anaerobic gas lift reactor

According to a report by The Energy and Resources Institute (TERI), cited by the International Trade Administration, out of the 62 million tonnes (MT) of waste produced in India annually, only 43 MT (69%) is collected with 12 MT (37%) treated before disposal and 31 MT (50%) directly discarded in landfills. It is projected that India will generate 165 MT of municipal solid waste (MSW) by 2030.[1]

Organic matter decaying in the absence of oxygen emits methane (CH_4) and carbon dioxide (CO_2), which is a major contributor to climate change. If burnt, it can be used as a source of energy and as an alternative to fossil fuels for different purposes like cooking, heating, and generating electricity. As per a team member involved in the development of the technology, "Methane has 21 times the global warming potential to that of carbon dioxide. The technology efficiently converts food and vegetable waste to biogas, which can be further utilized to replace LPG or power, reducing greenhouse gas emissions."

The Working of AGR

The AGR technology is a highly efficient system used for breaking down organic waste. It turns organic solid and

[1] *https://www.trade.gov/market-intelligence/india-solid-waste-management*

liquid waste into biogas and biomanure by using a process where slurry is mixed inside a reactor by the pressure created from the biogas produced.

The system consists of a vertical cylindrical tank with two interconnected compartments. Organic matters like food and vegetable waste are pumped into the bottom compartment, where it mixes with bacteria that convert it into methane and carbon dioxide. Biogas thus produced in the first compartment then creates pressure which moves the liquid upward into the second compartment.

At the top of the reactor, a three-phase separator sorts biogas, active biomass, and treated liquid. Biogas exits the reactor, while slurry returns to the bottom, and treated liquid is discharged. This process is repeated and driven by set pressure intervals. Some biogas is recycled back to the bottom compartment to boost pressure and increase mixing, enhancing the breakdown of volatile solids, biogas production, and heat transfer. The biogas is collected in a separate tank and utilized for cooking through a pipeline system. The mixing frequency depends on factors like biogas potential, , pressure, temperature, and solid degradation rate.

AGR technology at Dr BR Ambedkar Vegetable Yard, Bowenpally, Hyderabad

The reactor can break down waste in 14 to 22 days, reducing the waste by 65–80% while managing ammonia levels to prevent damage to the system.

The AGR system is a continuous digestive process that takes organic waste, breaks it down into useful gases (biogas), and turns the leftover materials into a safe liquid or biomanure, all while using pressure and bacteria to make it happen. However, the development of AGR has had its own set of challenges.

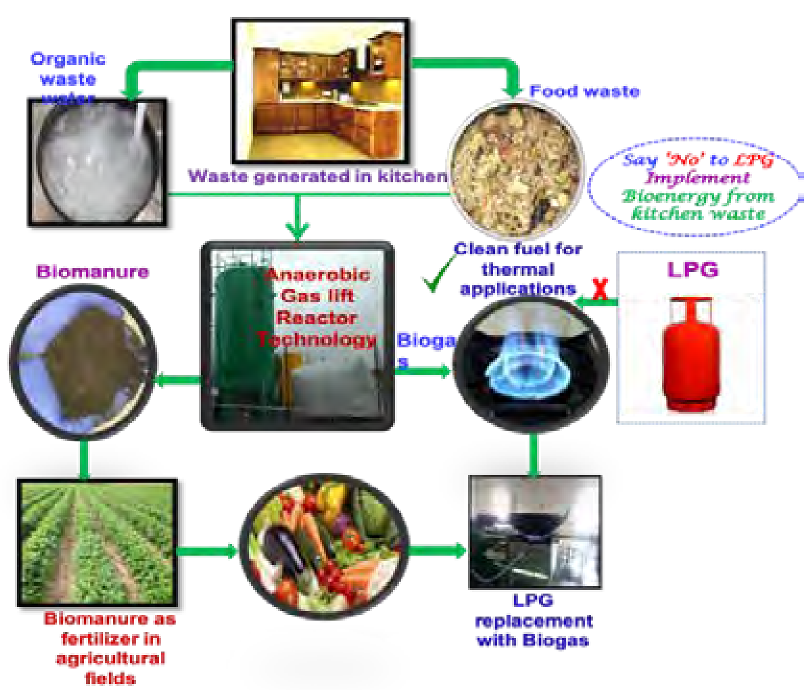

Figure 1: Waste to energy - kitchen to kitchen

Real-World Impact

Dr BR Ambedkar Vegetable Yard in Bowenpally, Hyderabad has reaped the benefits of this technology. The vegetable market produces 3–4 tonnes of organic waste and the plant can generate 450–550 units/day of electricity using 10 tonnes of waste (the rest sourced from nearby markets) which powers more than 100 streetlights and 170 stalls, cold storage, an administrative building and the market water supply network. The remaining biogas after being utilized for these purposes is used to replace 2 commercial LPG cylinders (i.e., 35–40 kg of LPG equivalent biogas) in canteens while the biomanure generated is sold as organic fertilizer.

