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Ensuring Energy Security
Role of Energy Policies of States



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Editorial



In January 2026, India reached a definitive turning point in the global economic order, officially overtaking Japan to become the world's fourth-largest economy with a nominal GDP of approximately \$4.19 trillion. This remarkable ascent—climbing six spots in just eleven years—is not merely a statistical achievement; it is a prelude to India's next objective: surpassing Germany to claim the third-largest spot by 2028. However, the path to \$5 trillion and beyond needs a singular, foundational pillar: the contribution from its constituent states.

While the Union Government sets the national vision—most notably through the "**Panchamrit**" targets announced at COP26—the execution of this energy revolution is increasingly decentralized. The five pillars of this strategy require state-level leadership to become a reality:

- **Capacity:** Reaching 500 GW of non-fossil energy capacity by 2030.
- **Mix:** Ensuring renewable energy constitutes 50% of the energy basket by 2030.
- **Abatement:** Reducing projected carbon emissions by one billion tonnes by 2030.
- **Intensity:** Lowering the economy's carbon intensity by 45% by 2030.
- **Net-Zero:** Achieving a carbon-neutral economy by 2070.

As one of the world's fastest-growing major economies, its energy consumption is projected to double by 2035, the nation faces a "dual-track" challenge: meeting surging demand while simultaneously decarbonizing. To meet this demand, India will need all types of energy. The diversity across India's states is vast, encompassing differences in available resources (solar, wind, hydro, coal), economic development trajectories, and existing infrastructure. This diversity necessitates a tailored approach to energy policy. In a federal structure, the states are no longer just implementers; they are the primary laboratories of energy innovation.

As per most of the energy outlooks, the most significant part of the energy transition in coming decades is electrification of energy which is expected to achieve almost one third share of total energy. The rising demand for electricity in India, necessitates a transformation at the state level. Most of the states have already begun tailoring policies to handle this shift.

These state-level policies are not merely environmental mandates; they are vital economic strategies. By fostering a diverse energy mix—including wind, solar, biofuels and emerging storage technologies—states are playing active role in national goals for decarbonisation.

India's status as the fourth-largest economy is a testament to its resilience, but to achieve the goal of Viksit Bharat with energy security and equity, energy must be made secure, affordable, and green. The states of India now hold the key to this future. By moving toward customized action plans—leveraging local strengths. The vast diversity of India's geography—from the wind corridors and the solar deserts to the hydro-rich regions, the coal belts, and biomass or organic waste feedstock rich regions, demands a tailored, state-specific approach. In last few years, it is seen that states are making policies to add solar

capacities including promoting national flagship programs, such as PM-Surya Ghar: Muft Bijli Yojana. Similarly, states are formulating policies for biofuels including CBG. States are also promoting usage of renewable energy including promoting EVs and domestic solar.

As policymakers convene for India Energy Week 2026, the message is clear: India's global climate leadership depends on federal cooperation. By active role of states, India can ensure that its transition is not only fast but inclusive, secure, and resilient for the decades to come.

In view of increasing role of states in energy transition, PPAC announced its annual IEW issue to be focused on energy policies of states. We are thankful for the overwhelming response from the experts and organizations. Subject is so wide that, another issue may be required to cover balance states.

We would like to add that Views expressed in the articles are those of the writers in their personal/official capacities and PPAC has only provided a platform for knowledge sharing. PPAC/MoPNG will not be responsible for any errors, omissions, discrepancies, and disputes arising out of these articles. PPAC/MoPNG are also in no way comparing any policies and objective is to learn from each other. PPAC/MoPNG are also not endorsing any of the organizations who have contributed to the journal.

Suggestions and Feedback from the readers are invited for improvement of the PPAC Journal. We also invite articles for our next issue which will be on the theme of **“Reimagining Mobility: Future Transportation Fuels for Viksit Bharat 2047”** and will be released in August 2026.

Warm regards,

Vijay Kansal, Additional Director

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Message from Director General

My vision for India's energy future has four pillars — energy access, energy efficiency, energy sustainability and energy security.”- PM Narendra Modi at the 16th International Energy Forum in New Delhi

As India advances steadily towards its vision of **Viksit Bharat 2047**, ensuring robust and resilient energy security has emerged as a national imperative. In this transformative journey, the role of States is increasingly pivotal. State-level energy policies, implementation frameworks, and localized innovations form the backbone of India's energy landscape, translating national objectives into tangible outcomes on the ground.

The **Petroleum Planning & Analysis Cell (PPAC)**, an attached office of the **Ministry of Petroleum & Natural Gas**, continues to play a vital role in supporting evidence-based policymaking through rigorous data collection, analysis, and dissemination. Over the years, PPAC has evolved as a trusted knowledge institution, providing sectoral insights that inform policy formulation, enable strategic planning, and strengthen coordination between the Centre and the States. In alignment with India's energy transition goals, PPAC has been actively engaging with State Governments to assess regional energy demand dynamics, infrastructure readiness, fuel diversification pathways, and policy best practices.

The **5th Edition** of the **PPAC Journal**, themed “**Ensuring Energy Security: Role of Energy Policies of States**”, is being released during **India Energy Week (IEW) 2026**, a global platform that underscores India's growing leadership in the energy sector. This edition seeks to highlight how progressive, forward-looking state energy policies are shaping India's energy security framework—by promoting fuel accessibility, enhancing infrastructure development, encouraging alternate and cleaner fuels, and fostering investments across the value chain.

States play a decisive role in strengthening last-mile energy delivery through initiatives such as promotion of cleaner cooking fuels, adoption of alternative fuels like CNG, LNG, EVs, biofuels and green hydrogen, and facilitation of refinery-linked and downstream infrastructure. State-specific policies and incentives have also been instrumental in accelerating energy transition while balancing regional development priorities and socio-economic considerations.

This edition brings together perspectives from State Governments, industry leaders, policy experts, and research institutions, offering insights into innovative policy frameworks, successful implementation models, and emerging challenges. It highlights how cooperative federalism, supported by data-driven planning and

institutional coordination, can ensure energy affordability, availability, and sustainability across diverse geographies.

Key focus areas of this transformation include:

- i. Strengthening Centre–State coordination for energy planning
- ii. Promoting state-level policy innovation and best practices
- iii. Expanding infrastructure for conventional and alternate fuels
- iv. Enhancing last-mile energy access and inclusivity
- v. Encouraging investments through stable and transparent policies
- vi. Integrating energy security with climate and development goals
- vii. Leveraging data, digital tools, and capacity building at the State level

India's journey towards energy security is intrinsically linked to the active participation of its States. Their policies and initiatives not only address regional energy needs but also collectively contribute to national resilience, reduced import dependence, and achievement of long-term climate commitments. I am confident that this edition of the PPAC Journal will serve as a valuable knowledge resource, fostering informed dialogue, collaboration, and policy learning among stakeholders.

I extend my sincere appreciation to all contributors, State Governments, and members of the editorial board for their valuable efforts in bringing out this edition. Inspired by the Hon'ble Prime Minister's vision articulated at India Energy Week 2025—that India's energy growth will be a catalyst for global progress—let us continue to work together to build an energy-secure, sustainable, and inclusive future. The oil and gas sector, supported by responsive and forward-looking state policies, will remain a cornerstone in powering India's development and realizing the vision of **Viksit Bharat 2047**.

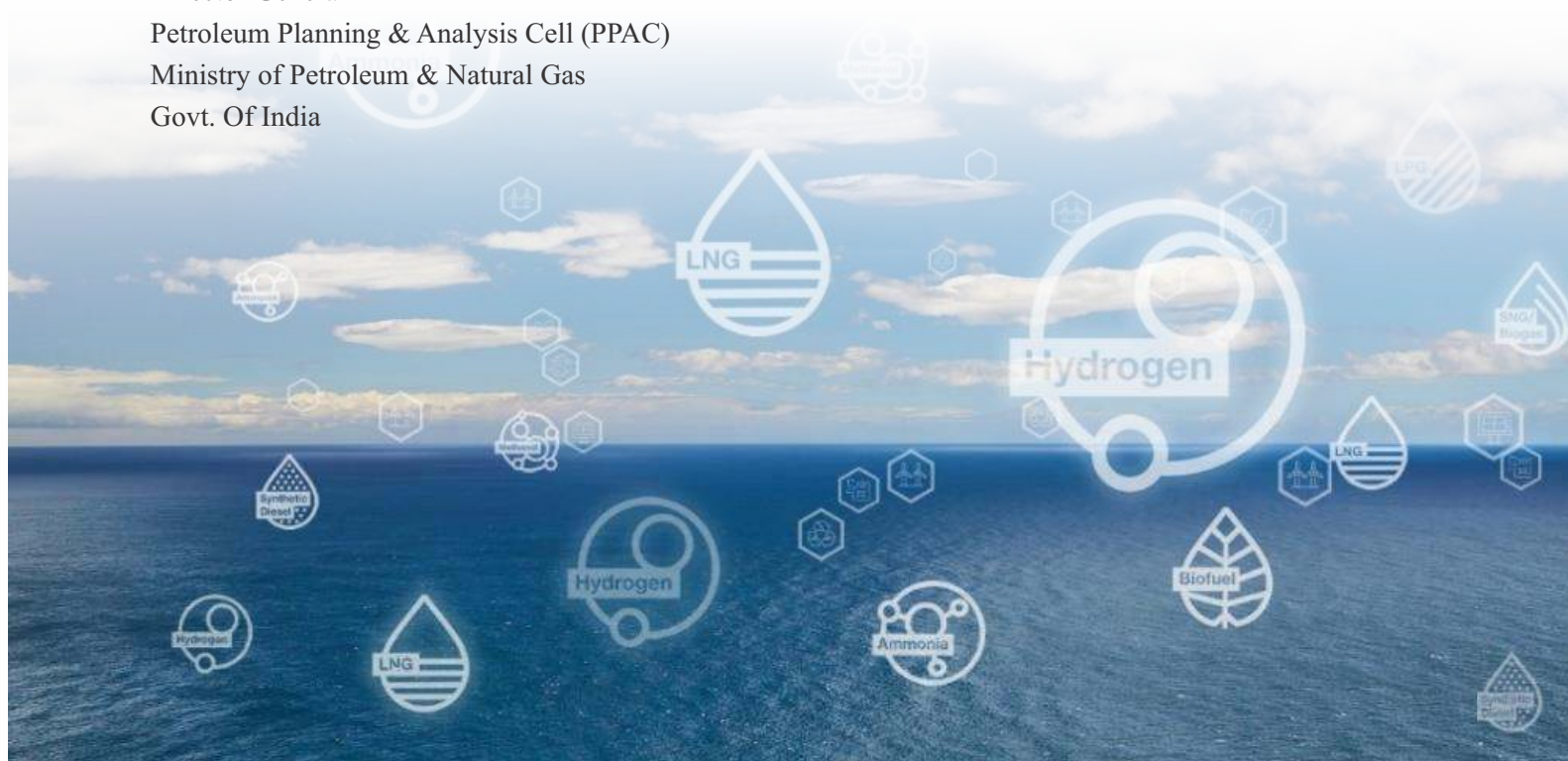
P. Manoj Kumar

Director General

Petroleum Planning & Analysis Cell (PPAC)

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Leveraging Industrial Policy for Energy Transition: Odisha's IPR 2022 Experience

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*Additional Chief Secretary, Industries & I&PR Department,
Government of Odisha*

1. Introduction

Odisha's Industrial Policy Resolution (IPR) 2022 was conceived as a comprehensive instrument to deepen industrialization, attract capital and create employment across the state. It is not an energy policy in the narrow but broader sense. However, while the primary objective was to strengthen the industrial base, the policy was drafted with a clear recognition that Odisha's metals and minerals driven economy is **heavily dependent on thermal power** and that this structure must gradually align with emerging domestic and global carbon norms.

A key design choice in IPR 2022 was therefore to embed **energy transition considerations** inside the wider industrial policy framework. The policy sought to give a head start to cleaner energy in the state

and to encourage a shift from an exclusively coal-based model to one that progressively relies on green energy and green fuels. This has been attempted in two complementary ways. First, the policy identifies **green energy equipment and green hydrogen with its derivatives as thrust sectors** and offers them best in class facilitation and the highest quantum of incentives. Second, it encourages all industrial projects to **adopt resource efficient and low emission practices** through targeted capital subsidies and concessions for renewable energy captive plants and environment-friendly infrastructure.

The sections that follow outline how IPR 2022 supports decarbonization and strengthens long term energy security in Odisha. They set out the key policy features, summarize the investment response, and highlight the linkages with the state's energy intensive industrial base and its broader development vision.

2. Industrial Context and the Need for a Policy Nudge

Odisha has historically been one of India's foremost states in minerals and metallurgy. It is the largest producer of steel and aluminium in the country, with the largest reserves of iron ore and bauxite and the second largest reserves of coal. This resource endowment has enabled the development of large steel, aluminium and other metal industries that are intensive in power consumption. Much of this demand has been met through coal based generation and coal-based captive power plants.

The state has also been a leader in the power sector reforms. Odisha was the **first state in India to privatise distribution of power**. It unbundled the sector early, created a regulatory framework and has progressively strengthened transmission and distribution systems. The result of these initiatives is that **Odisha today is an electricity surplus state with a relatively mature power sector architecture**.

At the same time, this industrial structure faces new challenges. International trade regimes and large buyers are increasingly sensitive to the carbon content of production. Instruments such as **border adjustment measures** and **green procurement norms** mean that producers who rely entirely on fossil fuel-based power may find it harder to access markets, especially International, or finance in the coming years. For a state whose industrial base is dominated by metals and mining, these developments carry significant implications.

The state government therefore saw value in using industrial policy to prepare for this transition. The aim was not to slow down industrialization but to guide it towards forms of production that are compatible with emerging carbon norms and that can anchor energy security in a future where green energy plays a much larger role.

3. Design of IPR 2022 with respect to Energy Transition

IPR 2022 covers the full range of issues associated with industrial development, including land, infrastructure, utilities, investment promotion and facilitation. Within this broad scope, three elements are particularly relevant for energy transition and energy security.

First, the policy identifies Green Energy Equipment as a thrust sector. This category includes manufacturing of solar panels, solar cells and wafers, equipment for other renewable energy technologies and related components. As a thrust sector, green energy equipment is eligible for the highest slabs of incentives under the policy. This decision was taken to create a manufacturing base that can support the rapid expansion of renewable energy capacity in Odisha.

Second, the policy classifies Green Hydrogen and its derivatives, as thrust sector with preferential support in power infrastructure. This reflects a strategic view that hydrogen-based fuels will be critical for the decarbonization of emission intensive industries such as steel, chemicals and petrochemicals, and that port-based states like Odisha have an opportunity to serve both domestic users and export markets in this area.

Third, IPR 2022 incorporates explicit provisions that encourage all industrial units, irrespective of sector, to adopt green infrastructure and renewable energy captive power. Through a combination of capital subsidies and exemptions from electricity duty and state transmission charges, the policy lowers the cost of shifting from conventional captive power to cleaner alternatives.

These three elements together ensure that the policy supports energy transition at three levels. It promotes new industries that manufacture green technologies, it attracts investments in green fuels such as hydrogen and ammonia, and it nudges the wider industrial ecosystem to adopt cleaner and more resource efficient practices.

4. Incentives for Green Infrastructure, Green Hydrogen and Renewable Captive Power

IPR 2022 offers **capital investment subsidies** to promote green infrastructure and resource efficiency. It provides a 25% capital investment subsidy (up to ₹10 crore) for green buildings, waste water treatment, effluent treatment and deep discharge facilities, and a 50% subsidy (up to ₹10 crore) for systems achieving at least 50% waste water recovery with zero liquid discharge.

The policy treats **renewable energy captive plants** as **industrial projects** eligible for a 30% capital subsidy on project cost with no upper cap, covering rooftop solar, ground mounted and floating solar, wind, hydro, pumped storage, battery storage and suitable hybrids. In addition, such plants are **exempt from state electricity duty and state transmission charges** for 20 years. This combination of uncapped capital support and long-term exemptions reduces both upfront and recurring costs, enabling industries to replace or supplement coal based captive power and thereby decarbonize the industrial power mix while strengthening energy security.

For **Green Hydrogen and Green Ammonia**, which have high electricity demand and long operating horizons, IPR 2022 provides differentiated benefits. Beyond thrust sector status, these units receive **higher reimbursement of power charges for a longer period and exemptions from electricity duty and state transmission charges for 20 years**. Together with the incentives for renewable captive plants, this creates an **integrated support structure** that lowers the effective cost of renewable power used in electrolysis, improves project viability and helps position Odisha as a leading destination for proposed green hydrogen investments.

5. Investment outcomes in Green Energy Equipment, Green Hydrogen and Green fuels

Prior to this, there were **no significant investments** in manufacturing of **solar panels, solar cells, wafers** or other major renewable energy equipment in Odisha. Since the notification of IPR 2022, Odisha has received investment proposals for **21 projects** in the green energy equipment segment, representing about **₹1 lakh crore** of investment with an estimated employment potential of **more than**

51,000 persons. This shift from a zero baseline to 21 projects of this nature within a short period clearly illustrates the signaling effect of the policy. By granting thrust sector status and offering attractive incentives & facilitation, IPR 2022 has helped Odisha carve out a new segment in its industrial portfolio.

A similar pattern is visible in the **Green Hydrogen and Green Ammonia** sector. Before **IPR 2022**, Odisha did not have any companies producing green hydrogen or engaging in the development such technologies, and there was **no established ecosystem** in this field. The policy and its provisions have changed the investment landscape, and the state has now approved **16 projects** in green hydrogen and its derivatives with a combined investment commitment of **more than ₹2 lakh crore** and a projected employment potential of about **36,000 jobs**. Many of these projects are concentrated around **coastal locations** with suitable **port infrastructure**. **Paradip Port** has been declared a **Green Hydrogen Hub** by the National Green Hydrogen Mission, and Odisha is also proposing to position **Gopalpur Port** as the next hub for the Green hydrogen sector. Once these investments are commissioned, Odisha will host a cluster of large-scale green fuel projects with backward linkages to renewable energy and forward linkages to domestic and international markets.

The scale of investment and the speed with which proposals have emerged indicate that the policy mix in IPR 2022 has successfully addressed investor expectations regarding project viability and long-term operating conditions.

6. Contribution to Decarbonization of a Coal based Industrial Base

Odisha remains a coal rich state, with reserves sufficient for the foreseeable future. In the absence of a strong policy push, it would have been easy for the state to continue relying almost entirely on coal-based generation to power its industries. **IPR 2022 represents a conscious decision to use industrial policy to influence this trajectory.**

By attracting new manufacturing in green energy equipment, the state is **building a domestic supply base** that can support the expansion of renewable capacity. By hosting large green hydrogen and green ammonia projects, it is **creating alternative fuels** that can in time serve its own metals, chemicals and petrochemicals-based industries.

At the same time, the incentives for renewable captive plants and for green infrastructure encourage existing and new units in traditional sectors to adopt cleaner practices. **A steel plant or an aluminium smelter in Odisha now has a clear policy route to invest in renewable captive capacity within the state**, to improve energy efficiency and to demonstrate progress toward decarbonization. This will be important as global buyers and regulators increasingly scrutinize the carbon intensity of production.

In this way, IPR 2022 helps manage both sides of the energy transition challenge. It supports the supply side by creating new green energy production and it supports the demand side by lowering the cost of adoption for energy intensive users.

7. Linkage with the State's Long-Term Vision and Energy Security

Odisha has articulated a long-term vision in the **Odisha Vision 2036 and 2047 – A Vikshit Odisha for a Vikshit Bharat** document, which seeks to combine high economic growth with environmental sustainability. A key goal under this vision is to increase the share of **renewable energy** in the state's **installed power capacity to 70% by 2047.**

The early momentum created by IPR 2022 is central to this trajectory. New green energy equipment manufacturing capacity and an emerging cluster of green hydrogen projects lay the groundwork for much higher renewable penetration in the coming decades, while incentives for renewable captive power and environmental infrastructure align private investment decisions with the state's long-term objectives.

Odisha's history of power sector reform, including being the first state to privatise distribution of power, provides an **institutional foundation for managing this transition**. The experience gained in unbundling, regulation and private participation can now be applied to new challenges such as integrating higher shares of renewable energy, developing storage solutions and adapting networks to new patterns of generation and demand.

From an energy security perspective, the shift encouraged by IPR 2022 **reduces future dependence on fossil fuel-based power and enhances resilience**. A diversified mix that includes significant renewable and green fuel capacity within the state will help safeguard Odisha's industries against volatility in fuel prices and regulatory risks associated with carbon emissions.

8. Conclusion

IPR 2022 was framed primarily as an industrial policy to accelerate investment and job creation in Odisha, but its design deliberately aligns industrialization with energy transition. By designating green energy equipment and green hydrogen and its derivatives as thrust sectors, and by providing strong incentives for renewable captive power and environmental infrastructure, it sets a clear low carbon direction for industrial growth.

The impact is visible: Odisha has moved from **to becoming a leader in decarbonization linked sectors**. For a coal rich, energy intensive state, this marks a significant structural shift, adding new green layers to its industrial base and strengthening the foundations of long-term energy security, while demonstrating how industrial policy can be used as a practical instrument for managing energy transition at the state level.



Compressed Bio Gas (CBG) Plant in Dhuri, Sangrur District, Punjab

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Ensuring Energy Security: Role of Energy Policies of Punjab State

Smt. Neelima, IAS

Chief Executive Officer, Punjab Energy Development Agency (PEDA)

Punjab Energy Development Agency (PEDA) is State Nodal Agency for the implementation of the New and Renewable Sources of Energy (NRSE) Policy on behalf of the GOVT. of Punjab. It is responsible for laying down the procedure for inviting of proposals from NRSE project developers i.e preparing bid documents, managing the bid process, evaluation of project proposals and its award to successful bidder, project approvals and scrutiny of DPR, project implementation and monitoring.

Punjab is predominantly rich in agriculture and contributes the major share to the grain basket of India. With its strong agricultural base and growing industrial and urban sectors, is a replica of India's energy challenges and opportunities. The state's electricity consumption per capita is higher than the national average, reflecting intensive irrigation pumping, agro-processing, cold chains, urban services and a

relatively high level of electrification. Power supply draws on a mix of state-owned thermal plants, allocations from central generating stations and significant hydro contributions from interstate river projects, supplemented by a growing portfolio of solar and biomass-based projects. Some sectoral consumption studies show that trucks and other commercial vehicles account for nearly two-thirds of diesel sales from retail outlets, with agriculture's direct diesel share declining compared to a decade ago due to improved rural electrification and mechanization efficiencies. These trends are relevant for Punjab, given its role as a major origin and transit state for freight, and its deep agricultural footprint.

The State is at the forefront and playing a major role to reduce the dependency on the fossil fuels and also in reducing the import bill. It is in this context that Punjab's proactive articulation of a long-term energy vision becomes particularly significant. In this endeavour State has achieved significant milestones in the following branches of energy sector:

Compressed Biogas Projects

Punjab being an agrarian state has intense cropping pattern of wheat and paddy. About 20 million Tonne of the straw/stubble is generated every year but only 12-13 million Ton is being used in biomass power plants, industrial boilers and plywood industry etc. Rest of 7-8 million Ton is required to be managed scientifically. In this direction, state has allocated 57 Compressed Biogas (CBG) Projects of total capacity about 822.68 Ton Per Day (TPD), based on paddy straw and other agro-residue. 6 CBG project of total capacity 107.48 TPD CBG are currently operational. 4 more projects of total capacity 45 TPD CBG are to be operational in the year. Remaining 47 CBG projects, are at different stages of execution/ pre-construction clearances and are expected to be commissioned in next 2 years. Once commissioned these projects shall consume about 2.80-million-ton paddy straw annually.

Biomass Power Projects:

Punjab has been meeting its electrical power requirements primarily through conventional thermal and hydro power generation. Hydro power generation has a tendency to fluctuate depending on the availability of water. Thermal power generation has to depend on coal which has to be transported from eastern part of India involving large distances. Cost of generation from coal continuous to escalate and moreover causes pollution.

The State Govt. under NRSE Policy 2012 has mandated PEDA to setup Biomass Power Projects for co-generation of electricity using Paddy straw. A total of 11 Biomass based Power Generation Projects of total capacity 101.50 MW have been commissioned in the State which are running efficiently and consuming about 1.0-million-ton paddy straw/ other agro-residue annually. In addition, PEDA is planning to set up 100 MW Biomass Power Projects for which the proposal has been forwarded to Ministry of New & Renewable Energy, GOI, for providing Viability Gap Funding (VGF).

Biomass / Bagasse co-generation Power Projects: -

The total capacity of 580MW Biomass/ Bagasse co-generation projects has been setup in the state of Punjab. The Projects has been installed by the industrial, Sugar Mill and Paper Mills developers under Independent Power Producer (IPP) mode. State is facilitating the power projects developers to sign the Power Purchase Agreement to sale the power to DISCOM. In addition, a project of 14 MW capacity is under construction and to be commissioned by March 2026.

Waste to Energy Projects:

For scientific disposal of cattle dung PEDDA has set up 1 Project in Haibowal dairy Complex, Ludhiana for production of about 3 Ton Per Day (TPD) CBG project, which is consuming about 200 Ton Cattle dung daily. Two more projects each of capacity 6.4 TPD CBG are in pipeline, to be setup in Haibowal and Tajpur Dairy Complexes in Ludhiana. These projects will consume about 300-ton cattle dung daily. Both projects are expected to be commissioned during 2027.

2G Bio-ethanol Project based on Paddy Straw:

State is facilitating M/s. Hindustan Petroleum Corporation Limited for setting up of 100 kl/day capacity 2G Bio-ethanol project based on paddy straw in Village Nasibpur, Tehsil Talwandi Saboo, District Bathinda. This project is expected to be completed by March 2026 and will consume about 2.00 lakh ton paddy straw annually at full capacity production.

Small/Mini Hydel Projects:

Punjab has substantial renewable energy potential in the area of Small/Mini Hydro. An estimated hydro potential of 250 MW was available on the various canal systems of Punjab, out of which 172 MW has been harnessed. The role of Small Hydro projects has been well identified and accepted to supplement energy generation as short/medium term measure. These projects have techno-commercial viability in view of the steep increase of costs of other forms of energy, latest technologies developed in small hydro projects and fiscal incentives granted pursuant to the policies of the State and Central Government. In the State, 171.30 MW Small Hydro Potential has been harnessed by setting 55 projects. One more project of capacity 2.00 MW is in pipeline and under to be commissioned in F.Y. 2025-26. In addition, about 65 MW potential has been identified on Bhakra Main Line, however in awaiting various approvals.

Solar Power Projects:

The State of Punjab has successfully installed 958 MW cumulative capacity of solar power projects within the State on Power Purchase Agreement (PPA) mode.

ENERGY CONSERVATION PROGRAMME:

The Government of India enacted the Energy Conservation Act, 2001, became effective from 1st March, 2002. The Act provides institutionalizing and strengthening delivery mechanism for energy efficiency programs in the country and provides a framework for the much-needed coordination between various government entities. Among the key stakeholders are the State Designated Agencies (SDAs) established by State Governments in consultation with Bureau of Energy Efficiency (BEE) with the responsibility to implement the Act within the State.

Punjab Energy Development Agency (PEDDA) has been declared as the State Designated Agency (SDA) to coordinate, regulate and enforce the Energy Conservation Act-2001 within the state of Punjab in 2005. The role of PEDDA as SDA is to create general awareness among masses about the importance and benefits of energy conservation measures and also to institutionalize the energy efficiency project implementation in the industry, agriculture, Public & Private Commercial and Residential buildings, Municipalities, Transport, DISCOM and cross sector. Approximately 5 MU's are being annually saved after implementing various energy conservation activities.

Fiscal assistance by Govt. of Punjab under State NRSE Policy 2012:

- i) Wherever irrigation land on canal banks is available, Water Resources Department of Punjab will transfer requisite canal land on notional lease amount of Rs. 1.5 lakh/annum/site for development of Mini/Small Hydel Projects.
- ii) Gram Panchayat Land wherever available, is provided to the upcoming units for setting up of production facilities CBG, 2G Bioethanol, Biomass power project and other biomass-based production units or for storage of feedstock on a long-term lease basis as per Gram Panchayat Land Lease Policy 2014, as amended time to time.
- iii) Wherever the required land belonging to local bodies is available, the State would encourage the local bodies to provide the land for NRSE projects.
- iv) The NRSE Power Generation and consumption by generators themselves as a captive unit from NRSE projects shall be fully exempted from levy of Electricity Duty.
- v) 100% Electricity Duty for power consumed from state licensee during construction and testing of the project shall be waived.
- vi) Octroi on NRSE fuels, to be used for energy generation and NRSE devices/ equipment/ machinery for NRSE Power Projects shall be fully exempted. Similarly, Octroi on self-consumption of power by captive power plants in the same premises or through wheeling by open access to same group companies shall also be exempted.
- vii) To promote usage /generation from NRSE, manufacturing & sale of NRSE devices/systems, and equipment's / machinery required for NRSE Power Projects shall be exempted from Value Added Tax (VAT) and any Cess there upon.
- viii) 100% exemption from entry tax in respect of all supplies (including capital goods, structure and raw materials) made for setting up and trial operations of the projects.
- ix) 100% exemption from payment of fee and stamp duty for registration/lease deed charges for the land required for the project.
- x) Agricultural land shall be allowed to be used for setting up of Renewable Energy Power Projects in the state and no CLU, EDC/or any other charges/fees for the same shall be payable.
- xi) All projects developed under this policy will be treated as industry in terms of Industrial policy of the state and all the incentives available to new industrial projects will be applicable to Renewable power projects set up under this policy as per industrial policy of the state, for which approval shall be taken from the Department of Industries and Commerce.
- xii) Any benefits under any relevant policy such as Mega projects Policy of State Government can be availed by the project covered under this policy, subject to qualifications and approval of the concerned departments, if any, and subject to conditions as may be prescribed on case-to-case basis by the Concerned Administrative Department.

Single Window Clearance:

For Time bound clearances required for the project, a single window system through Business First Web Portal of Punjab Bureau of Investment Promotion (Invest Punjab) has been put in place.



Karbighaiya Power Museum, Patna, Bihar- India's first dedicated power museum

3

Bihar's Green Shift: Forging Energy Security for Economic Growth

Shri Manoj Kumar Singh, IAS

Secretary, Energy Department, Govt. of Bihar

Bihar stands at a **critical juncture** in its developmental narrative. Historically plagued by **significant energy deficits** and a profound reliance on power purchased externally, predominantly from **coal-based sources**, the state's current rapid growth trajectory necessitates a fundamental, **sustainable transformation** of its energy landscape. This strategic pivot is far more than a policy choice; it is an **economic and geopolitical imperative**. It is driven by three core necessities, ensuring **Energy Security** for its populace and industry, aligning the state's development with India's ambitious **Net- Zero by 2070 commitment**, and **providing the reliable, clean power required to fuel rapid industrialization**. The transition to a greener, self-sufficient energy system is key to unlocking Bihar's full economic potential.

The state's vision is articulated through a comprehensive, incentivized framework anchored by the **Bihar Renewable Energy Policy (BREP) 2025** and the progressive **Draft Bihar Green Hydrogen Policy 2025**. These policies collectively outline a model for **sustainable energy growth** that aims to leverage Bihar's abundant solar resource, vast agricultural residue and strategic location to become a clean energy hub for Eastern India. Bihar is actively navigating the shift from traditional fossil fuels to a more **sustainable and green energy mix**, with significant developments in both advanced refining capabilities and the promotion of future fuels. This transition is crucial for the state's economic growth, energy security, and commitment to national climate goals.

The Apex Policy: Bihar Renewable Energy Policy 2025

The **Bihar Policy for Promotion of New and Renewable Energy Sources 2025** is the foundational document driving the green shift with the prospect of Granting '**Deemed Industry Status**' to RE projects and providing a single-window clearance mechanism through the **Bihar Renewable Energy Development Agency (BREDA)**. Bihar RE Policy 2025 supersedes the 2017 policy and sets a highly ambitious, five-year roadmap to fundamentally transform the state's power mix.

Recognizing the land scarcity, Bihar RE Policy 2025 promoted the land-lean solutions comprising of massive targeted installation of Floating Solar (Utilizing Reservoirs and Water bodies) in order to evade the hurdles pertaining to scarcity of high cost agricultural land. Bihar's Energy Department has also been encouraging the establishments of **Agrivoltaics**, combining solar panels with crop cultivation, ensuring optimized indigenous energy requirements. Projects like the **Kajra Solar Project** (301 MW solar with 495 MWh battery storage) demonstrate a commitment to **storage-backed solar**. The battery storage system is crucial for stability, ensuring power supply even after sunset and during peak hours, directly addressing power reliability and grid security concerns. Bihar's Energy Department has also eased the norms for solar adoptions carrying out large scale installation of Rooftop Solar over Govt. as well as Residential Buildings. The Bihar RE Policy 2025 offers significant fiscal and non-fiscal incentives including 100% exemption of SGST, Stamp Duty, Land Conversion Fee, Wheeling & Transmission Charges (Up to 20 years) along with allowing 100% banking of surplus RE Power maximizing the utility of C&I consumer segments

Decarbonizing the Future: Bihar Green Hydrogen Policy 2025

The **draft Bihar Green Hydrogen Policy 2025** targets the next generation of energy carriers, focusing on decarbonization of sectors like industry, transport and fertilizer production aiming to achieve a Green Hydrogen/Green Ammonia production capacity of 0.25 million **Metric tonnes per annum (MTPA)** by **2030** emphasizing use of Green Hydrogen in Nitrogenous fertilizers and Refinery industries in the State boosting the creation of **Green Hydrogen Hubs/Valleys** near consumption centres and promoting the manufacturing of **electrolyzers** and other components within Bihar. The Policy also offers **fast-track approvals** for environmental clearances, grid connectivity, and open access for RE projects associated with green hydrogen production

Bihar Pumped Storage Policy 2025

The Bihar Pumped Storage Promotion Policy, 2025, is a key pillar of the broader **Bihar Renewable Energy Policy 2025**, which targets **6.1 GWh of energy storage by FY 2029-30**, including **1,600 MWh**

of pumped storage capacity. The policy encourages private sector participation through the **Public-Private Partnership (PPP)** model and emphasizes the creation of local employment and technological innovation. Developers are offered attractive Fiscal incentives like **100% waiver of intra-state power transmission and wheeling charges (For 20 years), Stamp duty and Registration Fees accompanied with exemption for obligation of Power/contribution to Local Area Development Fund.** District administration will provide all sort of supports to expedite the identification of suitable non-forest land.

The successful implementation of the policy will not only ensure **round-the-clock, reliable, and affordable power** for necessary for catering the upcoming industrial growth but also unlock significant private investment and job creation. By leveraging the immense potential of PSPs to buffer the intermittency of renewables, Bihar is laying a solid foundation for its inclusive development and demonstrating a replicable low-carbon development pathway for other rapidly developing economies.

Social Welfare

Providing **free electricity up to a threshold (e.g., 125 units/month)** for domestic consumers (especially low-income groups) directly addresses the **affordability dimension** of energy security accompanies with efforts for providing 100% Govt. subsidy in installation of Solar Panels for **Kutir Jyoti consumers (for extremely poor households)** have been remarkable in ensuring that access of essential power doesn't rely on economic barriers.

Ensuring Energy Security

DISCOMs Financial and Operational Health are the most important factor in ensuring the Energy Security. The **Bihar Electricity Regulatory Commission (BERC)** determines the Aggregate Revenue Requirement (**ARR**) and retail tariffs, seeking to balance the financial viability of DISCOMs with consumer affordability. Implementation of Time of Day (ToD) structure, especially on High Tension (HT) consumers encourages shifting consumption to off-peak hours, helping manage peak load and improving **grid stability**, thereby contributing to Energy Security. DISCOMs have been making all possible efforts towards reducing the **Aggregate Technical and Commercial (AT&C) losses** through infrastructure investment (like the installation of smart meters and Supervisory Control and Data Acquisition-SCADA systems) are crucial, effectively increasing Supply Security. **Bihar Renewable Energy Development Agency (BREDA)** acts as the **State Nodal Agency (SNA)** for most of the renewable energy schemes supervising the implementation of RE Policies, Providing Clearances via Single window system along with encouraging Skill development and awareness towards various Renewable Energy Schemes. **Bihar State Power Generation Company Limited (BSPGCL)** is the key developer for Thermal and Hydro projects, including the planned **Pumped Storage Projects**, essential for the state's 6.1 GWh storage goal.

While challenges like **land acquisition, financing large-scale grid upgrades, and skill development** persist to an extent, the state's commitment is evident in its policy agility. The investor- friendly incentives and Policy driven strategies are expected to attract **substantial investment**, leading to the creation of **massive employment opportunities** and fostering a thriving local **green technology ecosystem**. By securing a **reliable and affordable power supply**, Bihar is eliminating a critical bottleneck that has historically **hampered industrial growth**. This clears the path for **robust, inclusive**

development and is essential for significantly **lifting the state's per capita income**. The focus on **decentralized renewable energy (DRE)**, which includes **mini-grids and solar pumps**, ensures that energy access is **equitable**. This technology will reach even the most **remote rural areas**, thereby strengthening the **agriculture sector** and fundamentally **improving the quality of life** for the entire populace. Significantly aligning with India's commitment to achieve **Net-Zero by 2070**, Bihar plays an **indispensable role** in the national climate mission. The state is positioning itself as a leader among high-growth regions that are successfully adopting a **low-carbon development pathway**.





Modhera-India's first 24/7 solar-powered village in Gujarat

4

Gujarat Renewable Energy Security: Integrated RE, Green Hydrogen, Pumped Storage, and the Bioenergy Road Ahead

Shri Ajay Prakash (IAS)

Director, Gujarat Energy Development Agency (GEDA)

Abstract

Gujarat occupies a distinctive position in India's energy security architecture: it is simultaneously the country's largest gateway for liquefied natural gas (LNG)¹, an early mover in renewable energy policy and deployment, and a manufacturing and logistics hub with fast-growing electricity demand.

Energy security—"the uninterrupted availability of energy sources at an affordable price"—has

¹ In fiscal year 2023–24, Petronet LNG Limited's Dahej Terminal handled approximately 74% of the country's total LNG imports and catered to roughly 34% of India's total natural gas consumption. Source: [Petronet LNG Limited : Dahej Terminal - Petronetlng](#)

expanded from oil stockpiling to a multi-system agenda spanning electricity reliability, distributed renewable energy (DRE), gas logistics, and clean-tech supply chains. In this broadened frame, Gujarat is pivotal. Its west-coast location, deep-water ports and industrial corridors make it India's natural gateway for hydrocarbons and a platform for scaling renewables and, increasingly, green hydrogen.

This article focuses on major shift towards the renewables in Gujarat, and the policy architecture that supports this shift – from a conventionally powered state to India's renewable energy powerhouse. The Gujarat Integrated Renewable Energy Policy 2025, the Gujarat Green Hydrogen Policy 2025, and the Gujarat Pumped Storage Project Policy 2025, all released recently in December 2025 push Gujarat towards its Net Zero by 2047 vision. This article outlines vision, targets, instruments, governance, and cross-policy alignment, and provides a cautious preview of the upcoming bioenergy policy contours.

I. Gujarat Integrated Renewable Energy Policy — 2025

Validity: Operative till 31st December 2030 or until a new policy is notified (whichever is earlier).

Benefit Period: Benefits and incentives applicable for 25 years from the date of commissioning or the project's lifespan (as per GERC/MoP/MNRE norms), whichever is earlier.

The Gujarat Integrated Renewable Energy Policy 2025 replaces the earlier Gujarat Renewable Energy Policy 2023 and significantly broadens its scope. It covers solar energy in all forms—ground-mounted, rooftop, floating, and canal-based—along with wind, wind-solar hybrid projects, and Battery Energy Storage Systems (BESS). The policy also embraces emerging technologies such as ocean and geothermal energy, while promoting repowering of aging wind turbines, rooftop wind installations, and the development of large-scale renewable energy parks. Beyond generation, it emphasizes greening the supply chain, fostering circular economy practices, and creating green jobs through targeted skilling initiatives. This integrated approach positions Gujarat as a leader in clean energy innovation and sustainable industrial growth.

Vision: To create energy independence with affordable and reliable renewable power.

Goal: Reach 100 GW+ of installed renewable energy capacity by 2030, 150 GW by 2035 and 300 GW by 2047.

The policy makes renewable energy easier to integrate by:

- Allowing flexible energy banking for consumers,
- Giving DISCOMs multiple ways to buy green power,
- Streamlining approvals through a single portal,
- Ensuring transmission infrastructure is planned ahead,
- Supporting large RE parks, upgrades, and storage for grid stability.

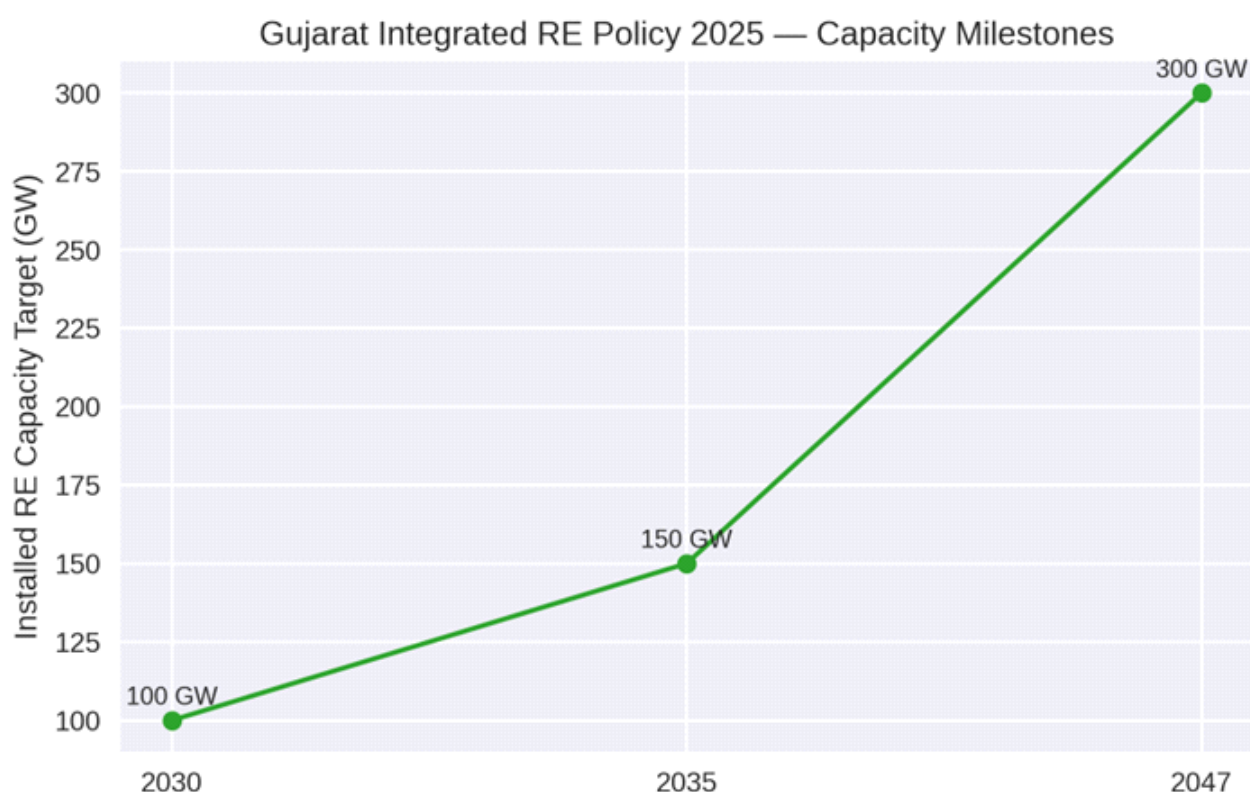


Figure A. Gujarat Integrated RE Policy 2025 — capacity milestones to 2047.

Source: Government of Gujarat, Energy & Petrochemicals Department (G.R. dated 24/12/2025).

II. Gujarat Green Hydrogen Policy — 2025

Validity: Operative till 31st December 2035 or until a new policy is announced (whichever is earlier).

Benefit Period: Incentives apply during the policy period; disbursal is staged and linked to commissioning milestones. Additional caps apply per section (e.g., MSME and CGD incentives capped overall and per beneficiary).

The Gujarat Green Hydrogen Policy 2025 marks a transformative step in decarbonizing Gujarat's economy and positioning the State as a global leader in clean fuels. With industries, mobility, and energy systems shifting toward low-carbon pathways, green hydrogen emerges as a versatile solution for deep decarbonization, energy security, and industrial competitiveness. Leveraging Gujarat's renewable energy potential, port infrastructure, and manufacturing ecosystem, this policy creates an integrated framework for production, storage, distribution, and utilization of green hydrogen and its derivatives. It aims to catalyze large-scale investments, foster innovation, and enable export opportunities.

Vision: To make Gujarat India's leading hub for green hydrogen production, utilization, and export.

Goals:

- Achieve 3 MMTPA Green hydrogen production
- Achieve 30 GW electrolyser capacity, and 75 GW linked renewable energy capacity by 2035 supported by ₹5 lakh crore investments and 6 lakh green jobs.

Top Incentives

• Electrolyser Projects

- Capital subsidy of 20% of capex, up to ₹1 crore per MW for green electrolyser projects.
- 50% reimbursement of transmission and wheeling charges for five years.

• Green Hydrogen Hubs

- Capital subsidy of 20% capex, up to ₹35 crore per hub.
- Support includes production, storage, and distribution infrastructure.

• Mobility & Refueling

- Refueling stations get 30% capex subsidy, up to ₹4 crore per station (first 20 stations).
- Passenger buses and heavy vehicles get 30% capex subsidy, up to ₹50 lakh per vehicle.

• MSME & CGD Incentives

- MSMEs using green hydrogen get ₹50 per kg for five years (capped).
- CGD networks blending green hydrogen get ₹50 per kg for five years, subject to GoI norms.

• Others

- Oxygen bottling system subsidy of ₹20 lakh/MW
- BESS linked to GH projects subsidy of ₹18 lakh/MWh
- Water desalination plants subsidy of ₹2 crore/MLD for first 5 plants

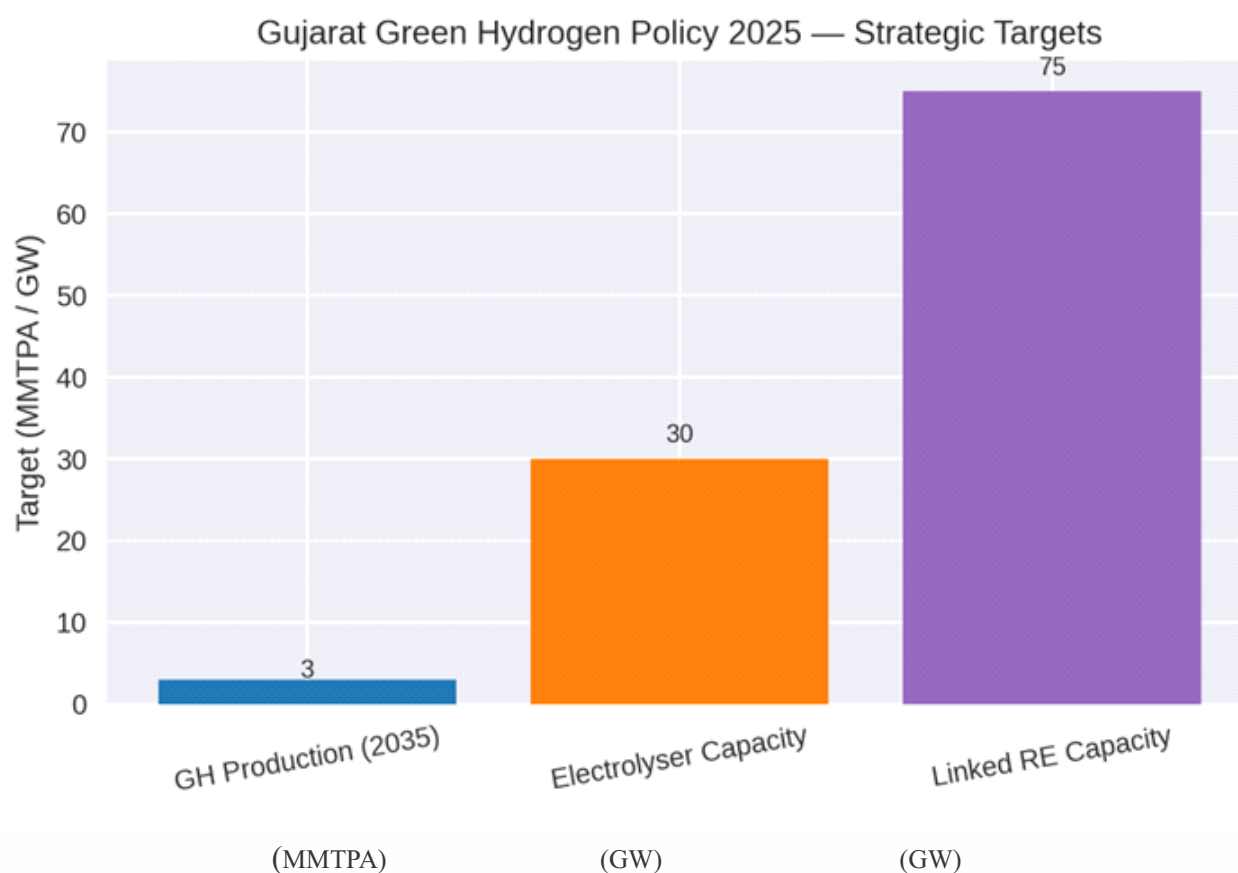


Figure B. Gujarat Green Hydrogen Policy 2025 — strategic targets. Source: Government of Gujarat, Energy & Petrochemicals Department (Policy 2025).

III. Gujarat Pumped Storage Project (PSP) Policy — 2025

Validity: Operative for 10 years from the date of notification.

Benefit Period: Benefits and incentives applicable for up to 40 years from the date of commissioning or the PSP's lifespan, whichever is earlier.

The Gujarat Pumped Storage Project (PSP) Policy 2025 addresses the critical need for grid flexibility and long-duration energy storage in an era of high renewable energy penetration. As solar and wind generation scale rapidly, their inherent variability poses challenges for grid stability, resource adequacy, and peak demand management. Pumped Storage Projects offer a proven, cost-effective solution by storing surplus renewable energy during off-peak periods and releasing it during peak demand, thereby ensuring reliability, reducing curtailment, and supporting round-the-clock clean power supply. This policy aims to position Gujarat as India's "Energy Storage Hub" by leveraging its geographical advantages, water resources, and industrial ecosystem to attract large-scale investments, create green jobs, and enable a resilient, low-carbon power systems aligned with national goals.

Vision: To make Gujarat "Energy Storage Hub of India" with 75 GWh by 2035

Goals:

- 75 Pumped Storage Projects (PSPs) to be developed by 2035.
- Target investment of ₹75,000 crore by 2035.
- Scale up to 100 PSP units by 2047.

The policy defines site categorization (I–IV), allocates GUVNL and GPCL as nodal agencies, and sets a three-tier governance (Apex, State Executive, District Implementation Committees).