Another team member noted that the technology's establishment at Bowenpally marked a breakthrough in demonstrating how innovative anaerobic digestion technology can efficiently treat organic waste, generate renewable energy, and scale inspiring, nationwide sustainable waste management practices.

Limitations and Potential

Thirty-two biogas plants of different sizes (250 kg/day to 10 tonnes/day) are currently operational for the treatment of a variety of organic wastes such as food waste, market & vegetable waste, organic fraction of MSW (OFMSW), poultry litter, MSW leachate, etc., and four are under installation.

While biogas technology has brought about numerous benefits, there are still challenges like material degradation from corrosive gases (e.g., hydrogen sulphide), scaling, and fouling on reactor surfaces. To address these, the AGR uses corrosion-resistant materials and requires regular maintenance, including cleaning and anti-scaling agents. Additionally, the system is sensitive to feedstock variability and requires stable feed quality and pH control.

As per the United Nations Food Waste Report Index 2024, Indian households generated an average of 55 kg food waste which amounts to 78.2 million tonnes. The data reveals the pressing need for a solution to treat food waste. The potential for this technology to support decentralized renewable energy systems and create value from waste materials was an inspiration for Dr Rao and his team.

The team members voice, "many existing technologies are either too costly or complex for decentralized applications. The AGR reactor offers a cost-effective, scalable, and adaptable solution, making it accessible for industries, municipalities, and small-scale operators alike".

AGR has already been adopted in large kitchens like the Akshaya Patra Foundation and installed in vegetable markets. Such models need to be replicated across India in different sectors to not only reduce waste but also convert waste into valuable products.

Innovations like the AGR technology are the need of the hour with India's growing waste management crisis. A robust public-awareness programme to educate people on how their actions contribute to waste could also make a significant difference.

The technology was developed under the leadership of Dr A Gangagni Rao, Chief Scientist; alongside Dr Sameena Begum, Scientist; Dr Vijayalakshmi, Women Scientist; and their dedicated team.

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Attention Innovators!

Show Your Mettle and Lead the Next Energy Revolution

Amid India's booming renewable energy landscape, multiple stakeholders are dishing out innovative and sustainable solutions which are both user-friendly and cost-effective. In this piece, **Arpo Mukherjee** explains how changemakers can seize an exciting opportunity to bag attractive prizes and nationwide recognition under an MNRE contest.

India stands at a critical juncture in its clean energy journey. With one of the world's most ambitious renewable energy targets of 500 GW of non-fossil fuel capacity by 2030. India's transition is not just about generating power, but about transforming systems, societies, and solutions. In this context, the rooftop solar (RTS) sector holds enormous promise. To fully unlock this potential, it must confront and creatively overcome key systemic and market barriers.

The PM Surya Ghar: Innovative Project Start-Up Grand Challenge, launched under the aegis of the Ministry of New and Renewable Energy (MNRE), aims to do just that. Focused on RTS and distributed renewable energy (DRE) technologies, this challenge is a call to India's start-up ecosystem to co-create the next generation of solutions that are not only scalable and sustainable but inclusive and locally tailored.

Rooftop solar is central to India's decentralized energy vision. It empowers households, reduces peak demand pressure on DISCOMs, and enhances energy security at the last mile. Yet, despite supportive policies and subsidies, RTS adoption has been uneven. Factors such as high upfront costs, lack of consumer financing options, inadequate awareness, technical constraints in shared spaces, and poor integration with urban infrastructure continue to hinder scale.

This is where the grand challenge takes a differentiated approach. Rather than focusing only on physical hardware or capacity targets, it invites innovation across four thematic pillars: affordability, resilience, inclusivity, and environmental sustainability.

Innovation for Affordability

Cost remains a major barrier to RTS adoption, especially for low and middle-income households. The challenge encourages startups to rethink financing models—think solar leasing, pay-as-you-go solutions, peer-to-peer lending, and modular rooftop kits that reduce upfront investment and payback time. By aligning innovation with affordability, startups can unlock mass market adoption and scale.