Top Incentives

- Exemption on input renewable energy used for PSP operations
- Allocation of government land under a separate Revenue Department policy
- Alignment with land policies for wind, solar, hybrid, and green hydrogen projects
- No charges for on-stream and off-stream open-loop PSPs
- Structured charges for off-stream closed-loop PSPs
- Sharing of carbon credit benefits as per agreements between PSP developers and procurers
- 10 years from notification
- Benefits and incentives applicable for up to 40 years from commissioning

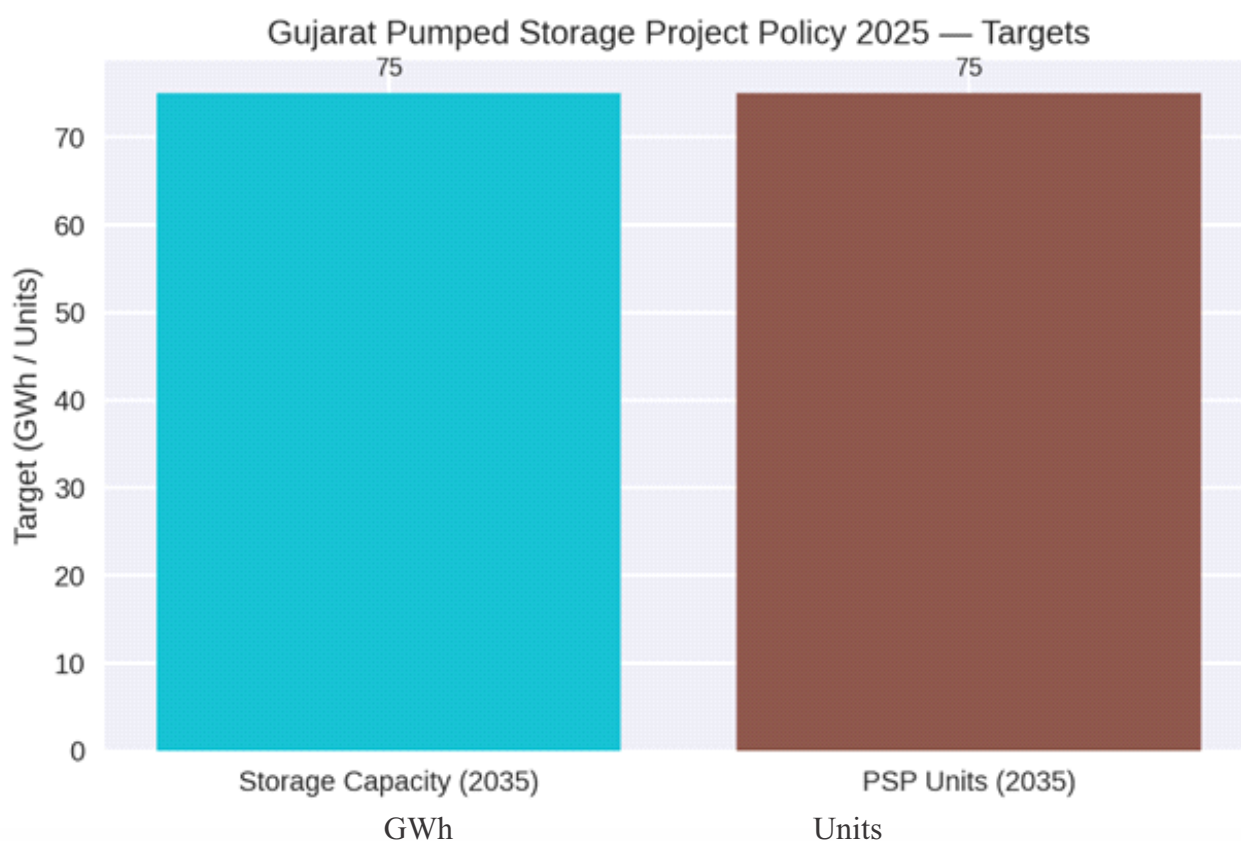


Figure C. PSP Policy 2025 — storage and unit targets. Source: Government of Gujarat, Energy & Petrochemicals Department (Policy 2025).

IV. Bioenergy Policy — Forthcoming (Contours)

Policy expected in 2026

Vision: To enable circular, sustainable energy through biomass and waste-to-energy solutions

A dedicated Bioenergy Policy is expected to build on Gujarat's integrated RE framework by enabling waste-to-energy and biomass-based solutions across industry and urban services. Likely pillars include:

- (i) Feedstock assurance and mapping for agro-residues, municipal solid waste, and industrial by-products
- (ii) Viability support and demand creation for bio-methane/CBG and advanced biofuels
- (iii) Grid and gas network integration (injection into CGD networks where feasible) with safety and certification
- (iv) Sustainability safeguards for air quality, residue management, and circular practices
- (v) Skilling, R&D, and standardization for distributed bioenergy assets.

V. Cross-Policy Alignment and Implementation Architecture

The three notified policies adopt complementary instruments: land and transmission facilitation (Integrated RE; GH), dedicated corridors (GH), storage obligations and flexibility (Integrated RE; PSP), and single-window portals with nodal agencies (GEDA/GUVNL/GPCL). Governance uses Apex and

Executive Committees with sectoral representation to resolve policy-level and implementation issues, and operational guidelines provide staged incentive disbursements and monitoring. Together, these create a coherent pathway to scale RE, firm capacity, and clean fuels while maintaining affordability and reliability.

VI. Gujarat RE Policy Dashboard (Key Metrics)

Policy Metric	Value / Provision	Source
Integrated RE Policy targets	100+ GW (2030); 150 GW (2035); 300 GW (2047)	Integrated RE Policy 2025
Banking & settlement	Banking on billing-cycle basis per GERC; time-block settlement option	Integrated RE Policy 2025
Procurement by DISCOMs	Competitive and small-scale non-competitive routes (pre-fixed levelized tariffs)	Integrated RE Policy 2025
Green Hydrogen production	~3 MMTPA by 2035	Green Hydrogen Policy 2025
Electrolyser capacity	~30 GW by 2035	Green Hydrogen Policy 2025
Linked RE capacity	~75 GW	Green Hydrogen Policy 2025
MSME GH usage reimbursement	INR 50/kg (5 years; caps apply)	Green Hydrogen Policy 2025
CGD blending reimbursement	INR 50/kg (5 years; subject to GoI norms)	Green Hydrogen Policy 2025
GH Hubs	Capex subsidy up to INR 35 crore; min. 10 units including at least 1 producer	Green Hydrogen Policy 2025
Refueling stations	30% capex up to INR 4 crore (first 20 stations)	Green Hydrogen Policy 2025
PSP Storage capacity	75 GWh by 2035	PSP Policy 2025
PSP Units & investment	75 units; ~INR 75,000 crore by 2035; 100 PSPs by 2047	PSP Policy 2025
PSP incentives	Electricity duty exemption on input RE; land facilitation; water charge relaxations	PSP Policy 2025

Executive Summary

- Integrated Renewable Energy Policy 2025 targets 100+ GW by 2030, 150 GW by 2035, and 300 GW by 2047, covering solar, wind, hybrids, and storage, with streamlined approvals and robust transmission planning.
- Green Hydrogen Policy 2025 aims for 3 MMTPA production, 30 GW electrolyser capacity, and 75 GW linked RE by 2035, backed by ₹5 lakh crore investments and major incentives for electrolysis, hubs, mobility, and MSME adoption.
- Pumped Storage Policy 2025 ensures grid flexibility with 75 GWh storage and 75 PSP units by 2035, offering duty exemptions, land facilitation, and water charge relaxations.
- Bioenergy Policy (upcoming) will complement these by enabling waste-to-energy and biomass pathways.

Together, these policies create a coherent roadmap for Gujarat to lead India's green transition, delivering reliability, affordability, and sustainability aligned with Panchamrit and Net Zero goals.



Khavda Hybrid Renewable Energy Park in Kutch District of Gujarat



Rajahmundry Oil Fields, Andhra Pradesh

5

Ensuring Energy Security: Role of Energy Policies of States

Shri M. Kamalakar Babu

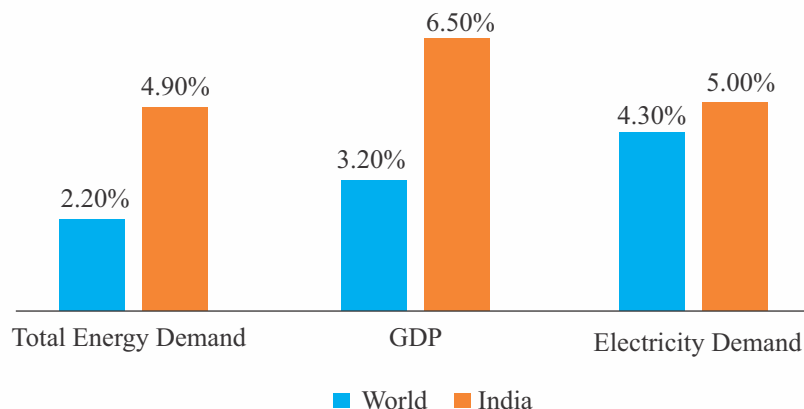
MD & CEO, APSPCL and VC & MD, New & Renewable Energy Development Corporation of Andhra Pradesh Ltd. (NREDCAP)

The global context: what recent trends mean for energy security

Around the world, energy systems are undergoing a structural transition that must deliver reliability and affordability while reducing emissions. In 2024, global energy demand rose by 2.2%, which was significantly higher than the average pace over the preceding decade (1.3% per year between 2013 and 2023). The share of electricity in final energy demand reached just under 22% in 2025. Emerging and developing economies, particularly China and India, have been the main drivers of this growth, with electricity rising from 5% of final energy use in the early 1980s to around 30% in China and 20% in India by 2023. Low-emission sources, i.e., renewables and nuclear, supplied approximately 80% of the increase in electricity generation, and their combined contribution reached about 40% of total global

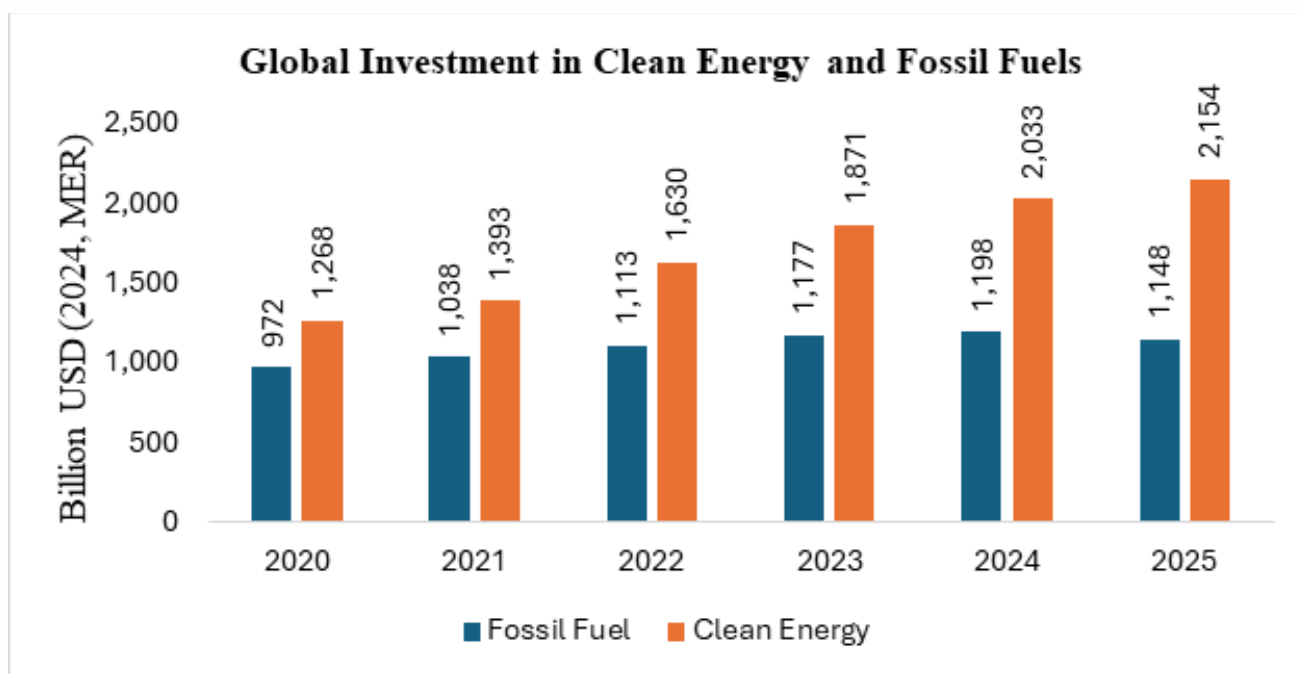
generation for the first time in many decades. These quantitative signals from the International Energy Agency show a World that is decisively electrifying and leaning on clean technologies even as overall demand continues to grow.

Key Growth Rates 2024



Total energy investment worldwide is poised to grow by 2% in 2025 to USD 3.3 trillion, reaching an all-time high despite elevated geopolitical tensions and economic uncertainty. Around two-thirds of all energy investment, or USD 2.2 trillion, is destined for clean energy technologies such as renewable energy, grids, battery storage, and electric vehicles. Meanwhile, investment in fossil fuels is expected to marginally contract to USD 1.1 trillion amid downward pressure on prices and pared-back expectations for oil demand.

Rapid growth in spending on energy transitions over the past five years was initially kicked off by post-pandemic recovery packages, but today industrial strategy and energy security considerations are playing a larger role. Some 70% of the increased spending since 2020 came from net fossil fuel importers, reflecting a strategic push to reduce import dependence. Investment trends are also being shaped by the onset of the “Age of Electricity,” as power demand for industry, cooling, electric vehicles, data centres, and artificial intelligence rises quickly.



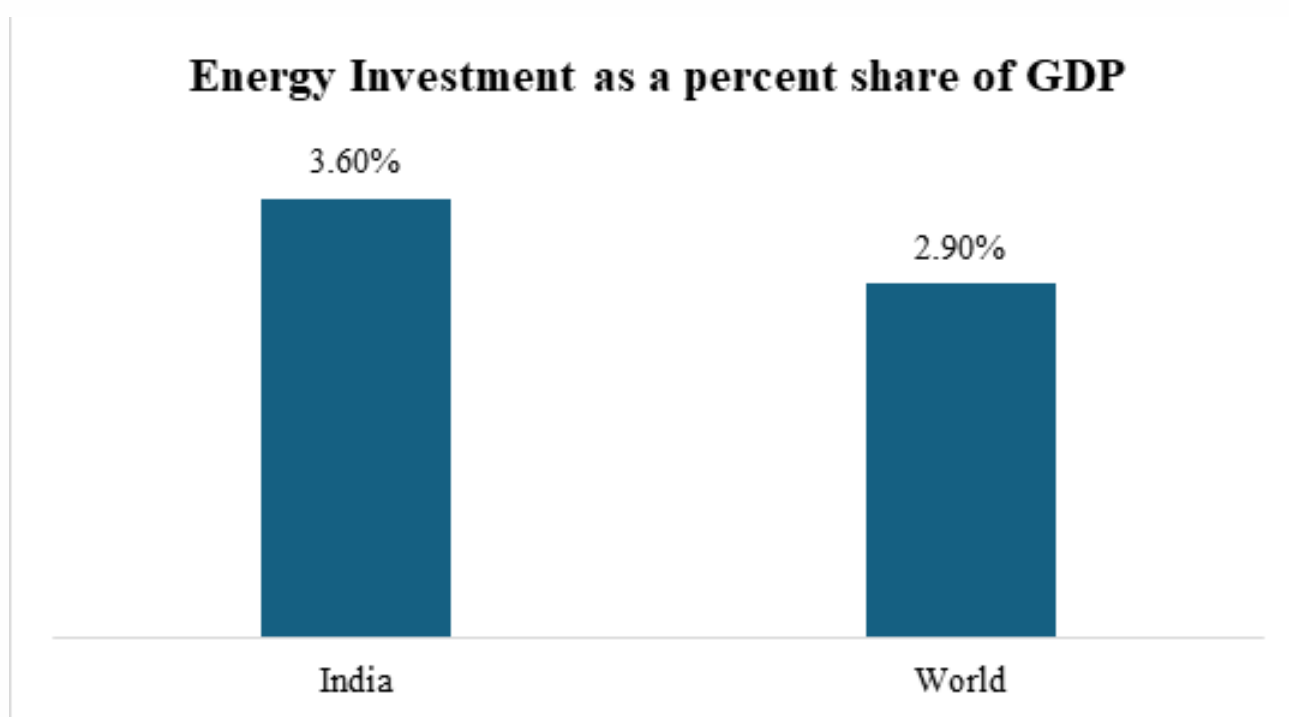
MER: Market Exchange Rate

Policy dialogues have converged on pragmatic pathways: hydrocarbons remain part of the near-term mix, but systems are expected to scale renewables, storage, demand-side efficiency, and modern transmission to keep power secure, affordable, and low-carbon. India's own flagship forum India Energy Week, being held under the patronage of the Ministry of Petroleum and Natural Gas explicitly frames energy security and equitable growth alongside decarbonization, signaling the importance of investment, diversified supply, and technology innovation to meet rising electricity needs without sacrificing reliability.

2. India's Perspective: A Roadmap That Balances Reliability, Affordability, And Decarbonization

India's energy landscape is in the midst of a profound transformation, and the country has already crossed a major milestone. By mid-2025, non-fossil fuel sources accounted for about half of India's total installed electricity capacity, a target originally set for 2030 and met five years early. Government data reported 51.37% of installed capacity from non-fossil sources as of October 31, 2025 (roughly 259.42 GW non-fossil out of 505.02 GW total). These achievements underscore a structural change in India's power system towards diversified, cleaner sources.

This transition is happening while India's energy demand continues to expand faster than advanced economies. The IEA notes that India posted the third-largest growth in power generation capacity worldwide over the past five years, behind only China and the United States, reflecting sustained growth in electricity consumption from households, commerce, and industry. Crucially, the investment profile has shifted: in 2024, 83% of India's power-sector investment went to clean energy (solar, wind, hydro, nuclear, and storage).



India was also the largest recipient of development-finance project funding for clean energy in 2024 (about USD 2.4 billion), while clean-energy FDI flows accelerated, reaching USD 3.4–3.7 billion across FY2024–25 depending on the period measured. These capital signals are consistent with India's declared path to 500 GW non-fossil capacity by 2030 and net-zero by 2070.

3. Policy levers for the State-level Energy Security

To sustain security and affordability as electricity demand rises, India must now lock in a practical, bankable roadmap. Policy alignment is key. Reforms must span power, industry, transport, buildings, and agriculture. Fragmented approaches will not deliver the required scale of transformation. The following guidance translates national goals into implementable levers across supply, grid, markets, and demand.

a. Adopt Least-cost firm renewable energy, the backbone of reliability

States can ensure reliability by contracting dispatchable renewable power or storage as service rather than relying on plain variable RE generation. Procurement should move decisively to products that combine solar and wind with storage and ancillary services, thereby delivering firm capacity and peak-hour supply on standard terms. Further, procurement should be determined by Least Cost Method. With solar and even battery storage now becoming cheaper than conventional power, least-cost studies can unlock significant savings for utilities and the nation, while enabling much higher RE penetration.

Key actions for states:

- **Design procurement to optimize cost and reliability:** Adopt **least-cost integrated resource planning** that accounts for variable demand and variable RE supply.
- **Incorporate storage for firm supply:** Batteries are already commercially viable for short-duration balancing; for **100% RE grids**, explore **Long Duration Energy Storage (LDES)** and other storage technologies to ensure round-the-clock reliability.
- **Structure tenders for flexibility and resilience:** Auctions should bundle **generation + storage + ancillary services**, with clear performance standards and settlement rules to minimize curtailment and financing risk.

b. Build transmission corridors first and track their performance rigorously

Green power must move from resource belts to demand centres to maintain reliability as renewable penetration rises. With India's non-fossil share now above 50%, States need robust evacuation systems for solar, wind, and storage projects concentrated in resource-rich interiors.

The financing model has evolved to a blended approach: central grants, concessional loans from multilateral agencies, State equity, and PPP options for fibre monetization. This reduces fiscal stress and leverages global green finance.

States should publish quarterly KPIs on circuit-kilometres (ckm), MVA capacity, losses, and OPGW utilization to ensure timely delivery and reduce curtailment risk. Andhra Pradesh's Phase-3 Green Energy Corridor exemplifies this approach, INR 28,000 crore to evacuate ~11 GW solar and ~7 GW pumped storage, adding 8,862 ckm and 9,500 MVA, linking generation zones to coastal industrial hubs and green hydrogen clusters.

c. Scale storage through a national pumped-storage mission and targeted battery deployments

States need multi-hour flexibility to meet evening peaks and manage variability. States can launch Pumped-Storage Mission that designate off-stream sites, simplify environmental clearances, and offer revenue models that blend capacity payments, energy arbitrage, and ancillary services.

In parallel, Battery Energy Storage Systems (BESS) should be deployed at urban substations, industrial clusters, and transport depots, where they can shave peaks, firm rooftop PV output, and support EV charging. Evidence from international and domestic analyses confirms that storage reduces the cost of integrating renewables while protecting affordability.

d. Use clean molecules to decarbonize hard-to-electrify sectors while enhancing energy security

Biofuels and green hydrogen are strategic complements to the power transition. Ethanol and compressed biogas (CBG) can lower import dependence and provide rural economic benefits, while green hydrogen, ammonia, and methanol should be prioritized for fertilizers, refining, steel, and select heavy mobility segments.

National guidance should encourage port-based hydrogen hubs with transparent land-lease terms and grid access, mirroring emerging state approaches that differentiate land pricing for hydrogen infrastructure.

e. Treat demand-side efficiency as new capacity

Efficiency remains the cheapest and fastest way to improve energy security and resilience. Scaling a National Efficiency Mission built on the model of State Designated Agencies such as APSECM in Andhra Pradesh to deliver industrial audits and retrofits, building code implementation, and public facility upgrades backed by recognition programmes, may work. These “negawatts” lower bills, reduce emissions, and free up generation capacity for growth.

f. Build an EV ecosystem that strengthens, rather than stresses, the grid

Electric mobility policy should focus on public and logistics fleets, depot-level PV and BESS, managed charging, and tariff design that flattens peaks. State policies like Andhra Pradesh's Sustainable Electric Mobility Policy (2024–29) directly target charging density and ecosystem development, and similar measures across India will reduce oil import dependency while improving urban air quality and grid stability.

g. Harmonize market rules and open access to reduce the cost of capital

Corporate procurement is a powerful decarbonization lever if rules are predictable. India should harmonize Green Open Access across State Regulatory Commissions by publishing handbooks that standardize banking windows, imbalance settlement, and SLDC procedures. Clear, consistent rules lower transaction and financing costs and accelerate captive and third-party renewable investments.

h. **Deepen manufacturing and industrial policy to reduce technology costs and create jobs**

Clean-energy manufacturing parks with plug-and-play infrastructure, guaranteed grid access, and transparent land terms should be integrated into updated industrial policies. Andhra Pradesh's Industrial Development Policy (4.0) 2024–29 is an example of how States can weave green-transition priorities into broader investment facilitation and self-financing incentive models; a national playbook would help replicate such approaches and ensure incentives correlate with delivery against transmission and storage milestones.

i. **Govern with data: monitor KPIs from the ground up**

National-state KPI dashboards that track corridor delivery, storage commissioning, efficiency savings, EV charging density, and affordability metrics, with visibility from mandal to district to state is needed. Andhra Pradesh's Swarna Andhra @2047 KPI portal demonstrates how vision documents can be tied to evidence-based implementation across sectors, including energy and fuel cost optimization.

4. **Southern India's opportunity within the national roadmap**

Southern India has the resource endowment and infrastructure to lead India's firm-renewable transition. The region combines high solar and wind potential with industrial bases, ports, and fast-growing digital loads, making it ideal for co-located hybrid projects (solar plus wind with storage), hydrogen hubs, and EV freight corridors. International analyses show renewables paired with storage are now the most competitive additions in most markets, and India's own policy conversations emphasize balancing security and affordability with clean growth. This regional configuration offers an immediate opportunity to build dispatchable clean power and exportable clean-molecule value chains.

5. **Andhra Pradesh: A concise exemplar aligned to India's guidance**

Andhra Pradesh provides a clear example of how a state can translate national priorities into implementable programmes.

First, launched in 2024, Andhra Pradesh's Integrated Clean Energy (ICE) Policy is an end-to-end clean energy framework designed to accelerate the State's transition toward net-zero by 2047 while ensuring reliability and affordability. The policy integrates generation, storage, green fuels, and demand-side measures under a single umbrella, making it a model for other States.

Key objectives and targets:

- **Capacity addition:** Over 160 GW of renewable energy including solar, wind, hybrid projects, and pumped storage.
- **Investment mobilization:** Attract INR 10 lakh crore in clean energy investments and create 7.5 lakh jobs.

Policy features that strengthen energy security:

- **Unified approvals:** A single-window digital portal managed by NREDCAP for time-bound clearances.

- **Land and resource allocation:** Transparent land-lease norms (e.g., INR 31,000/acre/year with escalation every 2 years) and differentiated rates for green hydrogen hubs and biofuel projects.
- **Grid integration:** Mandates coordination with APTRANSCO for transmission planning and banking provisions aligned with Green Energy Open Access rules.
- **Storage and flexibility:** Prioritizes pumped storage projects and battery energy storage systems (BESS) to firm renewable generation and meet peak demand.
- **Green hydrogen and biofuels:** Facilitates port-based hydrogen hubs and biofuel clusters to decarbonize hard-to-electrify sectors.
- **EV ecosystem:** Integrates charging infrastructure development with renewable generation and storage to support clean mobility.
- **Manufacturing incentives:** Encourages domestic production of solar modules, wind components, batteries, and hydrogen equipment through industrial parks to enable energy security.

Why ICE Policy matters for energy security: By combining generation, transmission, storage, electrification of transport and demand-side measures, the policy ensures that Andhra Pradesh can meet rising electricity demand without compromising reliability or affordability. It also aligns with national initiatives such as the National Green Hydrogen Mission, Green Energy Open Access, and Viksit Bharat @2047, making the State a frontrunner in India's Clean Energy Transition.

Second, the State has submitted a comprehensive Green Energy Corridor Phase-3 proposal for around INR 28,000 Crore to evacuate ~11 GW of solar and ~7 GW of pumped-storage output by adding ~8,862 circuit-kilometres of lines and ~9,500 MVA of transformation capacity. This extra-high-tension network directly addresses Andhra Pradesh's geography, where generation is concentrated in the interior while new loads, i.e., industry, data centres, and port-based hydrogen, are rising along the coast.

Third, the State has refreshed its electric-mobility policy (2024–29) to address charging density and ecosystem gaps, integrating EV infrastructure development with the ICE framework and rooftop-solar synergies. This increases electric-transport viability while flattening distribution peaks through managed charging and depot-level storage.

Finally, Andhra Pradesh's Swarna Andhra @2047 vision embeds energy and fuel cost optimization as a core principle and supports delivery with a KPI portal that tracks progress from the grassroots to the State level, thereby tying energy programmes to broader development outcomes such as jobs, innovation, and social equity.

6. The Way Ahead: What can be done to translate targets into delivered security

India's energy security will increasingly depend on firm renewable capacity, multi-hour storage, transmission delivery, clean molecules for hard-to-electrify sectors, and demand-side efficiency, all under predictable market rules and data-driven governance. The quantitative signals are encouraging, non-fossil sources now exceed 50% of installed capacity, and clean energy attracts the majority of investment.

However, execution at scale requires consistent scaling up of renewable and nuclear capacity, strengthening of grid infrastructure, acceleration of pumped storage and BESS, harmonization of open-access rules, and deepening of domestic manufacturing. A just, phased coal transition anchored in technology upgrades (e.g., supercritical plants, carbon capture), regulated emissions, and repurposing assets coexist with India's renewables ambition.

If India can pursue these actions with urgency, it will keep electricity reliable and affordable even as demand rises, while advancing toward 500 GW non-fossil by 2030 and net-zero by 2070. The southern region has the potential to lead in hybrid + storage deployments, and Andhra Pradesh's integrated approach, i.e., policy, infrastructure, demand-side, and governance, offers a practical State-level blueprint that other regions can adapt to their resource and demand profiles.



Polavaram Dam- A multi-purpose national irrigation project on the Godavari River in Andhra Pradesh



Kochi's Solar Powered Water Metro

6

Decarbonising Kerala's Energy Landscape: The Strategic Role of Energy Management Centre – Kerala

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As India moves towards achieving its long-term vision of energy independence by 2047 and net-zero emissions by 2070, the State of Kerala has emerged as a pioneering model in sub-national climate and energy governance. Through proactive policy formulation, technological innovation, and people-centric programmes, the **Energy Management Centre – Kerala (EMC)** has been spearheading the State's transition to a low-carbon and energy-efficient economy.

Functioning under the **Department of Power, Government of Kerala**, EMC serves as the **State Designated Agency (SDA)** of the **Bureau of Energy Efficiency (BEE)**, Ministry of Power, Government of India, for the implementation of the **Energy Conservation Act, 2001**. Over the past

decade, EMC has transformed Kerala's energy landscape by integrating energy efficiency across sectors, fostering renewable energy adoption, and building an ecosystem for sustainable financing and human resource development.

Kerala's decarbonization journey, driven by EMC's initiatives, demonstrates how policy vision combined with local innovation can yield measurable results in climate action, particularly in sectors such as buildings, industry, mobility, and community-level energy use.

Mainstreaming Decarbonization through Policy and Codes

One of the most transformative steps in Kerala's decarbonization strategy is the formulation and implementation of the **Kerala State Energy Conservation and Building Code (KSECBC)**. Kerala became the **first State in India** to notify a comprehensive sustainable building code integrating the principles of energy conservation, passive architecture, and renewable energy utilization.

Unlike traditional building regulations that focus primarily on safety and structural integrity, KSECBC emphasizes optimizing energy performance right from the design stage. It ensures that new constructions adopt energy-efficient materials, daylight integration, efficient lighting, HVAC systems, and renewable energy systems to minimize the operational energy demand of buildings.

A significant milestone is that the KSECBC has been formally incorporated into both the **Kerala Municipality Building Rules (KMBR)** and the **Kerala Panchayat Building Rules (KPBR)**. This ensures that the energy conservation mandate applies uniformly across urban and rural jurisdictions, covering residential, commercial, and institutional structures.

To ensure seamless implementation of the code, EMC has developed a **cadre of Building Energy Efficiency Experts (BEEEs)**. These certified professionals assist architects, engineers, and local self-governments in code compliance, design evaluation, and project-level energy assessments. The cadre is being continuously expanded through periodic certification programmes, thereby strengthening local technical capacity to mainstream energy-efficient construction practices throughout the State.

By integrating regulatory, technical, and capacity-building components, Kerala's building energy efficiency ecosystem has evolved into a replicable model for other States aiming to align with national energy efficiency targets.

Innovative Programmes Driving Energy Transition

The Energy Management Centre has successfully translated policy intent into on-ground transformation through innovative and socially inclusive programmes. Among these, three key initiatives — **Angan Jyoti**, the **Carbon-Neutral Electric Kitchen**, and the **Go Electric Campaign** — exemplify Kerala's commitment to decarbonising everyday energy use through electrification and awareness.

Angan Jyoti – Electrifying Cooking in Anganwadis

Cooking energy is one of the major sources of fossil fuel dependence in community-level facilities. EMC's **Angan Jyoti** programme aims to completely transform the cooking ecosystem in Kerala's Anganwadis from LPG-based systems to cleaner electric cooking.

Under this initiative, **2,811 Anganwadis** across the State have been equipped with **induction cooktops**

and eight induction-compatible utensils each. The programme not only ensures a shift away from fossil fuels but also provides a healthier and more convenient working environment for the Anganwadi workers.

Electric cooking through induction systems eliminates indoor air pollution, reduces carbon dioxide emissions, and enhances efficiency, as induction technology converts over 90% of electricity into heat compared to only 40–50% for traditional gas stoves. The Angan Jyoti programme thereby contributes directly to Kerala's climate goals while also promoting gender-responsive energy access, given the large number of women beneficiaries in the Integrated Child Development Scheme network.

Moreover, the initiative aligns with India's broader push for electrification of end-use sectors — one of the key pillars of national decarbonization strategy — and demonstrates how State-level innovation can lead to measurable reductions in fossil fuel consumption at the grassroots level.

Carbon-Neutral Electric Kitchen at A.C.K. Kannan Nair Memorial School

Kerala's journey toward carbon-neutral public institutions is best illustrated by the **Carbon-Neutral Electric Kitchen** project implemented by EMC at the **A.C.K. Kannan Nair Memorial School, Kanhangad, Kasaragod**.

Prior to this intervention, the school kitchen relied on LPG for daily cooking needs, consuming nearly **300 kilograms of LPG every month** to prepare meals for about **600 students**. Through the EMC project, the entire kitchen was converted to electric cooking, eliminating the use of fossil fuels.

In a significant display of community participation, the **Parent Teacher Association (PTA)** of the school complemented EMC's efforts by installing a **25 kW rooftop solar power plant** using the **MLA Local Area Development Fund**. The solar plant generates sufficient renewable energy to meet the entire electricity demand of the kitchen, making the institution **completely carbon neutral**.

This initiative not only reduces recurring fuel costs but also serves as a demonstration model for replicating carbon-neutral kitchens in schools, hostels, and community institutions across Kerala. It embodies the synergy between government intervention, community involvement, and decentralized renewable energy — a cornerstone of Kerala's decarbonization model.

Go Electric Campaign and Electric Mobility in Kerala

Another significant dimension of Kerala's decarbonization strategy is the rapid growth of electric mobility. Through the **Go Electric Campaign**, Energy Management Centre (EMC) has been at the forefront of promoting electric vehicles (EVs), charging infrastructure, and consumer awareness about the benefits of e-mobility.

As of 2025, **Kerala has 2,93,320 registered electric vehicles**, and the **EV penetration has surpassed 10%**, making it one of the **highest among Indian States**. What makes this achievement particularly remarkable is that this transition has occurred **without the Government offering any direct purchase subsidies** for EVs.

This underscores the effectiveness of EMC's awareness campaigns, infrastructure facilitation, and partnerships with local bodies, vehicle manufacturers, and charging solution providers. Public transport

systems are also increasingly electrifying — from electric auto-rickshaws to e-buses operated by Kerala State Road Transport Corporation (KSRTC).

The success of Kerala's EV ecosystem is rooted in EMC's emphasis on behavioural change through consistent outreach, the creation of enabling policies, and the demonstration of real-world benefits, including lower operating costs and zero tailpipe emissions. This consumer-driven adoption model is now being studied by several other States as a best practice in sustainable mobility.

Financing Energy Efficiency through the Kerala State Energy Conservation Fund

While policy and technology interventions are critical for decarbonization, sustainable financing mechanisms are equally essential for scaling up implementation. Recognizing this need, Kerala became the **first State in India** to operationalize a dedicated revolving financial mechanism for energy efficiency — the **Kerala State Energy Conservation Fund (KSECF)**.

The Fund provides low-interest financial assistance to government institutions, cooperatives, and private industries for implementing energy efficiency projects. It operates at **simple interest rate of 4% for private sector entities and 2% for public and cooperative sectors**, with a repayment tenure of up to five years. The revolving nature of the Fund ensures that repayments are reinvested into new projects, thereby sustaining the capital pool.

So far, **₹10.56 crore** has been disbursed under KSECF for **four industrial projects** implemented across **three major public sector undertakings** — **Travancore Titanium Products Limited, Hindustan Organic Chemicals Limited, and Travancore Cochin Chemicals Limited (two projects)**.

These projects targeted key energy-intensive processes such as high-efficiency pumping systems, process heat recovery, and lighting retrofits. Collectively, they have resulted in significant reductions in electricity and fuel consumption, demonstrating how financial innovation can drive industrial decarbonization.

Beyond direct financing, EMC also provides technical guidance and performance evaluation for funded projects, ensuring measurable outcomes in terms of energy savings and emissions reduction. The success of KSECF underscores the importance of institutional financing models that can be replicated by other States to accelerate the energy efficiency market.

Recognition and Continuing Leadership

Kerala's consistent performance in energy conservation and efficiency has earned national recognition. The State received the **National Energy Conservation Award (Best State Designated Agency)** from the Bureau of Energy Efficiency for **three consecutive years (2017–2019)**. Since 2019, Kerala has continued to maintain a **leading position in the State Energy Efficiency Index**, reflecting its sustained commitment to implementing the Energy Conservation Act in letter and spirit.

EMC's achievements extend beyond national recognition — the State has become a model for multi-sectoral decarbonization. From piloting **small hydro power projects** and **low-voltage DC-based houseboats** to drafting the **Pumped Storage Hydropower Policy**, Kerala continues to diversify its green energy portfolio. The establishment of the **Clean Energy Innovation and Business Incubation Centre (CEIBIC)** in collaboration with Kerala Development and Innovation Strategic Council (K-

DISC) and Clean Energy International Incubation Centre (CEIIC) further highlights EMC's focus on innovation-led energy entrepreneurship.

Conclusion

Kerala's decarbonization journey reflects the success of an integrated approach combining policy innovation, institutional capacity, community engagement, and sustainable financing. The Energy Management Centre – Kerala has positioned the State as a living laboratory of clean energy transition, demonstrating that sustained behavioural change, coupled with systemic reforms, can drive measurable climate action without compromising on economic growth.

By focusing simultaneously on **energy efficiency, electrification, and renewable integration**, EMC's initiatives ensure that the State's development trajectory remains aligned with global sustainable energy goals. The transformation achieved through programmes such as **Angan Jyoti**, the **Carbon-Neutral Electric Kitchen**, the **Go Electric campaign**, and the **KSECF financing model** showcases Kerala's pragmatic and inclusive approach to decarbonization.

As India continues its journey toward achieving the **Panchamrit goals** and **net-zero commitment**, Kerala's experience offers a scalable blueprint for other States — demonstrating that the path to sustainability begins with innovation, participation, and empowered local institutions.



Cochin International Airport- World's First Solar Powered Airport



7

Rajasthan City Gas Distribution (CGD) Policy 2025

Directorate of Petroleum, Government of Rajasthan

1. Introduction

The Rajasthan City Gas Distribution (CGD) Policy 2025 is a landmark initiative issued by the Government of Rajasthan through its Mines & Petroleum Department. It represents a forward-looking framework to accelerate the adoption of natural gas as a clean, efficient, and sustainable energy source across the State. Natural gas is positioned as a transitional fuel that reduces emissions, improves public health, and enhances industrial competitiveness. The policy is aligned with India's COP-26 commitments.

The policy is designed to provide a structured, time-bound framework for permissions, clearances, and infrastructure development, ensuring reliable access to Piped Natural Gas (PNG) and Compressed Natural Gas (CNG) for households, industries, and the transport sector.

2. Vision

The vision of the Rajasthan CGD Policy 2025 is to establish a robust, safe, and reliable CGD network across the State. It seeks to make clean energy accessible to households, industries, and transportation, thereby contributing to sustainable development and improved quality of life.

The policy envisions Rajasthan as a leader in clean energy adoption, supporting the national target of increasing natural gas share in India's energy mix from 6.7% (2023) to 15% by 2030.

3. Objectives

The policy outlines several key objectives:

- **Infrastructure Expansion:** Facilitate rapid development of CGD infrastructure to expand PNG and CNG access across sectors.
- **Standardization:** Establish a uniform, time-bound framework for permissions, clearances, and charges to streamline operations and attract investment.
- **Collaboration:** Encourage CGD entities to work with local bodies to develop Compressed Biogas (CBG) plants, supporting *Swachh Bharat Abhiyan*.
- **Pollution Control:** Expand PNG and CNG access in domestic, industrial, commercial, and transport sectors, with special focus on non-attainment cities, smart cities, and the NCR region in Rajasthan.

4. Policy Features

4.1 Duration

The policy is effective from its publication and remains valid until **31 March 2029**, unless replaced by a new framework.

4.2 Applicability

The policy applies to all land- and road-owning agencies, including municipal corporations, RIICO, Housing Board, Development Authorities, Gram Panchayats, PWD, and statutory authorities such as Transport, Industries, and Pollution Control Board.

4.3 Permissions and Clearances

Recognizing Natural Gas as an essential utility (like water and electricity), the policy establishes a streamlined framework for permissions:

Development of CGD Portal

- A dedicated **CGD Portal** will enable online submission, processing, and approval of applications.
- RSGL (Rajasthan State Gas Limited) will act as the **nodal agency**, coordinating with DoIT&C for portal development and maintenance.

Costs will be shared among 17 Geographical Areas (GA).

The portal will eventually integrate with the **single-window clearance system**.

4.3.1 Application Process for Underground Pipelines

- Applications submitted online with PNGRB authorization, maps, documents, and fees.
- Authorities must review within 10 days and request a **Bank Guarantee (BG)** equal to 20% of restoration cost.
- Permissions granted under “Dig and Restore” method.
- Escalation mechanisms ensures deemed approval if no decision within 45 days.
- Excavation restricted to 20% of permitted length or 5 km at a time.
- Restoration inspected and certified before BG release.

4.3.2 Installation of CGD Equipment

- Permissions for PRS, FRS, DRS, MRS, SCADA systems, and DCU stations.
- Land plots (45–60 sq.m for stations, 300 sq.m for DCUs) provided on rental basis.
- Rent determined via joint survey, payable in three-year increments.
- Permissions must be granted within 7 days of rent deposit; escalation to District Nodal Officer if delayed.
- Underground pipelines may be laid using open trench or trenchless methods, but HDD/manual moling is preferred to reduce road damage. During monsoon, only trenchless methods are permitted with safety and restoration measures.

4.3.3 Land Allotment for CGS/CNG Stations

- CGS and CNG stations classified as public facilities.
- Government land leased for 30 years, free or nominal rent.
- NOC process involves District Magistrate consolidating approvals from multiple departments (Fire, Pollution Control, Police, PWD, Forest, etc.).

4.3.4 Safety of Pipeline Network

- Other utilities must maintain safe distance from gas pipelines.
- If unauthorized persons damage gas pipelines/installations, Police will file a case upon CGD entity's complaint as per relevant Acts.
- Emergency response vehicles given “Emergency Vehicle” status.
- District authorities to conduct **mock drills** with CGD entities.

4.4 Adoption of CNG

The Transport Department will:

- Approve CNG vehicles/kits certified by ARAI/ICAT within 15 days.
- Endorse conversions on RCs within 10 days.
- Approve CNG retro fitment centres within 15 days.
- Exempt road tax/registration charges for CNG vehicles.
- Mandate transition of buses in cities >5 lakh population to CNG within 2 years, and others within 4 years.
- Include CNG options in RSRTC/CTC tenders.

4.5 Safety Measures for CNG Vehicles

- Establish inspection and certification centres for retrofitted CNG vehicles.
- Publish list of approved testing stations on Transport Department portal.

4.6 Use of Natural Gas in Industries and Commercial Segments

The Pollution Control Board will:

- Encourage conversion of DG sets to gas-based/dual fuel.
- Promote natural gas for telecom towers, apartments, and commercial buildings.
- Mandate phasing out of diesel in industrial areas with pipeline connectivity.
- Integrate cleaner fuel requirements into CTE/CTO approvals.

4.7 Land for Compressed Biogas Plants

- Allocate land for CBG plants in collaboration with local bodies.
- Support mandatory blending of CBG in CNG and PNG from FY 2025-26.
- Municipal bodies to provide segregated waste for CBG production.

4.8 PNG Pipelines in Building Plans

- UDH Department to amend by-laws mandating PNG infrastructure in new residential/commercial building plans.
- Government quarters, guest houses, and offices to be connected to PNG.

4.9 Organisational Setup

4.9.1 State-Level Committee

- Chaired by Chief Secretary, comprising senior officials from Finance, Revenue, Transport, PWD, UDH, Mines & Petroleum, Local Bodies, Food & Civil Supplies, Disaster Management, Pollution Control Board, RIICO, SIAM, RSGL, and Petroleum Directorate.
- Meets quarterly to monitor CGD progress.

4.9.2 District City Gas Committee (DCGC)

- Chaired by District Collector, with members from Police, Municipal bodies, Development Authorities, Zila Parishad, Pollution Control Board, Health, PWD, Power, PHED, Transport, Mines, and CGD entities.
- Reviews CGD progress monthly and resolves local issues.

4.9.3 Nodal Officers

- Director, Local Bodies as State Nodal Officer.
- District Magistrate as District Nodal Officer.
- Commissioners/Secretaries of municipalities, UITs, Development Authorities, and SDMs in rural areas designated as nodal officers.
- Senior-most officers of departments/PSUs act as nodal officers for their properties.

4.10 Obligations of CGD Entities

- Develop CGD networks in time-bound manner as per PNGRB authorization.
- Ensure compliance with statutory standards and Technical Standards for Safety (T4S).
- Establish CNG outlets and infrastructure adhering to PESO guidelines.
- Collaborate with local bodies for CBG plants.
- Maintain emergency response systems and participate in mock drills.
- Provide transparent reporting of progress to State and District Committees.

5. Implementation and Review

The policy mandates:

- Regular monitoring by State and District Committees.
- Escalation mechanisms for delays in permissions.
- Integration of CGD portal with single-window clearance.
- Periodic review of progress against defined targets.
- Flexibility to amend provisions based on evolving needs and technologies.

H₂ NATIONAL GREEN HYDROGEN MISSION



8

State Green Hydrogen Policies in India: A Comparative Analysis of Emerging Frameworks

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Abstract:

India stands at a transformative inflection point, pursuing Viksit Bharat and Aatmanirbhar Bharat by 2047 while committing to net-zero emissions by 2070, aligned with Panchamrit pledges at COP26. As the world's fastest-growing major economy, India must balance sustained growth with enhanced 2030 Nationally Determined Contributions (NDCs) through responsible decarbonization. Green hydrogen

emerges as a pivotal enabler, delivering a zero-carbon, versatile vector to decarbonize hard-to-abate sectors—steel, fertilizers, refineries, heavy industry, and long-haul transport.

The National Green Hydrogen Mission (NGHM), launched in 2023 by MNRE with ₹19,744 crore allocation, targets 5 MMTPA production by 2030, requiring 125 GW additional renewable capacity and mobilising investments exceeding ₹8 lakh crore. Amplified by state policies mobilizing ~USD 61 billion (₹5 lakh crore) in incentives, this framework is set to capture global market share through focussed efforts on export.

This article provides a comparative analysis of green hydrogen policies across 14 Indian states, evaluating targets, incentives, institutional mechanisms, and regional features against NGHM benchmarks. These convergent, decentralized initiatives—strengthened by subsidies, power exemptions, and innovation support—demonstrate India's federated strategy for an integrated, bankable hydrogen economy, securing energy independence, industrial competitiveness, and climate leadership.

1. Introduction

The global transition to hydrogen as a clean energy carrier originated from dual imperatives of energy security and climate mitigation. Early adopters—Europe, Japan, and South Korea—launched national strategies between 2017 and 2020, targeting decarbonization of industry, transport, and power systems. By late 2025, over 50 countries have formulated hydrogen roadmaps or strategies, as detailed in the International Energy Agency's Global Hydrogen Review 2025. In ambitious net-zero pathways, low-emission hydrogen demand is projected to surpass 80 million metric tonnes globally by 2030, rising to over 500 million tonnes by 2050. These initiatives have catalysed rapid progress in electrolyser efficiency, storage technologies, and harmonised certification regimes, cementing hydrogen's role as a cornerstone of the worldwide energy transition.

In India, this global momentum crystallised with the Prime Minister's announcement of the National Hydrogen Mission in 2021, followed by the Ministry of Power's Green Hydrogen Policy in 2022 and the launch of comprehensive National Green Hydrogen Mission (NGHM) in 2023. Supported by ₹19,744 crore budgetary allocation from the Ministry of New and Renewable Energy (MNRE), the NGHM targets 5 million metric tonnes per annum (MMTPA) production by 2030, requiring 125 GW additional renewable capacity with an estimated investments over ₹8 lakh crore. This strategic thrust promises to abate 50 million tonnes of CO₂ annually, save ₹1 lakh crore in fossil fuel imports, and generate over 6 lakh green jobs.

Realising this ambition, needs focussed execution tailored to India's heterogeneous geography. Coastal regions provide export gateways, industrial corridors anchor demand in steel and fertilizers, and solar/wind-rich zones supply low-cost renewables. States have responded with bespoke policies aligning local strengths to NGHM objectives. A recent study by CEEW estimates these state incentives could mobilise an additional USD 61 billion (~INR 5 lakh crore), with power-sector reforms—open access, banking, and concessional tariffs—contributing USD 38 billion (63%), pivotal to achieving competitive economics. This collaborative, multi-level governance model accelerates deployment and positions India as an emerging global leader in green hydrogen.

2. National Framework for Green Hydrogen Ecosystem

India's green hydrogen ecosystem is driven by a coordinated whole-of-government approach under the National Green Hydrogen Mission (NGHM), launched in January 2023. As of December 2025, key achievements include incentives awarded for 3,000 MW annual electrolyser manufacturing domestic capacity to 15 companies and 862,000 tonnes per annum green hydrogen production capacity allocated across 18 firms, alongside competitive bidding for 724,000 MTPA green ammonia supply to fertilizer units. Pilot projects, with outlays exceeding ₹1,466 crore across steel (₹455 crore), mobility (₹496 crore), and shipping (₹115 crore), are advancing demonstrations in hard-to-abate sectors, including hydrogen injection in steel production, deployment of hydrogen-powered vehicles and refuelling stations, dual-fuel vessels, and port infra with bunkering facilities. Four Hydrogen Valley Innovation Clusters (HVICs)—in Pune, Jodhpur, Bhubaneswar, and Kerala—are being established with a total investment of ₹485 crore (₹170 crore from NGHM, supplemented by industry contributions) to serve as integrated innovation testbeds showcasing the full value chain.

Complementary measures include the Green Hydrogen Standard (notified August 2023), the Green Hydrogen Certification Scheme of India (GHCI) launched in April 2025 for lifecycle emissions verification, extensive R&D initiatives (23 projects sanctioned in the first round), testing infrastructure development, and skill-building programs. Inter-ministerial support features the Power Ministry's 25-year ISTS charge waiver for projects commissioned by December 2030; identification of major ports—Deendayal (Kandla), Paradip, and V.O. Chidambaranar (Tuticorin)—as green hydrogen hubs; Indian Railways' "Hydrogen for Heritage" plan for 35 hydrogen trains; environmental exemptions for standalone plants; streamlined approvals via DPIIT's single-window portal; and advancing international cooperation under Article 6.2 of the Paris Agreement. This comprehensive national framework de-risks investments, accelerates technology deployment, and underpins India's goals of 5 MMT annual green hydrogen production by 2030, energy independence by 2047, and net-zero emissions by 2070.

3. State Policy Landscape

Complementing the national framework, state governments are vigorously translating NGHM objectives into actionable, region-specific strategies. As of December 2025, 13 states have notified dedicated or integrated green hydrogen policies, crafting a dynamic, federated ecosystem that harnesses localised assets to anchor demand, stimulate supply, and unlock export potential.

These policies blend potent fiscal levers—capital subsidies reaching 40–60%, full SGST reimbursements, and electricity duty exemptions spanning 10–20 years—with regulatory accelerators such as wheeling/transmission waivers, open-access banking, stamp-duty relief, and priority land allocation. Single-window clearances and dedicated nodal agencies further streamline execution, while green hydrogen hubs and valleys emerge as innovation anchors.

Solar-endowed states like Rajasthan, Gujarat, Madhya Pradesh, and Haryana prioritise gigawatt-scale electrolysis and renewable-powered parks. Coastal gateways—Andhra Pradesh, Maharashtra, West Bengal, and Odisha—focus on green ammonia exports and refinery/fertilizer substitution through port-centric clusters. Industrial powerhouses including Uttar Pradesh, and Telangana target steel, fertilizers, and mobility corridors with aggressive capex support. Agrarian Punjab champions biomass-derived

pathways, and integrated models in Kerala and Odisha embed hydrogen within broader clean-energy ambitions.