Strengthening Resilience in a Changing Climate

As climate volatility increases and energy systems become more digitized, resilience is no longer a luxury—it is a necessity. Rooftop solar systems must withstand extreme weather events, prevent cybersecurity breaches, and ensure grid stability even with high penetration. The challenge calls for innovations like AI-based demand management tools, grid-forming inverters, decentralized microgrids, and autonomous monitoring systems that protect both the consumer and the grid.

Inclusion at the Core

Energy transition must not leave anyone behind. Yet, informal households, remote villages, and tenants in multi-occupant buildings often remain outside the ambit of RTS schemes. Solutions like community solar, virtual net metering, shared infrastructure models, and mobile solar units could change that. Startups have the power to develop replicable models that democratize solar access and build energy equity.

Environmental Stewardship through Circularity

As solar installations grow, so do the concerns around land use, panel wastage, and lifecycle emissions. The challenge also emphasizes on sustainable solar deployment, urging innovations in panel recycling, e-waste management, robotic disassembly, and circular economy frameworks. This aligns with India's global climate leadership and its commitment to just, green growth.

The programme is not just a contest, it is a launching platform. With top prizes of ₹1 crore, ₹50 lakh, and ₹30 lakh, and ten consolation prizes of ₹5 lakh each, it offers meaningful fiscal incentives. But more importantly, winning startups will receive incubation support from the National Institute of Solar Energy (NISE) and will be eligible for pilot deployments, access to MNRE's ecosystem, and capacity-building support.

This ecosystem-oriented approach is crucial—startups often have the ideas but lack institutional access or visibility. By bridging that gap, the challenge aims to foster mission-driven entrepreneurship and drive real-world outcomes, not just prototypes.

India's rooftops are more than idle real estate, they are platforms for empowerment, innovation, and climate action. If every solar panel can be turned into a building block of resilience, equity, and sustainability, then this challenge has the potential to be a catalyst for an entire movement.

In the years to come, the success of rooftop revolution will be measured not just in megawatts, but in the millions of lives illuminated by clean, affordable, and inclusive energy. With the right ideas, incentives, and intent, it is achievable — one innovation at a time.

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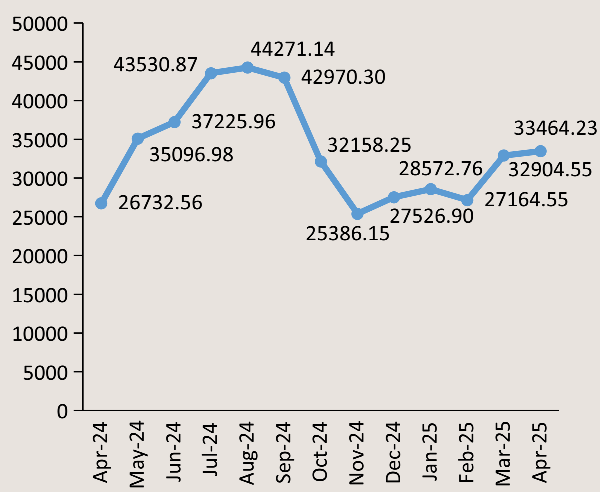
**Please check the back cover of this issue for more details.*