This strategic mosaic mobilises an estimated INR 5 lakh crore in incremental incentives—63% driven by power-sector reforms—dramatically lowering the estimated cost of hydrogen and enhancing project bankability. By synchronising regional strengths with national priorities, these policies are forging resilient production-storage-transport-export corridors, catalysing equitable growth, substantial employment, and India's ascent as a premier global green hydrogen powerhouse.

Table 1 : State Policy Landscape in Green Hydrogen

State	Policy Year/ Status	Key Targets	Key Benefits/Incentives
Andhra Pradesh	2023 (Notified)	0.5 MMT green hydrogen / 2 MMT green ammonia by 2028	100% SGST reimbursement (5 years), electricity duty exemption (5 years), 25% wheeling waiver (max ₹10 Lakh/MW/yr for 5 years), concessional government land lease
Maharashtra	2023 (Integrated with Renewable Energy)	Ecosystem development; aligned with national hub status; 10% blending by 2030	100% electricity duty exemption (10 years), 50% wheeling (5 years), 100% SGST, 30% capex subsidy, ₹2.5 Cr/km for H2 pipelines (max 10 km), 1% interest subsidy on transport projects
Rajasthan	2023 (Notified)	Pioneer status; green hydrogen parks/hubs; 10% blending in natural gas by 2030	50% electricity duty exemption (10 years), 100% ISTS & 50% wheeling, 75% SGST (7 years), government/private land allotment, 100% land tax exemption (7 years)
West Bengal	2023 (Notified)	Hub for steel/fertilizers; blending in CGD/PNG networks	Centre of Excellence, port proximity incentives (Kolkata/Haldia), natural gas blending support, expedited clearances
Uttar Pradesh	2024 (Notified)	1 MMT by 2028; 120,000 jobs	100% electricity duty exemption (10 years), 50% transmission & 100% distribution charges, 100% SGST, up to 60% capex for electrolyzers >50 MW, 50% employment subsidy (ESI/EPF for 7 years)
Haryana	2024 (Notified from Draft)	Ecosystem with R&D/skilling; integrated manufacturing	100% electricity duty exemption (10 years), 100% wheeling/transmission (10 years), 100% land tax exemption (7 years), single-window clearances, streamlined rare earth imports

State	Policy Year/ Status	Key Targets	Key Benefits/Incentives
Telangana	2025 (Clean & Green Energy Policy)	554 KTPA by 2030	100% electricity duty exemption (10 years), 100% wheeling/transmission (10 years), 100% SGST reimbursement, 30% capex for plant/equipment (over 5 years), 5% extra for anchor units >₹200 Cr
Madhya Pradesh	2025 (Integrated Energy Policy)	Prioritized land allocation; linked to biofuels	100% electricity duty exemption (10 years), 50% wheeling (5 years), priority land allocation, investment promotion incentives
Gujarat	2025 (Dedicated; AtmaNirbhar Gujarat Scheme)	3 MMT by 2035; 30 GW electrolyzers & 75 GW RE support	Concessional power charges, 100% OA clarity, stamp duty/land tax exemptions, 20% capex (₹1 Cr/MW electrolysis; ₹8 Cr/kTPA biomass), ₹35 Cr/hub subsidy, ₹50/kg for MSMEs, 1.99 lakh hectares land allocation
Kerala	2024 (Finalized from Draft)	0.155 MMT by 2040; 10% blending	₹200 Cr viability gap funding for hubs (Kochi/TVM), OA access & port approvals, coastal land support, desalination/water focus, maritime cluster incentives
Odisha	2022 (Integrated RE Policy)	Hubs for petrochemicals/steel; viability studies	100% electricity duty exemption (20 years), 100% wheeling/transmission, net SGST up to 100% (200% for GH2/GA), 30% capex (GH2/GA; 20% RE), R&D 50% up to ₹10 Cr, 25% investment subsidy (max ₹10 Cr/unit)
Punjab	2025 (Draft Notified)	8% blending by 2030; biomass focus	100% electricity duty exemption, 50% transmission & CD concession, max ₹15 Cr capex for biomass (up to 5 TPD), agri-waste utilization incentives
Chhattisgarh	2024 (Integrated Industrial Development)	Ecosystem for steel/fertilizers; industrial clusters	100% electricity duty exemption (12 years), 100% SGST reimbursement (12 years), 25% additional surcharge reimbursement, 25% water charges (10 years), 100% stamp duty exemption

4. NGHM-Aligned Harmonization and Acceleration Plan

India's green hydrogen ecosystem is at a pivotal inflection point: the ₹19,744 crore NGHM, bolstered by ~USD 61 billion in state incentives, offers a compelling investment opportunity, yet regulatory fragmentation in safety, certification, power access, banking, and offtake elevates risks and constrains scale-up. A focused NGHM-led conformance layer is critical to convert diverse state momentum into bankable projects, minimizing uncertainty, accelerating financial close, and facilitating cross-state trade and exports.

Key priorities include: (i) a mandatory national safety code with emergency protocols to reduce insurance and contingency costs; (ii) an operational Guarantee of Origin (GoO) regime with lifecycle emissions traceability for fungibility and premium export pricing; (iii) standardized guidelines for non-potable water sources to expedite siting; and (iv) model PPAs/GSAs featuring indexed pricing and robust dispute resolution to streamline offtake.

Power harmonization is the primary lever: states should enact 10–15 year open-access stability commitments, monthly banking aligned to renewable variability (lowering LCOH by 8–10%), and uniform concessional wheeling/transmission regimes (saving ₹0.5–0.7/kWh). NGHM-backed procurements—refinery/fertilizer pilots, steel/mobility corridors, and ammonia terminals with unified procedures—will generate replicable demand and enable India to capture share in the projected USD 200 billion global trade by 2050.

Progress must be monitored through transparent KPIs: offtake volumes/duration, landed power costs, approval timelines, certification rates, non-potable water use, electrolyser capacity, workforce metrics, and certified exports, reported via quarterly dashboards.

Priority states—Gujarat (exports), Maharashtra (refineries), Odisha/Rajasthan (steel/RE), Karnataka (manufacturing)—warrant immediate facilitation; the next cohort (Uttar Pradesh, Andhra Pradesh, Telangana, Haryana) should emphasize OA stability and GoO integration.

This integrated framework will deliver uniform compliance, predictable economics, and seamless market access, propelling India to its 5 MMT target by 2030, energy independence by 2047, and net-zero by 2070.

5. Conclusion and Way Forward

India's green hydrogen ecosystem exemplifies robust federal synergy, with 14 state policies effectively complementing the National Green Hydrogen Mission (NGHM) by harnessing regional strengths—high solar irradiance, industrial clusters, biomass resources, and strategic ports—to decarbonize hard-to-abate sectors and bolster energy security. Leading states including Gujarat, Maharashtra, Rajasthan, Odisha, Andhra Pradesh, and Telangana have created strong enablers via anchored offtake in refineries/fertilizers/steel, multi-year power concessions, and export infrastructure, while Uttar Pradesh, Haryana, Kerala, and Punjab are advancing pilots in mobility, blending, and biomass applications. These frameworks collectively unlock ~USD 61 billion in incentives—largely power waivers and fiscal reimbursements—amplifying the NGHM's ₹19,744 crore allocation and ensuring a credible trajectory to the 5 MMT annual production mandate by 2030.

Regulatory fragmentation—varying banking/settlement rules, open-access tenure, safety protocols, and water guidelines—remains a key barrier, adding risk premiums and limiting fungibility. NGHM, coordinating with CEA, CERC, and other departments, should swiftly implement a conformance layer: (i) mandatory national safety code; (ii) operational Guarantee of Origin (GoO) with emissions traceability; (iii) uniform non-potable water guidelines; and (iv) model PPAs/GSAs with indexed pricing and dispute clauses.

Investors should target jurisdictions with secured demand, 10–15 year power stability, and port readiness, while modeling incentive continuity. Policymakers must deliver enforceable concessions, integrate derivatives into REC/RPO frameworks, and publish quarterly KPIs (offtake, power costs, timelines, certification). This integrated, bankable market will drive India to its 2030 milestone, Aatmanirbhar energy independence by 2047, and net-zero by 2070, cementing global leadership in green hydrogen.





Barsana Biogas Plant, Mathura, Uttar Pradesh- India's largest agri-waste-based bio-CNG facility

9

Synergizing Biogas: The Vital Role of State-Level Energy Policies in Ensuring India's Energy Security for future

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Abstract

India's **Viksit Bharat** vision for 2047 demands an energy system that is secure, affordable, and set to power sustained high and rapid growth. As energy demand increases with development, enhancing the reliance on a diversified suite of low carbon fuels that are indigenously available can help hedge against geopolitical uncertainties and risks on account of price volatility and supply chain disruptions. Among

clean solutions, **biomass-based bioenergy such as biogas and Compressed Bio-Gas (CBG)** offer a scalable, rural-centric pathway that converts agricultural residues, municipal organic wastes, and agro-industrial by-products into grid-ready green gas for transport and cooking. Central policies have created demand signals and offtake assurance, but execution success hinges on **state capacity**: land facilitation, feedstock aggregation, and last-mile pipeline connectivity. This paper synthesizes **some State-level best practices** that are already moving the needle: **Uttar Pradesh's** Bio-Energy Policy; **Gujarat's** CBG injection pilots; **Punjab–Haryana's** ex-situ paddy-straw programs; and **Odisha's** waste to energy integration within its broader RE framework. Drawing on these, we propose harmonization of state incentives; expand CBG-CGD injection nodes and virtual pipelines; de-risk feedstock via MSP-like floors and mechanized aggregation; digitize biomass logistics using GIS/IoT; valorize digestate (Fermented Organic Manure-FOM) to reduce fertilizer imports; and unlock blended finance and credit guarantees. Together, such steps could help position biogas/CBG as a key component of India's **secure, self-reliant, and low-carbon** energy future by mid-century.

1. Introduction

Energy is central to modern development underpinning economic activity, social welfare, and essential services. Reliable, affordable access is vital for sustained growth; yet heavy reliance on fossil fuels has created environmental and economic externalities, from greenhouse gas emissions and air pollution to vulnerability arising from fuel price volatility and import dependence. These challenges are particularly salient for India, where rapid economic growth must be balanced with climate commitments, resource constraints, and livelihood security.

India the world's third-largest energy consumer relies on imports for ~88-90% of its crude oil, exposing the economy to international price swings and supply disruptions^{1,2}. LNG imports can constitute nearly half of India's natural gas availability in certain periods, adding a further layer of exposure to global markets³. In parallel, India's COP26 Panchamrit committed to a target of 500 GW non-fossil capacity by 2030 and net-zero emissions by 2070 underscoring the urgency of transitioning toward clean, indigenous energy systems.⁴ Against this backdrop, biomass-based fuels, especially biogas and Compressed Bio-Gas (CBG), present a scalable, decentralized, and rural centric pathway to energy independence, converting agricultural residues, municipal organics, and agro-industrial by-products into green gas.⁵

India's electricity consumption has grown rapidly, crossing about 1,532 TWh in 2024, with annual growth of nearly 7%.⁶ Under high-growth scenarios, long-term projections indicate electricity generation could reach about 3,500 TWh by 2040 and rise further to around 5,300-5,400 TWh by 2050.⁷ Complementing this outlook, TERI's analysis suggests that on-grid demand will exceed 5,000 TWh by 2050 (four times from 2019), driven by structural economic shifts and deepening electrification across sectors.⁸

Independent assessments project electricity demand growth of around 6-6.5% CAGR during FY2026–FY2030, with electric vehicles, data centres, and green hydrogen together accounting for 20–25% of incremental demand.⁹ Alternative projections suggest even faster growth, exceeding 7% CAGR during FY2024-FY2027, with data-centre electricity consumption potentially increasing from about 8-9 TWh today to as high as 80 TWh by FY2030, and green hydrogen production adding approximately 150-300 TWh of annual electricity demand in the longer term.¹⁰ These emerging loads are continuous, power-quality sensitive, and energy-intensive, necessitating rapid expansion of clean and reliable power generation.

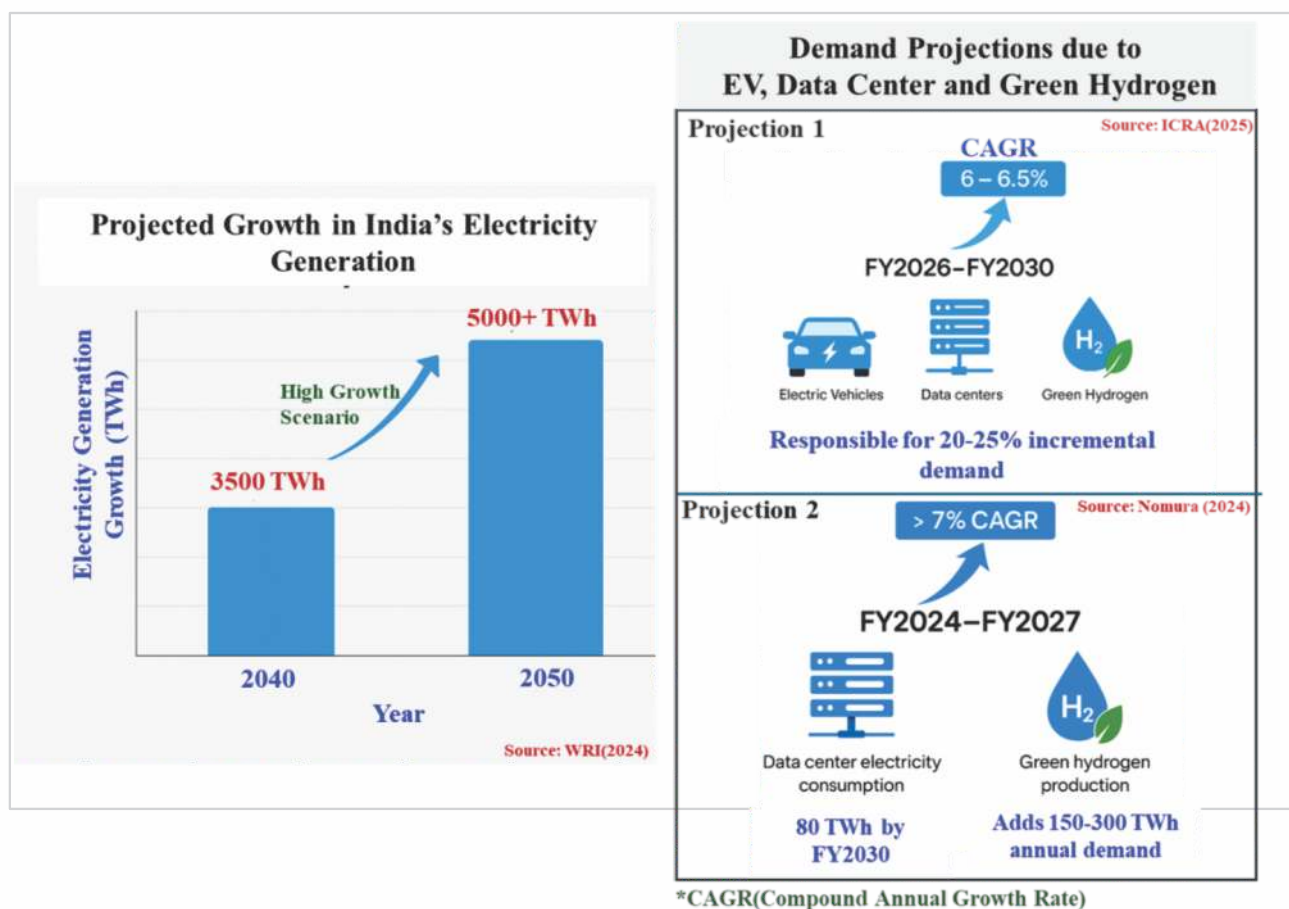


Figure.1. Indias Electricity demand Projections

Current constraints include: high fossils import vulnerability, climate pressures, as coal remains predominant despite the push toward non-fossil capacity; and fiscal risks arising from volatile crude prices that strain the national import bill and macroeconomic stability.

On the supply side, coal **accounted for ~70% of electricity generation in 2023**, contributing to high carbon intensity of grid power and local air-pollution despite accelerating non-fossil additions¹¹. Encouragingly, India has already **surpassed ~50% non-fossil installed capacity** ahead of its 2030 milestone, with **total non-fossil capacity reaching ~262.7 GW (Biomass 11.61 GW) by Nov 2025** creating headroom to integrate **green gases** such as CBG into transport and city gas networks¹². On the social front, **PM Ujjwala Yojana (PMUY)** has expanded clean-cooking access to **>10.33 crore households**, yet **refill affordability** challenges could persist for PMUY customers, especially in rural regions establishing the need for **low-cost, localized fuels** (biogas-digesters, CBG-fed-PNG-mini-grids) that complement LPG and enhance resilience^{13,14}.

Within this context, this paper evaluates **central missions** (e.g., SATAT, CBG-CGD Synchronization Scheme, CBG-Blending Obligation), **state policies**, and **scaling challenges**, demonstrating why **decentralized execution and coordinated governance** are decisive for India's bioenergy transition. We highlight some of the **state best practices** and recommend strategies such as detailing harmonized incentives, infrastructure synchronization for **CBG-CGD injection**, feedstock monetization, digital logistics, digestate valorization, and blended-finance instruments to support **biogas/CBG** playing a larger role in India's **secure, self-reliant, low-carbon** future.

2. Biogas: India's Domestic Engine

India's biomass resource base includes cattle dung, crop residues, municipal solid waste (MSW), and agro-industrial by-products supports large-scale anaerobic digestion to produce raw biogas (Figure.2). Upgrading technologies (e.g., pressure swing adsorption, scrubbing, membrane separation) remove CO₂, hydrogen sulphide, and moisture to raise methane content to $\geq 95\%$, meeting IS 16087:2025 product standards for CBG. In this upgraded form, CBG is fully substitutable for CNG in transport and PNG for domestic/industrial use^{15,16}. Beyond fuel, the digestate/FOM coproduct enhances soil health and can displace chemical fertilizers, while captured CO₂ from upgrading processes has local industrial uses both improving project economics^{17,18}. Typical medium-scale facilities (5-10 TPD) involve capital outlays of ₹20–80 crore depending on feedstock complexity, technology choice, and offtake model, underscoring the importance of policy-backed offtake and pipeline connectivity for bankability^{19,20}. Key enablers are outlined in Table.1.

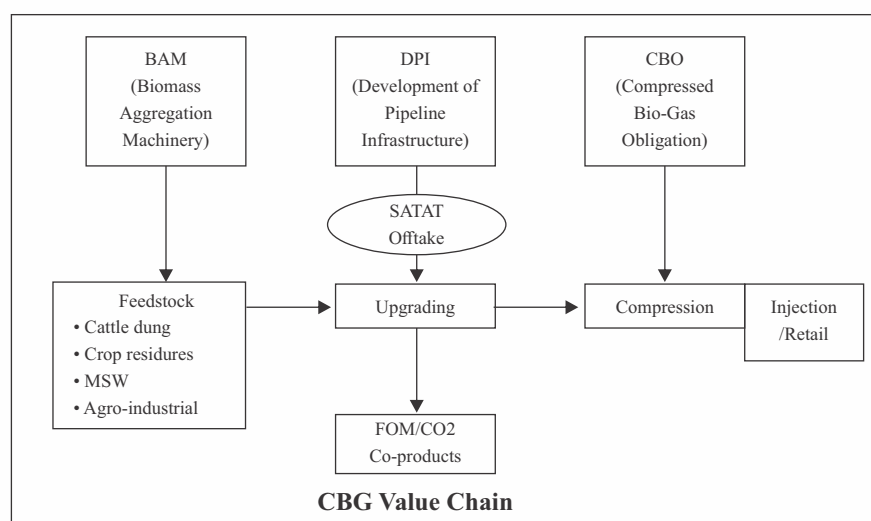


Figure.2. CBG Value-Chain for Biomass feedstocks

2.1 SATAT: India's Transformational Biofuel Mission

SATAT (Sustainable Alternative Towards Affordable Transportation) catalyzes private investment by providing structured CBG offtake pathways with oil marketing companies (OMCs) and complementary ecosystem support. Demonstrated progress includes ~2,227 active LOIs nationwide, 94 operational plants of CBG in FY 2024-25 increasing to 132 commissioned plants by early 2026^{21,22,23}. To reduce logistics costs and flaring risk, the Development of Pipeline Infrastructure (DPI) scheme commits ₹9.94 billion to co-fund CBG-CGD injection nodes, tying production clusters to city-gas networks^{24,25}.

2.2 CBG Blending Obligation (CBO)

The CBG Blending Obligation (CBO) mandates a 1% blend of CBG into CNG/PNG in FY 2025-26, rising to 5% by FY 2028-29, thereby creating a multi-year, ramping demand floor that supports financing and accelerates scale-up. As CGD coverage expands and tariff reforms improve delivered costs, CBO seeks to strengthen investor confidence and reduce RLNG dependence in gas networks^{26,27}.

2.3 Clean Cooking, Livelihoods, and Social Impact

While PM Ujjwala Yojana (PMUY) has extended LPG access to >10.33 crore households, refill affordability remains challenging for low-income and rural segments in these customers. CBG-fed-PNG mini-grids and household/community digesters offer localized, affordable clean-cooking solutions that reduce indoor air pollution and insulate communities from international price swings. The ₹300/cylinder PMUY subsidy supports LPG usage for PMUY customers but does not substitute the resilience provided by local bio-fuels. Meanwhile, the CBG value chain can also generate rural jobs across feedstock aggregation, transport, plant operations, slurry processing, and FOM distribution linking clean energy access with inclusive development^{11,12,15}.

Table 1. Quality, Policy, and Market Enablers for India's CBG Ecosystem

Theme	Mechanism/ Standard	Status	Outcomes/ Implications
Product Quality ^{13,14}	IS 16087:2025 CBG specification ($\text{CH}_4 \geq 95\%$, $\text{CO}_2 + \text{N}_2 + \text{O}_2 \leq 5 \text{ mol}\%$, total sulphur $\leq 10 \text{ mg/m}^3$, etc.)	National updated standard in force	Ensures safety/ interchangeability with CNG/PNG; enables pipeline injection and retail
CBG-Offtake (SATAT) ^{17,18,19}	OMC procurement via LOIs; standard specs/ pricing	~2,227 LOIs; 94 plants sold ~31,422 t CBG (FY 2024-25); 132 plants / ~920 TPD by early 2026	Demand visibility; revenue de-risking; improved debt service and bankability
Injection(DPI Scheme) ²¹	Central assistance for CBG-CGD injection nodes	₹9.94 billion allocated; national roll-out	Lowers logistics cost vs. cascade retail; mitigates flaring; ties producers to CGD
Mandatory Demand (CBO) ^{22,23,28}	1% blend in FY 2025-26 → 5% by FY 2028-29	Phased obligation in CGD segments	Multi-year demand floor; strengthens investor confidence; reduces RLNG reliance
Coproducts & Circularity ¹⁵	FOM/digestate marketing; CO_2 utilization	Regional markets expanding	Diversifies income; boosts IRR; supports soil health and local industry
Capital Economics ¹⁶	Tech/feedstock/scale dependent CAPEX	₹20-80 crore typical for 5-10 TPD	Larger plants favour pipeline injection economics; policy support essential

3. Role of States: Policy Innovation and Decentralization

Central schemes help build scale, but states determine success through land allocation, feedstock management, and last-mile pipeline connectivity.

3.1 Exemplary State Initiatives

Table 2 illustrates how different states are driving India's bioenergy transition through key state level policy innovations and project initiatives that strengthen CBG and biogas deployment across the country.

Table 2: Select State Initiatives in Bioenergy

Theme	Key Policy Initiatives	Details
Uttar Pradesh (Sugar-belt biogas leader) ^{25, 29}	UP Bio-Energy Policy 2022	100% stamp duty exemption - Land leases at ₹1 per acre per year - Production-linked subsidies up to ₹20 crore - Strong integration with sugar-mill residues (press-mud, bagasse)
Gujarat (Gas-grid model for CBG injection) ^{30, 31}	CBG-CGD Integration	- Tripartite agreements (GAIL-Gujarat Gas-Baba Deep Singh CBG plant) - Proven model for pipeline injection of CBG - Helps reduce RLNG consumption in CGD networks
Punjab & Haryana (Paddy straw to CBG) ^{32, 33}	Ex-situ crop residue CBG strategy	14.8 lakh tonnes projected annual straw collection 60 CBG projects with 852 TPD combined capacity - Several plants operational (107 TPD total) - Parallel push for boiler conversions & straw palletisation

3.2 Key Challenges Hindering Scale

- **Feedstock variability:** High logistics cost and seasonality; BAM (Biomass Aggregation Machinery) subsidy helps reduce collection barriers.³⁴
- **High CAPEX:** A 5-TPD, CBG-plant costs ₹20-25 crore; a 10 TPD plant ₹25-80 crore, depending on technology and model^{17, 18}.
- **PNG/CGD gaps:** Despite 307-GAs covering almost 100% of geographic area, pipeline access remains uneven; unified tariff reforms aim to improve affordability^{35, 36}.
- **Institutional coordination:** Need for convergence among agriculture, rural development, urban bodies, and energy departments; lessons from EPA/GMI highlight operational and permitting bottlenecks¹⁶.

4. Recommendations & Conclusions

Recommendations are as follows:

- **Policy Harmonization & Infrastructure Enablement:** Harmonize state bioenergy policies by adopting best-practice incentives (e.g., stamp duty waivers, land-use facilitation, production-linked subsidies, electricity ISTS & wheeling charges waiver) and expand CGD networks with DPI-enabled CBG-CGD injection, targeting ≥ 100 plants by 2026.
- **Feedstock Assurance & Digital Oversight:** Derisk biomass supply via MSP-like price floors through FPOs, scale mechanized harvesting and aggregation under MoPNG's BAM, and deploy GIS-based biomass mapping with IoT-enabled logistics integrated into SATAT dashboards.
- **Circularity Through Digestate Valorization:** Build markets for FOM with organic farming incentives, reducing urea imports while improving soil health and creating additional revenue streams for plant operators.
- **Fit for Purpose Financing Architecture:** Establish a CBG-Viability Gap Fund, expand credit guarantee schemes, and incentivize CO₂ capture and digestate productization to strengthen project IRRs and crowd in private capital.

CBG present a strategically important pathway for India's energy transition, delivering a triple dividend of energy security, rural prosperity, and environmental sustainability. In the context of widening fiscal and climate risks from fossil fuel imports, accelerating domestic biomass utilization through coordinated central-state action is imperative. Success hinges on systematic biomass monetization, robust market linkages, and institutional mechanisms that enable farmers to become **Urjadata**(energy providers), thereby advancing a self-reliant, low-carbon, and resilient energy future.

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10

Insights from State-level Renewable Energy Policies: Advancing India's Energy Security

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Vasudha Foundation

India's Energy Transition Over the Last Decade (2015–2025): A Data-Driven Review:

India's RE integration has accelerated remarkably since 2015, its installed capacity having grown from 88.7 GW to 254.01 GW as of November 2025¹, a massive 186.36% jump. Solar grew from 6.76 GW in 2015-16 to 132.85 GW in 2025 backed by national schemes like PM Surya Ghar Muft Bijli yojana, Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahabhiyan (PM KUSUM), to name the most pioneering ones,

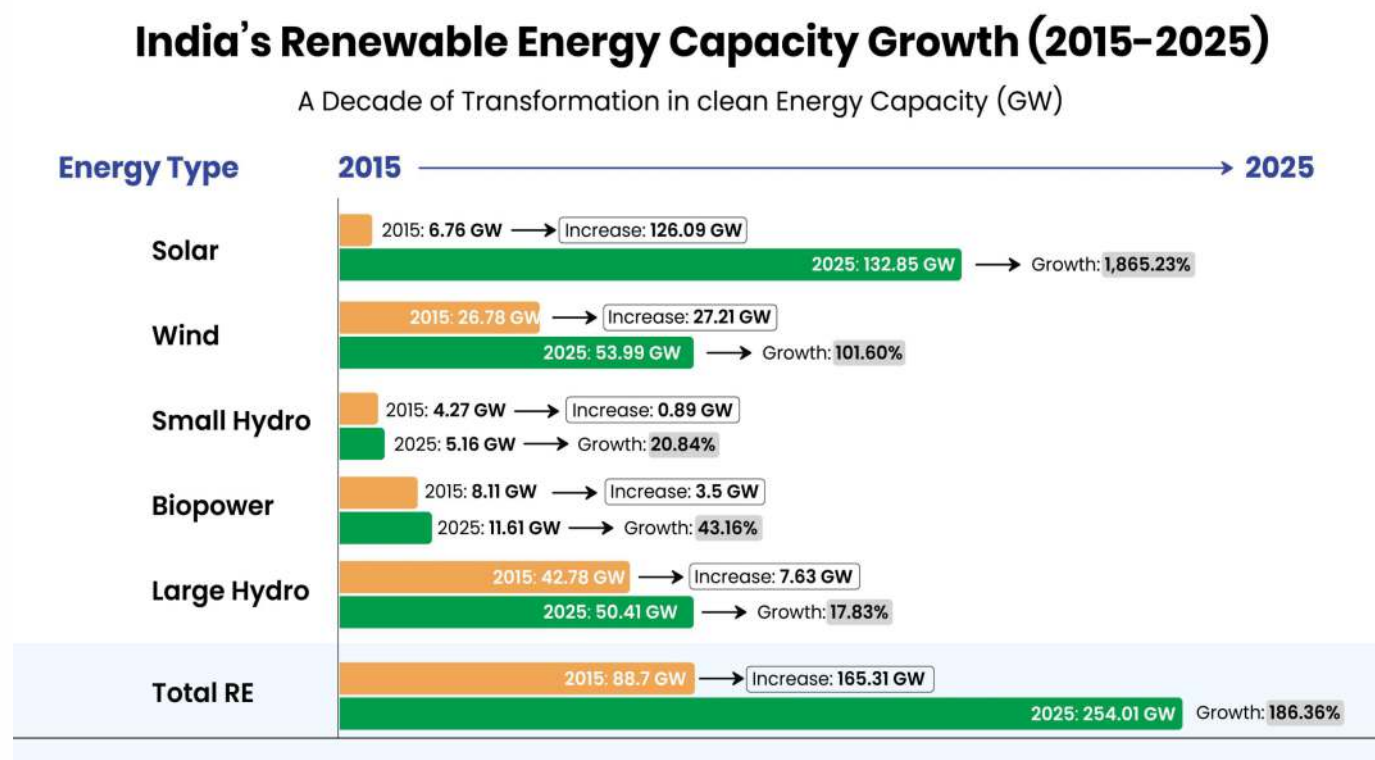
thereby becoming the largest RE source; while wind reached 53.99 GW, strengthened by interventions like the National Offshore Wind Policy, viability gap funding mechanisms and tariff based competitive bidding etc., (see **Figure-1**). To overcome the intermittency associated with wind and solar, storage deployment is gradually emerging, with approximately 490 MWh of grid-connected battery storage made operational by mid-2025², supported by national Energy Storage Systems (ESS) guidelines.

Simultaneously, biofuels have expanded, with ethanol blending rising from 1.53% (2013–14) to 20% (Ethanol Supply Year 2024–25) resulting in 1,810 crore litres of production capacity³. Under the National Green Hydrogen Mission (NGHM), as of late 2025, tenders for a cumulative annual capacity of 862,000 tonnes of green hydrogen and 3,000 MW of electrolyser manufacturing have been awarded⁴. Transmission strengthening through the Green Energy Corridor II is expecting the integration of 20 GW of RE by 2026⁵.

India's electric mobility (EV) market has progressed from a nascent stage to a rapid growth phase, driven by comprehensive government policies like Faster Adoption and Manufacturing of Electric Vehicles Scheme (FAME) - II, PM Electric Drive Revolution in Innovative Vehicle Enhancement Scheme (PM E-DRIVE), Production linked incentive (PLI) schemes and tax benefits. The market is also driven by substantial investments and increasing consumer acceptance. The national vision is to achieve 30% EV penetration in sales by 2030⁶.

With more impetus given to aforementioned renewable and newer technology adoption, large hydro, India's more stable and reliable clean energy source, grew at a slower pace from 42.78 GW in 2015 to 50.41 GW as of November 2025 (17.83%).

Figure 1: India's RE Capacity Growth (2015-2025) from India Climate & Energy Dashboard (ICED) (as of November 2025)



The following sections will cover how RE technologies witnessing significant growth (solar, wind, small hydro and biopower) have been established and adopted with relevant policy support to achieve maximum resource potential utilisation in leading states. Further, this paper attempts to unpack the contributing factors especially policy support of RE adoption in leading states that in turn contribute to India's long-term vision of achieving net-zero emissions by 2070 and energy independence by 2047.

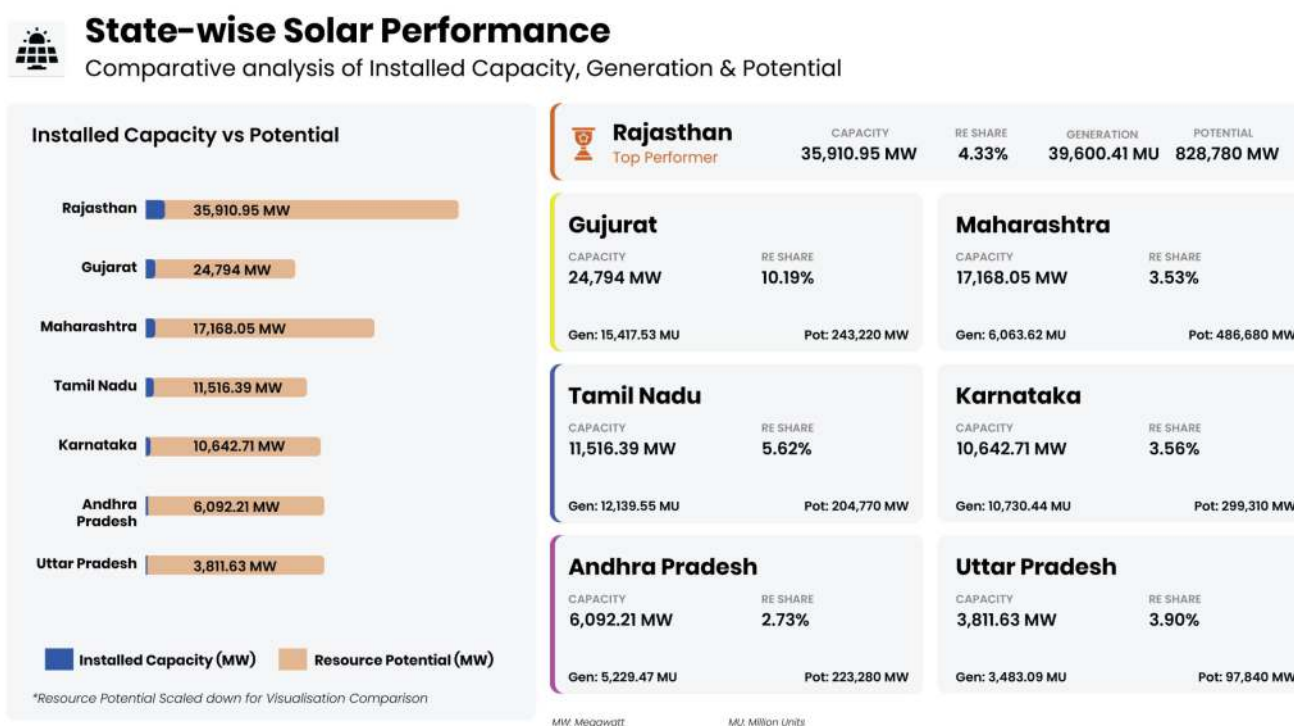
Technology Adoption & Innovation Across States

1.1 Solar

State-level solar deployment in India reflects a combination of resource suitability, transmission facilitation, rooftop-regulatory frameworks and the development of utility-scale solar parks.

Rajasthan (35 GW) and Gujarat (24 GW) lead in solar deployment. This is also supported by large feasible ground-mounted potential identified in recent assessments by National Institute of Solar Energy (3,343 GW feasible national potential)⁷ and Mercom (Rajasthan ~828.78 GW; Gujarat ~243.22 GW)⁸. Gujarat and Maharashtra demonstrate strong rooftop uptake through DISCOM-led net-metering and digitalised approval systems, while Karnataka and Tamil Nadu benefit from stable regulatory orders and long-standing tender mechanisms.

Figure 2: State-wise Solar Performance comparison for top performing states (ICED – as of Nov 2025)



As shown in Table 1, high solar performance across states is consistently associated with four structural drivers: clear land and solar-park allocation mechanisms that reduce siting uncertainty; streamlined grid-interconnection and transmission planning that lower developer risk, predictable rooftop and prosumer regulations supported by DISCOM-level implementation; and alignment of state policies with national frameworks including PM-KUSUM, Green Open Access Rules (2022) and MNRE's Solar Park Guidelines.

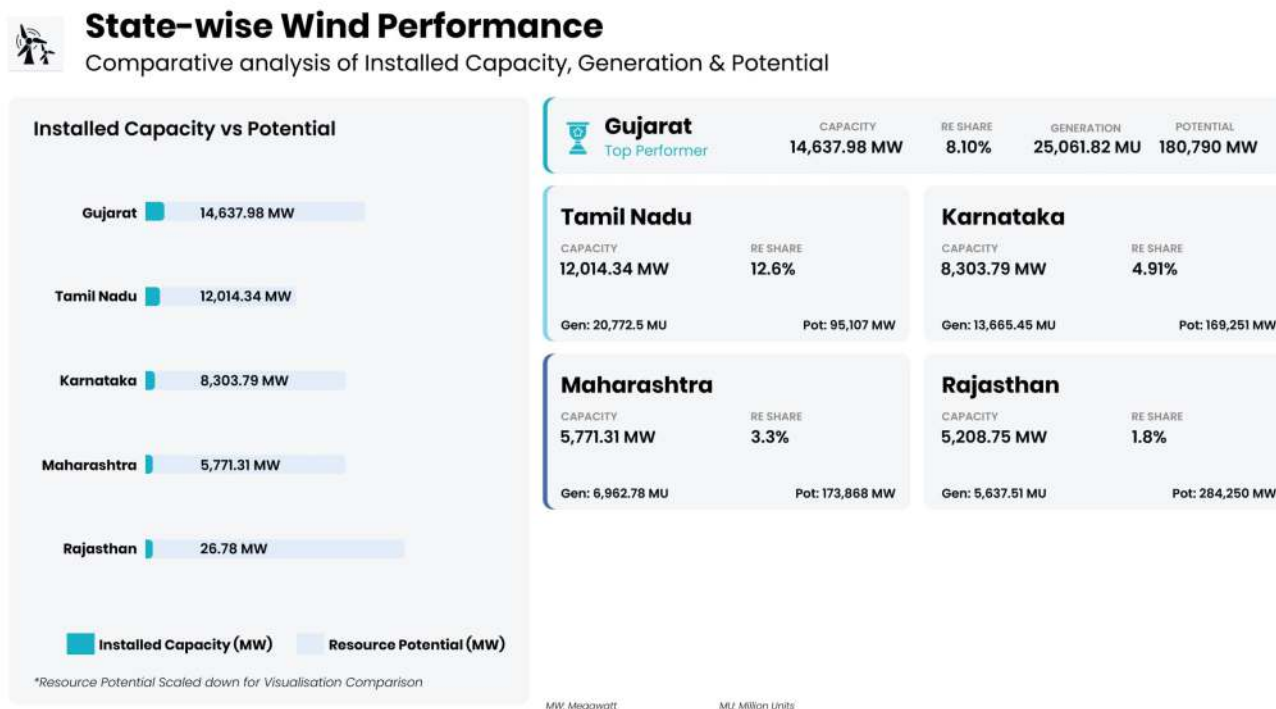
Table 1: Solar Performance Drivers

Driver Category	Description
Land & Park Facilitation	Clear land allocation mechanisms, solar park policies, availability of large land banks, and facilitation of large contiguous project parcels For instance in Rajasthan, MP
Transmission & Planning Readiness	Proactive large-scale transmission planning aligned with RE zones and utility-scale project development
Rooftop & Distributed Solar Policy	Advanced • rooftop and net-metering regulations • DISCOM-led rooftop programmes • Feeder-level solar initiatives • Strong urban prosumer focus For instance, in states like Gujarat, Maharashtra, UP, AP
State Renewable Energy Policy providing Frameworks	Dedicated multi-year renewable energy policies long-term visibility and implementation clarity
Procurement & Tariff Stability	Stable tariff orders, structured procurement mechanisms, and strong RE tendering processes
Institutional & Nodal Agency Capacity	Strong role of • state nodal agencies, • structured tenders, • digital portals, • fast-track approvals, and • effective on-ground implementation. For instance, UP, Maharashtra, Gujarat, Karnataka, AP
Agricultural–Solar Integration	PM-KUSUM–driven deployment, feeder-level solarisation. For instance in UP, Maharashtra

1.2 Wind

Wind energy is India's second-largest renewable source, with deployment concentrated in a handful of high-resource states that combine favourable wind regimes, early policy adoption and maturing grid infrastructure as depicted in **Figure 3** below.

**Figure 3: State-wise Wind Performance comparison for top performing states
(ICED – as of Nov 2025)**



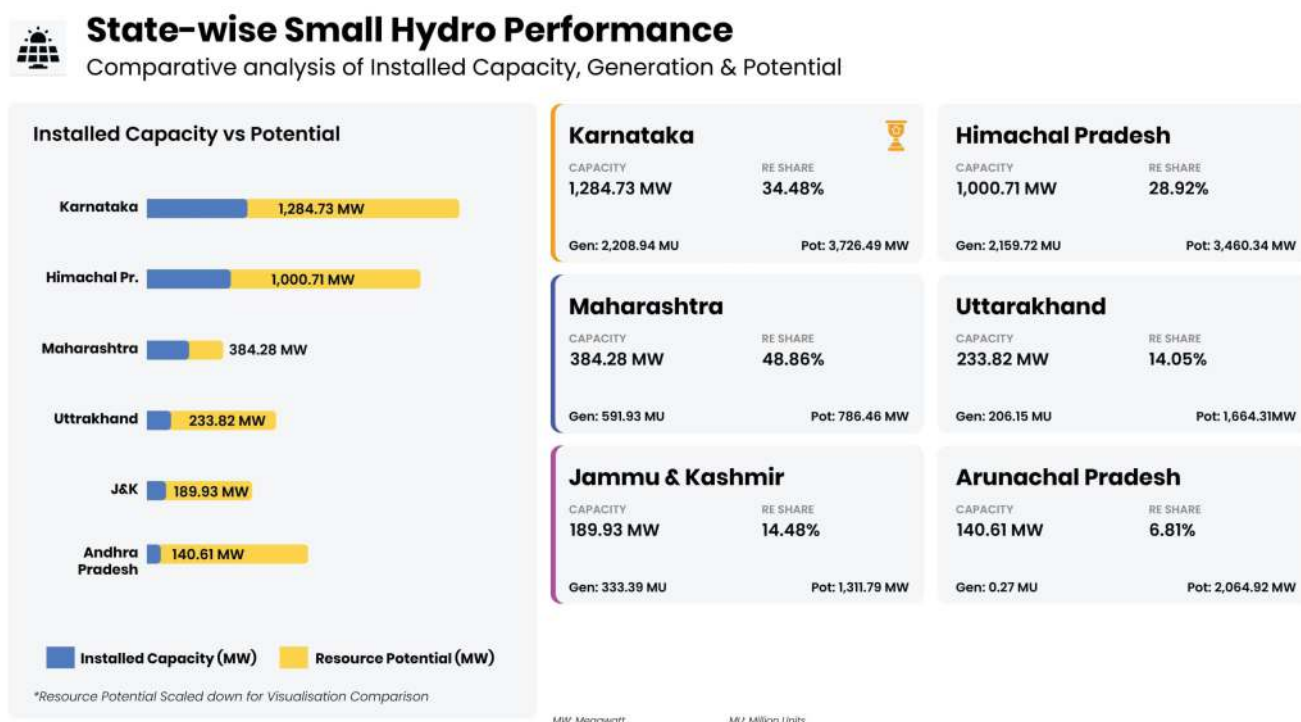
Wind performance across leading states is driven by wind resource conditions, procurement frameworks and infrastructure readiness (Table 2). Gujarat leads in installed capacity and wind generation driven by strong developer participation in central auctions, extensive Inter-State Transmission System (ISTS) connectivity and expansion of wind-solar hybrid parks in Kutch and Saurashtra. Tamil Nadu continues to sustain high output despite ageing turbines through repowering and hybrid procurement, while its well developed grid integration and long operational experience provide system stability. Karnataka's steady performance is anchored in consistent participation in hybrid and round-the-clock (RTC) tenders combined with well-developed wind zones especially in Chitradurga, Gadag and Vijayapura⁹. Maharashtra and Rajasthan illustrate the contrast between large technical potential and uneven deployment momentum, shaped by transmission constraints and the timing of large-scale procurement. Collectively, these dynamics position wind as a central balancing component in India's renewable portfolio and a key contributor to achieving the 2030 clean energy targets.

Table 2: Wind Performance Drivers

Driver Category	Description
Wind Resource Strength	NIWE-certified high-quality wind zones, favourable hub-height profiles. For instance in Gujarat, TN, Karnataka & Rajasthan
Grid & ISTS Integration	Transmission readiness, ISTS-connected capacity, evacuation corridors
Procurement & Auctions	Participation in SECI wind, hybrid, RTC tenders; stable procurement visibility
Hybrid & Co-location Potential	Wind-solar hybrid parks, land aggregation, complementarities. For instance in Gujarat
Repowering & Fleet Modernisation	Replacement of ageing turbines, improved PLFs. For instance in TN and Gujarat
Land & Park Facilitation	State-led wind parks, hybrid park designations. For instance in Gujarat & Rajasthan

1.3 Small Hydro Power (SHP)

Karnataka and Himachal Pradesh are the two strongest performers, with installed capacities of 1,284 MW and 1,001 MW and high annual generation of 1,843 MU and 1,905 MU, respectively (**Figure 4**). Maharashtra demonstrates a unique profile: despite modest potential, nearly half of its RE generation is derived from small hydro (48.86%). Uttarakhand, Jammu & Kashmir and Arunachal Pradesh exhibit substantial untapped potential, highlighting opportunities and scope to expand future development. Figure 4: State-wise Small Hydro Performance comparison for top performing states (ICED – as of Nov 2025)



Himachal Pradesh translates its **3,460 MW assessed SHP potential** into high generation through Himachal Pradesh Energy Development Agency (HIMURJA's) centralized project allocation, and dedicated SHP programmes¹⁰. Karnataka, a leader in installed SHP capacity, prioritizes small hydro under its Renewable Energy Policy (2022–27)¹¹, providing streamlined land conversion, assured grid evacuation via Karnataka Power Transmission Corporation Ltd. (KPTCL) and repowering provisions for ageing projects. Maharashtra's hydel policy¹² supports a relatively high contribution of SHP within the state's RE mix. Despite having a 1,664 MW SHP potential in Uttarakhand, deployment remains constrained as it relies on its Micro & Mini Hydro Policy (2015)¹³ and Uttarakhand Jal Vidyut Nigam Limited (UJVNL)'s community-oriented development model. Jammu & Kashmir and Arunachal Pradesh have introduced SHP policies with tax incentives and structured project allocation, yet progress continues to be limited by terrain, clearances and power evacuation timelines.

Table 3 represents key policy drivers influencing Small Hydro deployment across leading states.

Table 3: Small Hydro Performance Drivers

Driver Category	Description
Dedicated Small Hydro Policy Frameworks	State-specific small hydro or hydropower policies prioritizing SHP development, with defined targets, incentives, and programme support For instance in Karnataka, Maharashtra, Uttarakhand, Jammu & Kashmir, Arunachal Pradesh
Land, Site & Project Facilitation through implementation by Nodal Agency	States have strengthened project deployment by providing site identification support, establishing transparent project allocation mechanisms, and facilitation of DPR preparation with state nodal agencies playing an active role in monitoring and coordination with developers. For instance, in Himachal Pradesh, Maharashtra and Uttarakhand
Grid Evacuation & Utility Coordination	Structured coordination with state utilities for grid evacuation, transmission planning, and integration of SHP projects
Repowering & Modernization Support	Policy support for repowering and upgrading of ageing SHP assets to improve utilization and generation performance
Incentives & Early-Stage Project Support	Fiscal incentives, tax benefits, and policy clarity aimed at supporting early-stage project pipelines
Strategic Integration of Geography, Policy, and Resource Potential	By aligning terrain-specific planning, environmental safeguards, and project logistics with evolving policy and implementation frameworks, states are progressively unlocking resource potential and enabling steady renewable energy capacity growth, including in regions with substantial small hydropower opportunities.

1.4 Biopower

Biopower performance across Indian states (**Figure 5**) is shaped by feedstock concentration, tariff stability, procurement visibility and the maturity of ethanol–Compressed Biogas (CBG) ecosystems. Maharashtra leads with an installed capacity of 2,998 MW owing to its largest cluster of integrated sugar and distillery complexes, complemented by Maharashtra Electricity Regulatory Commission (MERC)'s long-standing technology-specific tariff orders^{14 15}, and targeted procurement windows. These features reduce revenue uncertainty and enable continuous cogeneration investment.

Karnataka's predictable feed-in tariffs for biomass and cogeneration, early adoption of grid-connectivity reforms and rapid expansion of municipal and agricultural CBG projects¹⁶, helps it to perform well and also diversifies revenue sources beyond bagasse. Uttar Pradesh having India's largest sugarcane output has a high feedstock base, combined with explicit policy incentives for bio-CNG, biomass utilization and distillery-linked cogeneration, enables steady scaling despite high seasonal variability.¹⁷ Tamil Nadu's performance stems from regulatory continuity: Tamil Nadu Electricity Regulatory Commission (TNERC) tariff orders¹⁸ and long-term Power Purchase Agreements (PPAs) have preserved investment attractiveness even as the state's sugar sector stabilizes. Andhra Pradesh, while smaller in scale, has recently tightened the policy–implementation pathway through its Integrated Clean Energy Policy¹⁹, clearer ethanol/CBG guidelines and nodal-agency execution, positioning the state for higher future uptake.