All India Total Renewable Energy Generation in April 2025



Source: CEA

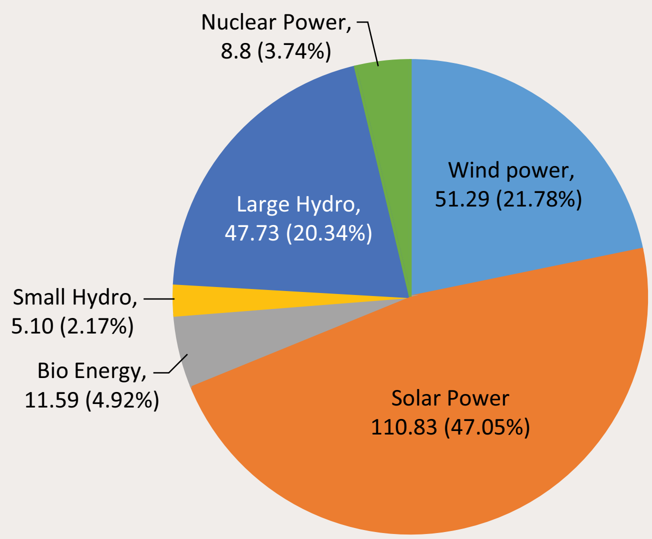
Month	Wind	Solar	Biomass	Bagasse	"Small Hydro"	"Large Hydro"	Others	"Total (MU)"
Apr-24	4729.26	12021.05	278.73	781.11	581.9	8109.14	231.36	26732.56
May-24	8257.63	12645.99	295.16	317.07	734.16	12595.42	251.56	35096.98
Jun-24	10134.92	11445.66	273.43	188.61	776.37	14173.69	233.29	37225.96
Jul-24	13627.00	10356.35	284.12	132.36	1323.02	17562.91	245.11	43530.87
Aug-24	10268.88	10157.52	297.05	132.17	1600.37	21565.90	249.24	44271.14
Sep-24	8870.62	11302.62	258.15	118.58	1612.83	20574.25	233.26	42970.30
Oct-24	3238.28	12256.61	337.9	166	1457.59	14455.88	245.98	32158.25
Nov-24	3109.33	11246.52	321.47	980.79	860.92	8630.89	236.23	25386.15
Dec-24	5747.49	10707.21	350.76	1935.01	807.35	7753.43	225.65	27526.90
Jan-25	5637.69	12285.74	356.41	2041.06	624.57	7388.05	239.24	28572.76
Feb-25	4592.48	12913.58	339.16	1556.29	561.87	6970.88	230.79	27164.55
Mar-25	5133.63	16811.38	346.33	986.25	615.16	8763.28	248.51	32904.55
Apr-25	6330.71	15811.82	325.96	444.44	687.48	9618.15	245.67	33464.23

Source: CEA

State wise RE Generation (MU)		
Name of State/UT	**Apr-25**	**Apr-24**
NORTHERN REGION		
Chandigarh	0.40	1.02
Delhi	58.62	64.04
Haryana	194.75	175.86
Himachal Pradesh	2814.55	2172.64
Jammu & Kashmir	1702.40	1500.23
Ladakh	26.49	14.89
Punjab	393.97	542.27
Rajasthan	6432.56	4522.39
Uttar Pradesh	738.79	706.52
Uttarakhand	851.09	801.82
SUB TOTAL (NR)	13213.62	10501.69
WESTERN REGION		
Chhattisgarh	1771.97	1377.74
Gujarat	2387.37	1936.11
Madhya Pradesh	2.68	2.69
Maharashtra	5.44	5.44
Dadra and Nagar Haveli and Daman and Diu	9750.88	7309.67
Goa	5.44	5.44
Sub Total (WR)	10298.04	7299.07
SOUTHERN REGION		
Andhra Pradesh	1437.17	1402.75
Telangana	745.01	696.02
Karnataka	3792.42	2751.57
Kerala	714.39	768.34
Tamil Nadu	2414.33	1970.23
Lakshadweep	0.01	0.01
Puducherry	1.02	1.02
SUB TOTAL (SR)	9104.35	7589.94
EASTERN REGION		
Andaman Nicobar	2.13	3.89
Bihar	34.81	23.94
Jharkhand	5.30	9.85
Odisha	538.11	538.10
Sikkim	97.23	75.24
West Bengal	349.72	306.48
SUB TOTAL (ER)	1027.30	957.49
NORTH-EASTERN REGION		
Arunachal Pradesh	199.04	237.47
Assam	79.97	68.14
Manipur	9.31	18.11
Meghalaya	66.69	41.18
Mizoram	9.06	12.39
Nagaland	3.44	7.86
Tripura	0.58	0.56
SUB TOTAL (NER)	368.08	385.71
ALL INDIA TOTAL	**33464.23**	**26744.50**