Figure 5: State-wise Biopower Performance comparison for top performing states (ICED – as of Nov 2025)

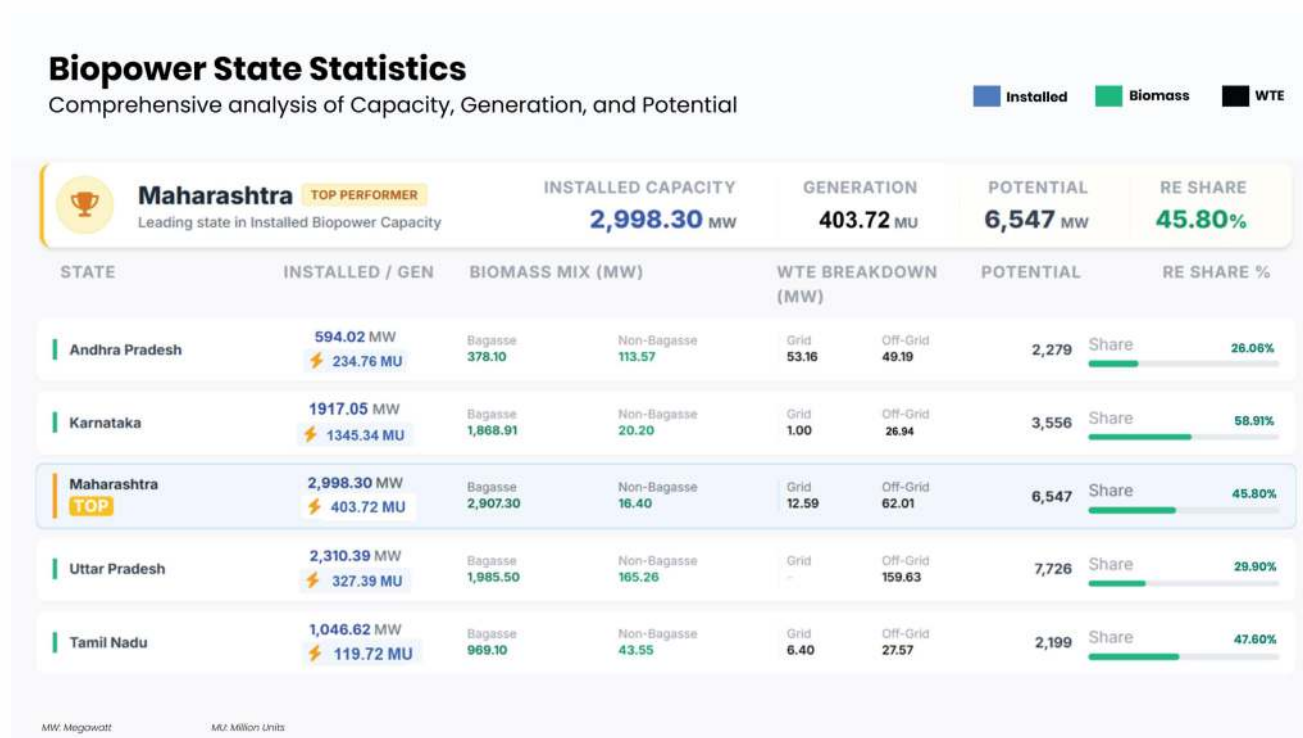


Table 4 represents key policy drivers influencing Biopower integration across leading states.

Table 4: Biopower Performance Drivers:

Policy Driver Category	Description
Regulatory Stability	Technology-specific tariffs, defined operating norms and long-term PPAs For an instance in Tamil Nadu, Karnataka, Maharashtra
Biomass Ecosystem Development	Support for cogeneration, press-mud, agri-residues and Municipal Solid Waste (MSW) utilisation For an instance in UP, Maharashtra, Karnataka, Rajasthan
CBG Programme Enablement	Capital support, MSW-CBG concessions, Sustainable Alternative Towards Affordable Transportation (SATAT)-linked facilitation For an instance in Karnataka, Maharashtra, Punjab, Haryana, Telangana
Ethanol & Distillery Integration	Dual-feed distilleries, cogeneration-linked ethanol expansion
Incentives & Land Facilitation	Subsidies, SGST reimbursement, stamp-duty waiver, clearances
Institutional Execution	Active nodal agencies - For example, New & Renewable Energy Development Corporation of Andhra Pradesh Ltd (NREDCAP), Karnataka Renewable Energy Development Ltd (KREDL), Gas Authority of India Limited (GAIL)-linked entities

Beyond these top performing states, there are other notable states with evolving non-bagasse pathways. For instance, Rajasthan's strong biomass gasification outcomes are supported by targeted Rajasthan Electricity Regulatory Commission (RERC) tariffs for decentralized units using mustard and cotton stalk, enabling the state to emerge as India's leading non-bagasse biomass performer. Punjab's paddy-straw biomass²⁰ and CBG projects²¹ converge with national stubble-management programs, whereas Haryana's SATAT-linked CBG ecosystem²² and urban bio-methanation illustrate diversified waste-to-energy models. Telangana²³ and Chhattisgarh²⁴ further demonstrate how MSW-based projects and rice-husk cogeneration can broaden sectoral participation.

Frontrunner States Leading India's Energy Transition: State-Level Performance, Policy Drivers and National Alignment

India's renewable energy transition is increasingly shaped by state-level policy design and execution. While national missions provide overall direction, states determine land access, grid integration, procurement structures, demand-side reforms and industrial linkages that translate targets into deployment. The frontrunner states discussed here anchor India's renewable capacity growth and strengthen long-term energy security through differentiated transition pathways aligned with national priorities.

Gujarat, Rajasthan, Karnataka and Tamil Nadu lead India's utility-scale renewable expansion through large renewable parks, hybridization, storage integration and advanced grid planning. Rajasthan and Gujarat emerge as the country's principal solar and hybrid generation hubs, supplying surplus clean power across regions. Karnataka and Tamil Nadu, with mature renewable ecosystems, are increasingly shifting towards higher system value through repowering, improved asset utilization and storage integration.

Maharashtra and Uttar Pradesh represent a demand-driven, decentralized transition pathway. In both states, renewable energy supports distribution reliability and stabilizes daytime demand, particularly in rural and agricultural systems. Andhra Pradesh reflects a system-oriented model centred on firm and dispatchable renewable power, with emphasis on hybrid systems, pumped storage, manufacturing and hydrogen corridors, positioning the state as a key anchor for future grid stability and industrial decarbonization.

Across all frontrunner states, electric mobility and clean industrial value chains are accelerating the transition through expanded EV manufacturing, charging infrastructure and clean fuel integration. Together, these pathways demonstrate that India's clean energy transition is driven by coordinated state-level innovation within a common national framework. **Table 5** summarizes the key policy anchors, quantified targets and energy security levers across these frontrunner states.

**Table 5: Key Policies, Targets and Energy Security Levers Across
Selected Frontrunner States (as of 2025)**

State	Anchoring State Policies	Quantified State RE Target	Verifiable Outcome / Indicator	Energy Security Lever (to be read in conjunction with technology-specific drivers)
Gujarat	Integrated Renewable Energy Policy 2025 ²⁵ ; EV Policy 2021–25 ²⁶	100 GW by 2030; Aims for 2,00,000 EVs (1,10,000 2W, 70,000 3W and 20,000 4W)	~60% installed capacity from RE; Khavda Ultra Mega RE Power Park (world's largest) under development ²⁷ ; 5 lakh+ rooftop solar systems installed (delivering 1,879 MW of installed capacity) ²⁸	Inter-state clean power exports and industrial supply; 25% subsidy on equipment and machinery, capped at ₹10 lakh per station, for the first 250 commercial charging stations
Rajasthan	Integrated Clean Energy Policy 2024 ²⁹	125 GW by 2029–30	Highest cumulative RE additions; Bhadla Solar Park 2,245 MW; 6 MNRE solar parks (5.4 GW); 76.25% of RE installed capacity	Large-scale surplus generation and inter-state exports
Karnataka	Renewable Energy Policy 2022–27; Clean Mobility Policy 2025 ³⁰ ; Mandate of battery storage for solar plants ³¹	+10 GW RE including ≥1 GW rooftop	First state to mandate storage with solar; Pavagada Solar Park 2,050 MW; highest number of public EV charging stations (5,765) ³² ; launched the country's first solar-powered EV charging station integrated with second-life battery storage ³³	Grid stability and peak management through storage
Tamil Nadu	Wind Repowering, Refurbishment and Life Extension Policy for Wind Power Projects-2024 ³⁴ PSP Policy 2024 ³⁵ ; SHP Policy 2024 ³⁶	Repowering of >20-year wind fleet; 20 GW new RE by 2030 target by TANGEDCO	11.9 GW wind installed; repowering focused on CUF improvement	High utilisation of legacy renewable assets

State	Anchoring State Policies	Quantified State RE Target	Verifiable Outcome / Indicator	Energy Security Lever (to be read in conjunction with technology-specific drivers)
Maha-rashtra	Maharashtra Unconventional Energy Generation Policy 2020 ³⁷ ; EV Policy 2025 ³⁸ ; Energy Transition and Resource Adequacy blueprint	52% RE in DISCOM portfolio by 2030 ³⁹ ; EV charging facilities at 25 km intervals along highways; mandatory charging points in government office parking areas	Feeder-level solarisation scaled statewide; energy transition plan notified	Distribution reliability via decentralised solar through Mukhyamantri Saur Krishi Vahini Yojana 2.0 (State's rendition of PM - KUSUM)
Andhra Pradesh	Integrated Clean Energy Policy 2024	~160 GW RE and PSP; net-zero by 2047	Pinnapuram IREP operational with solar, wind and PSP ⁴⁰ ; 199% growth in large hydro from 2015-25	Firm and dispatchable renewable power; grid reliability
Uttar Pradesh	Solar Energy Policy 2022 ⁴¹ ; State Bio-energy Policy 2022 ⁴² ; UP GH2 Policy 2024 ⁴³	22 GW solar by 2026–27; 1 MTPA green hydrogen by 2029	India's highest CBG output; large solar parks under development; Surya mitras	Daytime load substitution and rural reliability

Figure 6: RE Status comparison for top performing states (from 2015 - 2025)

State-by-State Overview

Detailed breakdown of Installed Capacity (MW), Growth, and Generation (MU) across 7 key states

Metric / Technology	Rajasthan	Gujarat	Maharashtra	Tamil Nadu	Karnataka	Andhra Pra.	Uttar Pra.
RE Capacity	41,763.57	41,665.14	29,368.94	26,903.6	25,837.48	14,538.52	6,674.22
Decadal Growth Absolute (MW)	35,868.64	34,493.18	19,077.32	14,967.83	16,507.01	10,637.21	3823.33
Decadal Growth Percentage (%)	608.47%	480.94%	185.37%	125.40%	176.92%	272.66%	134.11%
Solar (MW)	35,910.95	24,794.01	17,168.05	11,516.39	10,642.71	6,092.21	3,811.63
Wind (MW)	5,208.75	14,637.98	5,771.31	12,014.34	8,303.79	4,397.78	0
Small Hydro (MW)	23.85	113.3	384.28	123.05	1,284.73	164.51	50.6
Large Hydro (MW)	412.5	1,990	3,047	2,203.2	3,689.2	3,290	501.6
Bio Power (MW)	207.52	129.85	2,998.3	1,046.62	1,917.05	594.02	2310.39
RE Share % of Total Installed	75.40%	62.96%	51.61%	60.37%	70.61%	48.13%	17.28%
RE Generation 2025–26 (MU)	46,251.25	45,870.42	17,670.46	37,787.77	38,774.5	17,202.67	5,231.12

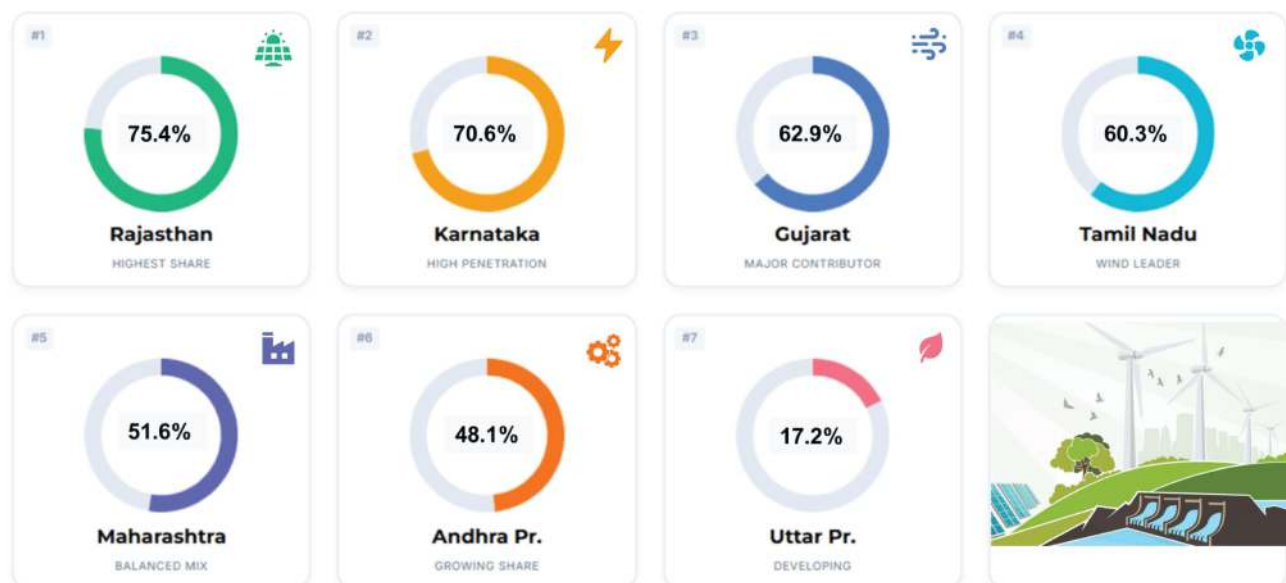
Figure 7: RE Share of Total Installed Capacity (%) - High Performing States

RE Share of Total Installed Capacity (%)

Percentage of State's total power capacity derived from renewable sources

State Average

55.7%



Conclusion:

The trajectory of India's increase in renewables installation and generation is enabled by central policies, and also anchored by state-level policy action in achieving the national climate vision and ensuring energy security. This paper demonstrates that states contribute to India's RE transition through different pathways that are aligned with their respective resource endowments and by building their respective strengths in technology and policy to advance RE deployment.

For instance, Rajasthan's solar and Gujarat's wind-solar resources are being scaled through large renewable parks and infrastructure investments. Uttar Pradesh and Maharashtra have advanced decentralized solar and biopower deployment, strengthening distribution reliability and rural energy systems. Himachal Pradesh continues to leverage river-based resources through small hydropower. Tamil Nadu combines high wind utilization with repowering policies and established automobile supply chains to consolidate its position as a leading EV manufacturing hub. Andhra Pradesh has demonstrated, through projects like Pinnapuram, how hybrid renewable-storage systems on barren land can deliver firm RTC power. Karnataka's solar-powered pilot EV charging station using second-life batteries highlights the integration of circular economy principles with clean mobility, alongside its consistently strong renewable project clearance performance.

Differences in clean energy performance across states are currently driven by the strength of policy frameworks across the value chain. There are instances or cases wherein the leading RE states are performing well in certain technologies, however, have not fully explored the potential of other RE endowments. A case in point being Rajasthan. It fares well across renewable energy sources - especially solar, due to focused interventions leading to investment in utility-scale solar parks. However, despite possessing the largest wind potential, it is Gujarat and Tamil Nadu that lead in wind installation due to targeted policy, and regulatory clarity that strengthens their rollout.

Energy security lies at the heart of the renewable energy policies of the states discussed, reflected through a balanced mix of demand-side and supply-side interventions. In areas where gaps have been identified, states have attempted to address them in a sustained manner through updating policies, regulatory reforms, and targeted notifications. The experience across states highlights that resource availability alone does not guarantee deployment outcomes. In the long run, it is state-level policy actions that leverage local resource endowments and enable the deployment of appropriate technologies that will determine India's ability to achieve its clean energy goals.

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INDIA'S FIRST MAKE-IN-INDIA GREEN HYDROGEN PLANT COMMISSIONED AT KANDLA



11

State Green Hydrogen Policies: A Comparative Analysis of Policy Frameworks Across India

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Green hydrogen is emerging as a critical pillar of India's long-term decarbonization and energy security strategy, specifically for hard-to-abate industrial and mobility sectors. While the *National Green Hydrogen Mission* (NGHM) sets the broader goals, direction and framework for implementation, the evolution of India's green hydrogen ecosystem has also been and will continue to be shaped by state-level action. Even before the NGHM was launched, the states Tamil Nadu, Madhya Pradesh and Odisha offered supportive provisions for green hydrogen through their industrial and renewable energy policies as evident from Figure 1. These policies, along with the ones notified hence, have significantly augmented the national ambition on green hydrogen.



Figure 1 States have been proactive in policy development within the green hydrogen space

Source: (Pal, et al. 2025)

The effect of a coordinated policy support, combining central incentives under the NGHMs with complementary power- and non-power-related support offered by states is visible in the record-low price discoveries for green ammonia under the competitive auctions conducted by the Solar Energy Corporation of India (SECI) under the NGHMs' Strategic Interventions for Green Hydrogen Transition (SIGHT) scheme. This outcome has strengthened the economic case for offtake and investment by bringing green ammonia closer to viability (Kothadiya and Yadav 2025).

Findings from CEEW study: A detailed look at what states are doing

A CEEW analysis estimates that existing state-level policies embed a cumulative financial potential support of approximately INR 5.05 lakh crore (~USD 61 billion) over their respective lifetimes (Pal, et al. 2025). The realization of this support will depend on market conditions and the scale of green hydrogen production achieved by each state. CEEW estimates this potential support on a baseline production capacity of 8.33 MTPA across India, factoring in the state-wise targets for green hydrogen production, which cumulatively exceed the national target. A split of the power- and non-power-related incentives across various state governments is indicated in Figure 2.

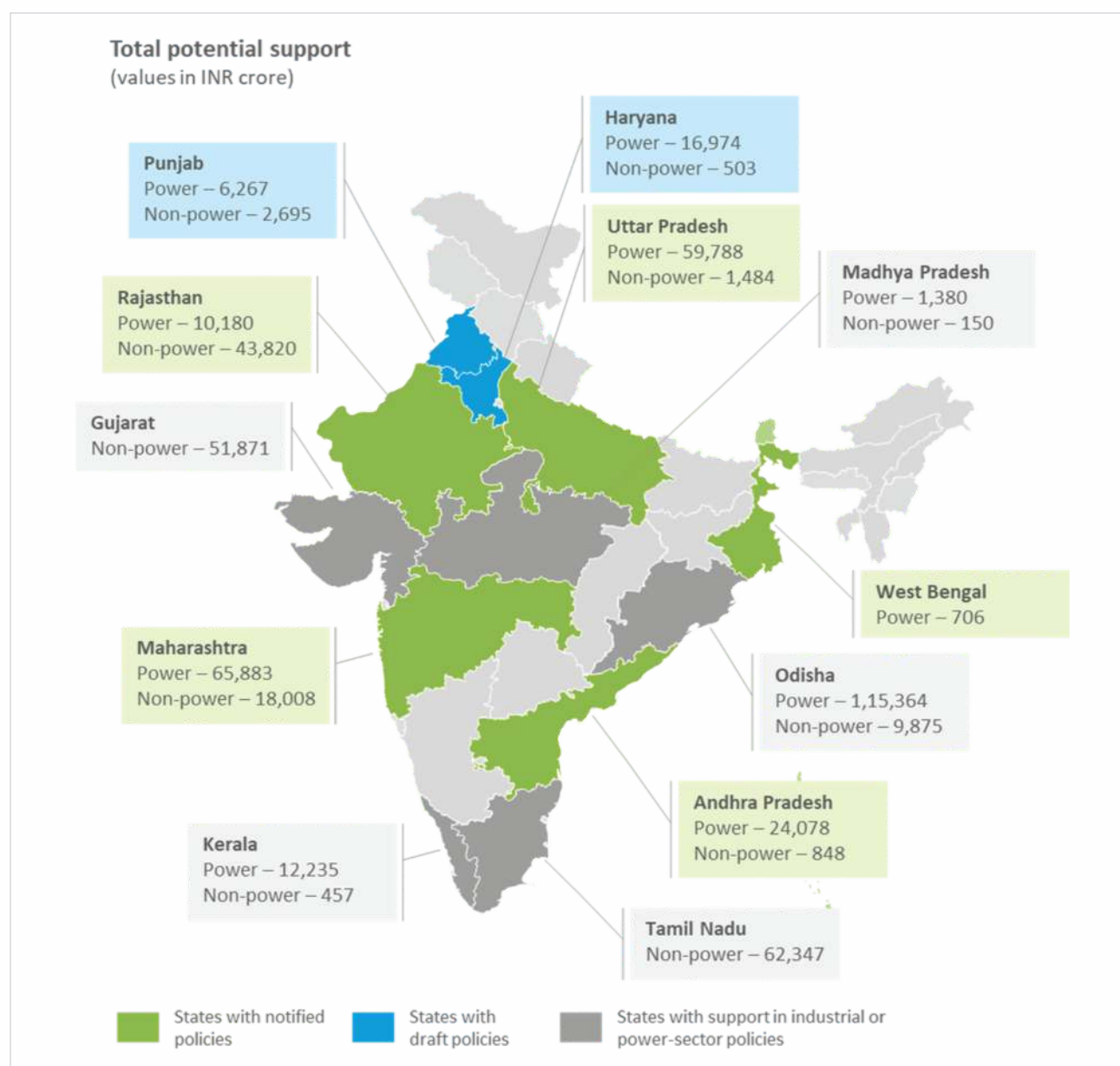


Figure 2 Seven states – Odisha, Maharashtra, Tamil Nadu, Uttar Pradesh, Rajasthan, Gujarat, and Andhra Pradesh – account for a cumulative 92 per cent of the potential support

Source: (Pal, et al. 2025)

We find that seven states—Odisha, Maharashtra, Tamil Nadu, Uttar Pradesh, Rajasthan, Gujarat, and Andhra Pradesh—could account for 92 per cent of both total potential support and projected green hydrogen capacity through 2030. Power-related incentives dominate in Odisha, Uttar Pradesh, Maharashtra, and Andhra Pradesh, while Gujarat and Tamil Nadu offer non-power provisions through their industrial policies. The policy landscape for green hydrogen is characterized by a diverse set of instruments employed by states. Table 1 provides a mapping of support components across the twelve states assessed in this study.

Table 1 Each state presents a distinct structure of support to the green hydrogen sector

Particulars	GJ	RJ	TN	UP	AP	MH	OD	HR*	KL	PB*	WB	MP
Applicable policies												
Green hydrogen policy												
Industrial policy												
RE/Power electricity policies												
Support components – power-related												
Electricity duty waiver												
Intra-state transmission charge waiver												
Wheeling charge exemption												
Power tariff rebate												
Support components – non-power-related												
Blending subsidy												
Capital subsidy												
Consumption subsidy												
Interest subvention												
Land support												
PLI top-up**												
Refuelling station subsidy												
R&D support												
SGST reimbursement												
Training support												
Vehicle subsidy												

Source: (Pal, et al. 2025)

- Note:
1. We include only the highest-outlay option where policies offer multiple forms of support options
 2. Inter-state transmission charge waiver and Electricity Rules 2005 (and its amendments), which fall under the central government's jurisdiction, is an additional component not shown in the table
 3. An asterisk (*) indicates policies still in draft stage.
 4. ** - Production Linked Incentive (PLI)
 5. Electricity Policies refers to state's integrated Renewable Energy (RE) policies, state's wind solar hybrid policy

Power-related incentives could account for over 62 per cent of the total estimated support under central and state policies, as depicted in Figure 3. This includes waivers on electricity duty, inter- and intra-state transmission charges, wheeling charges, and power tariff rebates, thus making power access and pricing the most significant enablers for green hydrogen cost competitiveness. Among non-power-related support components, capital subsidies, interest subvention, and SGST reimbursement offered by states are likely to be the most prominent. Capital subsidy accounts for the largest share of non-power related support as a few states like Odisha offer up to 30 per cent subsidy on investments in green hydrogen projects.

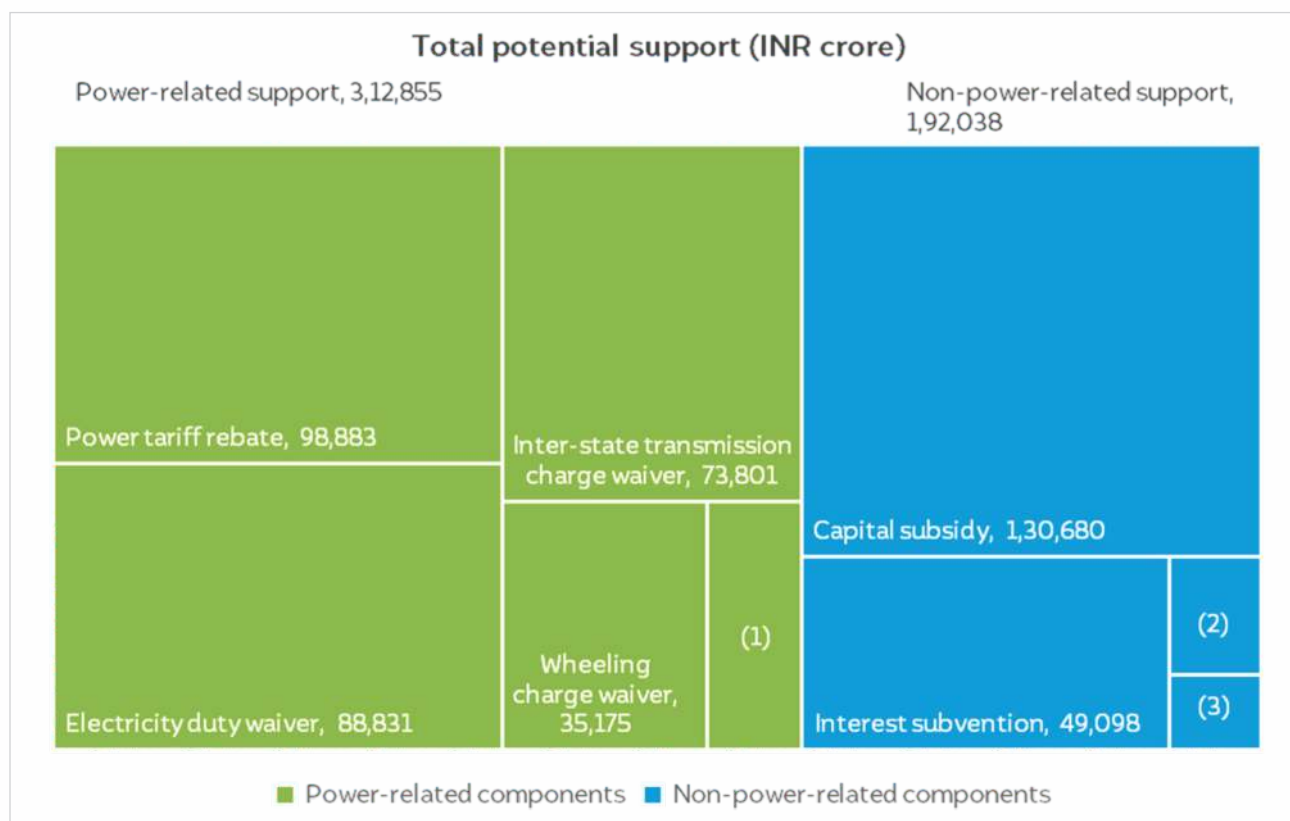


Figure 3 Power-related support components account for 62 per cent of the potential support

Source: (Pal, et al. 2025)

Note: (1) Intra-state transmission charge waiver, INR 16,164 crore
 (2) SGST Reimbursement, INR 7,469 crore
 (3) Other non-power components INR 4,791 crore

Based on their fiscal implications for states, the support components can be categorized into three groups: those involving direct budgetary expenditure, those resulting in foregone revenues, and components like Inter-State Transmission System (ISTS) waiver, which constitutes a nationally socialized cost. Figure 4 provides a bucketing of various power and non-power incentives under these three categories. We find that around 66 per cent of the total support could entail budgetary expenditure. This includes components from capital subsidies and interest subvention to waivers on grid charges and electricity duty. States could plan not just for one-time capital outlays but recurring revenue hits and infrastructure costs arising from these waivers if the green hydrogen deployment gets realized at the envisioned scale.