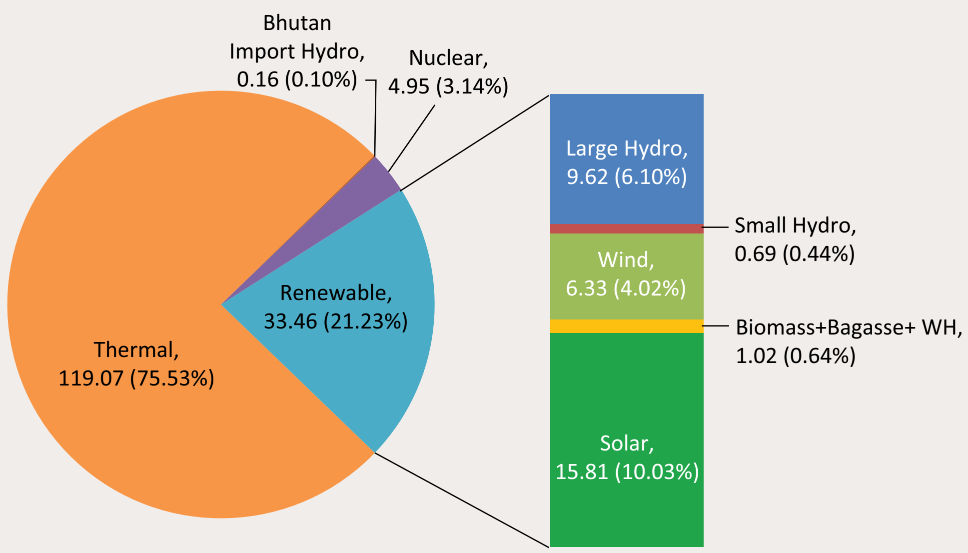
Source: CEA

Installed RE Capacity as on May 2025: 228.27 GW

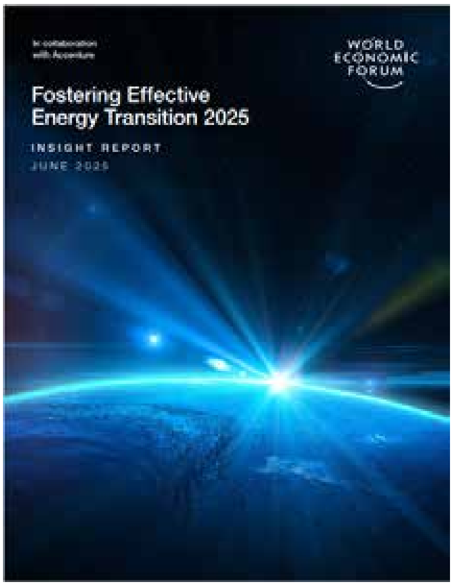


Source: MNRE

All India Monthly Energy Generation in India, 160.40 BU and Share of RE, 32.90 BU (20.51%) May 2025



Source: CEA



Fostering Effective Energy Transition 2025
by World Economic Forum
Year: 2025

The World Economic Forum's *Fostering Effective Energy Transition 2025* report indicates that following several years of sluggish advancement, the process of energy transition has intensified. The Energy Transition Index (ETI) evaluates 118 countries based on their energy system performance and the preparedness of their enabling environment, revealing advancements in energy equity and sustainability attributed to declining energy prices, subsidy reforms, reduced energy and emission intensity, and a higher proportion of clean energy. Nonetheless, advancements in energy security have been rather constrained, and the momentum for transition readiness has diminished. Simultaneously, global energy systems are encountering escalating pressures from climate change, geopolitical tensions, economic fluctuations, and technological changes.

Blueprint for Action on Just and Inclusive Energy Transitions
by International Energy Agency
Year: 2025

This year's G20 President, South Africa, is emphasizing equitable and inclusive energy transformations. This builds upon Brazil's 2024 G20 Presidency, which prioritized equitable and inclusive energy transitions on the global agenda. During Brazil's Presidency, the G20 leaders approved ten voluntary Principles for Equitable and Inclusive Energy Transitions.

The Global Commission believes that these principles constitute a robust framework for governments, each addressing their unique circumstances, to advance clean energy transitions that yield benefits and reduce harm. The Global Commission has created a guide for governments and other stakeholders on designing and implementing equitable and inclusive renewable energy transitions in this blueprint for action. In accordance with the voluntary principles adopted by G20 leaders in 2024, the Global Commission has presented examples of how energy policies might be formulated and executed to promote equitable outcomes. The Global Commission has concentrated on essential elements of each principle and disseminated specific policies from many countries to illustrate their implementation in diverse contexts.

NATIONAL

Mercom India Renewables Summit
July 24-25, 2025 | New Delhi, India

4th Green Hydrogen India
August 6-8, 2025 | New Delhi, India

POWERGEN India & Indian Utility Week 2025
September 2-4, 2025 | New Delhi, India

ICE3 2025: International Conference on Electrical and Electronics Engineering
September 19-20, 2025 | Uttar Pradesh, India

Renewable Energy India Expo 2025
October 30 - November 1, 2025 | New Delhi, India

INTERNATIONAL

ASEAN Sustainable Energy Week
July 2-4, 2025 | Bangkok, Thailand

UK Solar Summit
July 1-2, 2025 | London, United Kingdom

19th International Conference on Energy Sustainability
July 8–10, 2025 | Westminster, Colorado, USA

ASES SOLAR 2025: Innovation for Universal Renewable Energy Access
August 4-6, 2025 | University of Colorado Boulder, USA

RE+ 25
September 8-11, 2025 | Las Vegas, Nevada, USA

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