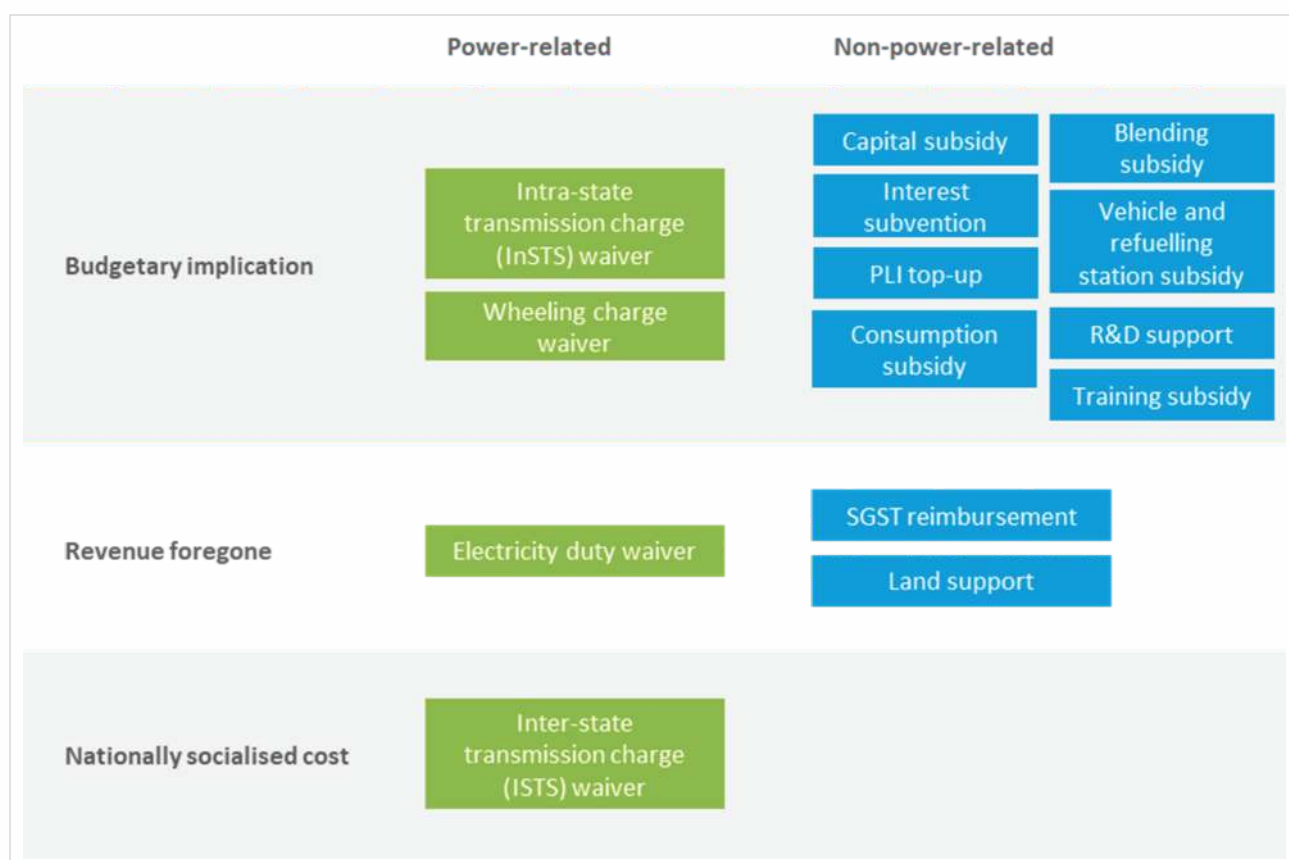


Figure 4 Most support components for green hydrogen under central- and state-level policies have a budgetary implication

Source: (Pal, et al. 2025)

Next steps: What are the open questions that need to be addressed?

First, there are two critical gaps in existing policy support. While state policies offer multiple incentives for producing green hydrogen, they lack mechanisms to promote offtake and create sustained domestic demand. In the absence of long-term demand assurance, through offtake agreements or government-mediated procurement, project bankability, commercial viability, capacity utilization, and risk–reward dynamics are adversely affected. In addition, policies provide limited support for innovation, perpetuating reliance on imported key technologies, such as membranes and catalysts (Patidar, Yadav and Mallya 2024). We find that only Uttar Pradesh explicitly incentivizes green hydrogen-related R&D among the twelve states analyzed.

Second, states will need to deal with the implications of green hydrogen on their power systems on numerous fronts. Most states are likely to see green hydrogen investments supported by renewable energy plants set under captive open access route. This shift calls for coordinated grid planning—specifically, identifying green hydrogen production hubs to guide national and state transmission planning, and recognizing electrolyzers as a flexible resource under the Central Electricity Regulatory Commission's Ancillary Services Regulations, 2022, given their potential to support grid balancing at scale (Pradhan, et al. 2024). Policymakers may revisit legacy surcharges, like the cross-subsidy surcharge and the additional surcharge, which were not designed for this new industrial load. Depending on project design, standby and balancing needs may be met either through the distribution company or through third-party service providers; in either case, any charges levied should be based on robust, cost-reflective methodologies linked to the services actually provided. In Odisha, where a power rebate through the state distribution company is offered, a deeper scrutiny of the economic, fiscal, and operational implications could be undertaken.

Third, it is important to assess how states' green hydrogen policies affect the power sector at a national level and to address associated trade-offs in a phased manner. Given India's single integrated grid, state-level efforts to attract investments may dilute the advantages of states with more favourable renewable energy profiles. A CEEW study highlights the wide inter-state differences in the potential to produce low-cost green hydrogen (Mallya, et al. 2024). Uncoordinated competition among states could therefore lead to a suboptimal national renewable energy rollout. A state with low RE quality might offer significant incentives for green hydrogen projects that might attract investments in that state but at a national level it may lead to suboptimal utilization of RE. A CEEW study finds that not utilizing the ISTS network could increase the levelized cost of hydrogen generation from USD 3.6 per kg to USD 4.1 per kg (Pradhan, et al. 2024). Therefore, stronger inter-state alignment is needed to ensure that sub-national policies reinforce national decarbonization and energy security objectives.

Lastly, the long-term sustainability of these support measures remains an open question. If the recent record-low prices of green ammonia are driven largely by incentives rather than robust techno-economic fundamentals, green hydrogen prices may rise if support tapers off beyond 2030. Policymakers may need to assess how and when state support can be phased down without undermining investor confidence or disrupting the investment outlook for green hydrogen. The industry, through innovation, needs to establish robust proof-of-concepts by 2030 in order to progress on a self-sustaining trajectory.

India's green hydrogen trajectory will depend on sustained policy coherence across states and the Centre. As early cost reductions materialize, the focus must shift towards demand creation, innovation, and power system alignment to ensure durable, efficient, and nationally aligned scale-up.

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Rooftop Solar's Next Act in India: How *PM Surya Ghar Yojana* Is Reshaping State Policy—and Why Storage Is Entering the Conversation

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1. Introduction

India's rooftop solar (RTS) market has entered a qualitatively new phase. The launch of *PM Surya Ghar: Muft Bijli Yojana* has expanded the policy lens from “adding rooftop capacity” to “scaling residential adoption at speed”—with a strong emphasis on standardized processes, a national portal, and time-bound subsidy workflows. The result is a shift in how states and distribution utilities are looking at

approvals, consumer onboarding, and, increasingly, grid management as daytime exports rise. The scheme's operational guidelines position RTS as a household-facing program with institutional support for implementation and consumer facilitation (MNRE 2024a).

At a macro level, India already had a significant grid-connected rooftop base before *PM Surya Ghar*: MNRE's official statistics report 11.87 GW of RTS installed as of 31 March 2024 (MNRE 2024b). That installed base provides the platform on which *PM Surya Ghar* is now accelerating a residential-led buildout.

2. Scale-up under *PM Surya Ghar* and where installations are concentrating

Government reporting indicates rapid build-out under the new program architecture. The *PM Surya Ghar* national portal reports 7.85 GW of rooftop solar capacity installed as of 08 January 2026. This comprises a total of 2.67 million households have installed RTS systems with an average subsidy release of Rs 56,610 per household (MNRE 2026).

A state-wise view reinforces a familiar pattern in India's power-sector transitions: a small set of states account for a disproportionate share of implementation. Gujarat, Maharashtra, Uttar Pradesh and Kerala stand out on both installed systems and capacity in the portal-linked reporting. As per the *PM Surya Ghar* portal, installed capacity is 1.96 GW in Gujarat, 1.49 GW in Maharashtra, 1.14 GW in Uttar Pradesh and 0.71 GW in Kerala; together, these states account for about 68% of total RTS installations (MNRE 2026).

A practical inference follows: as *PM Surya Ghar* pushes residential adoption, the “front-runner” states are those combining (i) consumer appetite, (ii) administrative throughput, and (iii) utility processes that minimize friction. The scheme's own operational framework is designed to drive precisely these outcomes through standardized workflows and portal-based processing (MNRE 2024a).

3. What states are changing in solar policy: reducing friction and clarifying aggregation models

A notable development over the past policy cycle is that many states are updating regulations and utility processes around:

1. Deemed acceptance / time-bound approvals,
2. Lower transaction costs, and
3. New accounting constructs such as Virtual Net Metering (VNM) and Group Net Metering (GNM)—intended to extend RTS benefits beyond a single meter.

3.1 Gujarat: deemed acceptance and compensation for avoidable delays

Gujarat's regulatory trajectory illustrates “process hardening”—codifying timelines and consequences to reduce bottlenecks. The Fourth Amendment text provides that RTS applications up to 10 kW that are complete “shall be deemed to have been accepted” without requiring technical feasibility study, with associated consumer load-related actions to be undertaken by the distribution licensee. It also introduces a compensation principle for unjustified delay—not less than INR 500 per day for each day of default (GERC 2024).

This kind of provision matters because residential programs typically fail not on technology but on transaction costs: repeated site visits, unclear timelines, and “back-and-forth” documentation. Deemed acceptance coupled with a compensation backstop is a direct attempt to realign incentives toward speed and certainty.

3.2 Maharashtra: VNM for apartments and a 5,000 MW-linked incentive to accelerate uptake

Maharashtra's latest notified update to its rooftop framework moves beyond the “single-premises prosumer” model by formally enabling Virtual Net Metering (VNM) for residential consumers in multi-storied buildings / housing societies, and by introducing a governance construct—the “Lead Person”—to coordinate all correspondence and agreement execution on behalf of participating consumers. The amendment also explicitly recognizes a society-level grid-connected micro-grid encompassing renewable energy systems with or without storage, for serving multiple consumers and/or optimizing emergency use of diesel generation (MERC 2024a) (MERC 2024b).

Critically, the amendment embeds a threshold-based promotional incentive: applicability of Open Access charges and losses for sourcing electricity from the VNM arrangement is exempted until Maharashtra's rooftop solar installed capacity reaches 5,000 MW. The Commission further clarifies that for agreements executed before the state reaches the 5,000 MW threshold, the exemption (as incorporated in the agreement) continues for the validity period of the agreement.

3.3 Rajasthan: formal definitions for VNM and GNM, including Battery Energy Storage System-linked exports

Rajasthan's Third Amendment Regulations explicitly add definitions for VNM and GNM. VNM is defined as an arrangement where exported energy from a single location is adjusted across more than one electricity service connection of participating consumers within the same distribution licensee area. GNM is defined as adjustment of surplus energy across more than one service connection of the same consumer. Importantly, both definitions explicitly recognize exports from (i) a renewable energy system and (ii) a Battery Energy Storage System (BESS) charged through a renewable energy system (RERC 2025).

This is consequential: it mainstreams the idea that “distributed renewable energy + storage” can be treated as a portfolio resource whose benefits can be allocated across multiple connections—expanding the economic logic for storage beyond a single prosumer's meter.

3.4 Kerala: introducing a phased storage requirement via hybrid inverters

Kerala's regulations provide one of the clearest examples of a policy system anticipating the next constraint: *daytime surplus exports versus evening peaks*. For domestic consumers, the regulation sets capacity-wise storage requirements through hybrid inverters:

- Above 10 kW up to 15 kW: minimum storage of 10% of energy generation potential;
- Above 15 kW up to 20 kW: minimum storage of 20%; and
- From 01.04.2027, for plants above 5 kW up to 10 kW: minimum storage of 10%.

Two implementation-oriented details are also notable. The regulations align payment of certain charges for applicants using the National Portal by allowing applicable charges to be collected through bills raised after energization for solar plants up to 10 kW (KSERC 2025).

This is consistent with the broader objective of reducing front-loaded friction for residential consumers.

At the same time, it is important to note that Kerala's storage-linked provisions have been under legal review, with Kerala High Court staying the operation of the KSERC regulations that mandate storage for rooftop solar users (Poswal 2025). Even as litigation evolves, the regulatory intent is clear: storage is being positioned as a tool to preserve the viability of net metering as penetration rises.

4. Why storage is entering rooftop policy: the net metering “evening peak” problem

As rooftop penetration expands, a predictable system dynamic emerges:

1. Midday: high rooftop exports coincide with lower residential demand;
2. Evening: solar generation falls while demand rises;
3. Under net metering, prosumers can offset evening imports with daytime exports, but the distribution utility still has to procure or schedule energy for the evening peak, often at higher marginal cost.

In other words, the “household bill” may look neutral, but the “system cost” can rise as penetration increases—especially in high-load-factor urban networks where evening peaks drive capacity procurement and reliability management.

This is the structural context in which “Behind-the-Meter (BTM) storage” requirements become intelligible. Kerala's phased storage approach is effectively an attempt to retain consumer-facing net metering benefits while partially internalizing system costs through local flexibility (KSERC 2025).

Rajasthan's explicit inclusion of BESS in VNM/GNM definitions suggests a parallel approach: enable storage so exported renewable energy can be shaped and allocated across multiple connections (RERC 2025).

5. Delhi's complementary pathway: “storage near the demand centre” via distribution-level BESS

While BTM storage targets flexibility at the prosumer edge, a different pathway is gaining relevance: distribution-level utility-scale BESS located inside the load pocket.

A prominent example is BSES Rajdhani Power Limited's (BRPL) 20 MW / 40 MWh BESS at the 33/11 kV Kilokari substation, for which the utility sought regulatory approval of a capacity-charge framework and the associated project agreement (DERC 2024).

The same filing contextualizes why a Discom-led BESS is increasingly viewed as a grid resource, referencing national developments such as energy storage obligations, the grid code's allocation of responsibilities for managing reserves including energy storage, and CEA's National Electricity Plan modelling of BESS requirements (DERC 2024).

From a tariff innovation perspective, the Kilokari case is notable. BRPL's prayer includes adoption of a single-part capacity charge with an annual fixed cost of Rs 57,59,610 per MW per year, billed monthly (DERC 2024).

This is the kind of “distribution-asset-like” tariff framing that can make BESS bankable while keeping procurement and dispatch aligned with distribution network needs.

The substantive value proposition is not only peak shifting. The filing articulates the broader system services role of BESS—supporting renewable integration by enabling generation shifting, dispatch regulation, transmission flow control, and overall reliability without adding conventional generation capacity (DERC 2024).

6. Behind-the-meter vs. utility-scale BESS: a policy and system planning comparison

Both approaches—BTM storage (embedded with rooftop) and distribution-level standalone BESS—have defensible rationales. The practical policy question is: which tool should be emphasized at which penetration level, and who should bear the cost?

6.1 Behind-the-meter storage: advantages and constraints

Advantages

- Can reduce local reverse power flows and improve voltage management at the feeder/DT level.
- Helps align prosumer exports with evening consumption, protecting utility peak procurement economics.
- When coupled with net metering, can preserve consumer bill benefits while improving system value.

Constraints

- Higher unit costs and consumer financing barriers; hybrid inverters and batteries add cap-ex.
- Equity concerns: mandates can disproportionately burden households with limited ability to pay
- Operational coordination is harder: thousands of small batteries are more complex to orchestrate unless aggregated and digitally managed.

6.2 Distribution-level BESS: advantages and constraints

Advantages

- Sited and sized based on utility knowledge of load shapes, congestion points, and reliability requirements—a key reason why “storage near demand centres” is strategically attractive.
- Benefits are socializable across consumers because system services (peak shaving, reliability) accrue at network level.
- Enables a more professionalized procurement and dispatch model, with performance monitoring and contractual enforceability.

Constraints

- Requires regulatory comfort with new tariff forms (capacity charges, availability norms, degradation considerations).
- Must be integrated into planning (resource adequacy, Long Term-Distribution Resource Adequacy Plan (LT-DRAP), and distribution network reinforcement).

The Delhi experience suggests an emerging template: treat BESS as a distribution resource, procure competitively, and recover costs through a regulated capacity-charge framework.

7. Implications for the next policy cycle

Three policy implications stand out:

1. **Process reform is not optional:** Gujarat's "deemed acceptance" and delay compensation logic signals a hardening of accountability for residential adoption at scale (GERC 2024).
2. **Aggregation models will matter:** Rajasthan's VNM/GNM definitions—explicitly accommodating BESS—create legal scaffolding for new business models (e.g., RESCO-led shared assets; community solar; storage-backed portfolios) (RERC 2025).
3. **Storage will become a design variable:** Kerala has already embedded storage requirements into domestic segment regulations with a phased timeline; Delhi is testing a distribution-level procurement and tariff model (KSERC 2025) (DERC 2024).

A reasonable "sequencing" approach for many states may therefore be:

- **Stage 1:** maximize residential RTS uptake via streamlined approvals, portal integration, and reduced up-front friction;
- **Stage 2:** deploy distribution-level BESS in identified load pockets and congestion nodes;
- **Stage 3:** consider targeted BTM storage requirements only where network constraints and penetration levels justify it (and where financing mechanisms exist).

8. Conclusion

PM Surya Ghar has brought rooftop solar back to the centre of India's energy transition—but with a crucial difference: the transition is now residential-led and process-intensive. National reporting shows substantial installations and capacity additions under the scheme within a short period. States are responding by tightening timelines, lowering transaction barriers, and clarifying multi-connection accounting constructs like VNM and GNM.

As penetration rises, storage is no longer a peripheral add-on; it becomes a system design lever. Kerala's phased hybrid-inverter storage provisions and Delhi's distribution-level BESS tariff experiment together map the boundaries of the next debate: *how to preserve consumer value while maintaining distribution utility viability in a high-rooftop future.*

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Bio- CNG and organic fertilizer plant at Vav- Tharad,Gujarat

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Assessing State Energy Policies for Advancing India's Energy Security – Policy Perspective

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Introduction

In today's scenario, India's energy security management has become one of the issue in field of attaining rapidly growing energy demand. India is completely dependent on imported fuels and non-renewables. As one of the world's largest and fastest growing energy consumers, India should ensure that the energy system remains adequate, reliable, affordable and in reach of all individual. This should also align with long-term sustainability and climate objectives fulfillment. Energy security today extends beyond mere availability of resources to include system reliability, financial viability, infrastructure resilience and environmental compatibility are the key points to ponder.

While Central-State policies and missions together align strategic regulations, India's energy system depends significantly on state-level policy design and implementations. Indian states exercise substantial authority over electricity generation and distribution, renewable energy deployment, etc. which serve as the operational foundation of India's national energy strategy.

State Policies and Action towards National Energy Security

State governments are trying their very best to support national energy security and aiming to achieve the objectives for national progress. However, there are three hurdles in this field, i.e.

1. Exploration & Production (E&P)
2. Universal Accessibility and Affordability
3. Transition to Renewable Energy

Exploration and production along with achieving sustainability, easy accessibility and affordability, have accounted for mixed support at all levels. They are often constrained by administrative bottlenecks such as delayed land acquisition, prolonged regulatory approvals and institutional capacity limitations.

India should plan to achieve a balanced and resilient energy future. For this, state governments must reduce administrative delays, strengthen regulatory coordination and should demonstrate greater political resolution programs in supporting central government initiatives. energy security outcomes.

Energy Security Trilemma in India

In the Indian scenario, energy security encompasses supply adequacy, reliability of service, affordability for consumers, etc., which aligns with climate and sustainability goals. States play the major role in all these areas as they are the building block of operational decisions such as power procurement, tariff setting, management of utilities and implementation of efficient programs.

Even fully equipped and properly crafted schemes fall when there is weak policy or state governance, On the other hand, stable policies enhance the effectiveness of national initiatives. It can be concluded that the success of India's energy framework depends on how effectively states formulates the objectives into grass root level in the best efficient possible way.

Diversification of Energy Sources

India has various diversification in the field of energy sources, and the states have made notable progress in this area. Many Indian states have started decentralizing schemes like rooftop solar, biomass-based power, biogas plants, solar irrigation systems etc. which fully aligns with the scheme of growth. These routes help to meet local demand, control transmission losses and promote resource utilization in rural and remote areas, i.e. formula of Vasudhaiv Kutumbhakam.

By diversifying sources and using all available centralized energy systems, states can formulate an idea of less dependence on imported fuel, and this will limit exposure to global price fluctuations also. This pillar will strengthen long durability and whole nation also.

Exploration and Production (E&P)

While the Central Government formulates E&P policy, state governments play a crucial facilitative role

through administrative clearances, regulatory coordination, and local compliance. Proactive states can significantly shorten the cycle time from discovery to production by addressing bottlenecks in approvals and land access.

Reassessment of India's sedimentary basins completed in 2017 estimated prognosticated hydrocarbon resources of (41.87 billion tons of oil equivalent) across 26 basins. Notably, nearly half of these basins remain under-explored, highlighting untapped domestic potential.

Key indicators of effective state support include:

- Timely Petroleum Exploration License (PEL) approvals
- Expedited environmental and forest clearances
- Functioning state-level coordination committees to resolve operational issues

State performance is ultimately reflected in how quickly E&P operators can commence ground-level operations.

Crude Oil and Natural Gas

India's crude oil production has declined from a peak of 38.1 million tons to 29.4 million tons (According to the report of year 2011-12). The above decline was largely due to aging off fields and delayed development of new assets. Streamlining state-level approvals is now essential or to be precise is an act of necessity for reversing the above trend.

Natural gas expansion is even more dependent on state cooperation because of extensive infrastructure requirements like pipelines, City Gas Distribution (CGD) networks, LNG terminals and so on. Domestic gas output has increased by 28% between Financial Year 2021 and 2024 (till 2025), which mentions the importance of supportive state action in achieving the national target and to satisfy human wants.

Accessible and Affordable Energy

Under India's concurrent legislative framework, (the Centre's policy direction) completely depends on state-level efficiency. The Saubhagya scheme's achievement of universal household electrification in 2019 marked itself a major milestone. Going forward, states must prioritize supply reliability, financial sustainability of DISCOMs and consumer service quality (efficiency + availability) through smart grids, tariff rationalization, loss reduction, transparent subsidies, and demand-side management.

Transition to Renewable Energy

India has now ranked amongst the top 133 GW (Source- Renewable Energy deployment report, November 2025). State planning, renewable energy utilization schemes all cooperatively tailored India in achieving this goal. However, this is just a steppingstone towards our future progress. Various challenges like grid integration cost management, lack of cheaper energy growth constraint, issues of land acquisition and improper implementation of the State policies stop the growth. To overcome these issues, initiatives such as PM-Surya Ghar, PM-KUSUM, PLI schemes etc. brings a platform, from which India can aim to strengthen state capacity and accelerate energy transition planning.

State Energy Policy Action - Electricity Distribution and Financial Viability

The financial and operational health of state-owned electricity distribution companies (DISCOMs) are one of the biggest challenge for Indian state policy makers. Heavy commercial losses, subsidy issues, week schemes all collectively harass the state energy policies and hamper loss. Financially loaded DISCOM used to struggle a lot for their infrastructure, and they are completely tied up dependent on renewable energy which is the biggest issue.

State are looking at a lot of ideas as well as various techniques like smart meter, restructuring basics and infrastructure compliance to implement better way and policy for solving those issues and attaining the financial performance and providing adequate quality according to the need. This is very important and necessary in order to accommodate affordable electricity, improve investor confidence, and support the broader energy transition.

Key Policy Challenges

There is progress in this field, but we are deprived due to various challenges and lack of effective government energy policy. There are frequent policy changes and inadequate regulations of those plans and scheme at ground state level, which is the sore throat of Indian Energy scheme.

Limitations in institutional capacity within state departments and regulatory commissions affect planning and enforcement too. Financial issues arising from subsidy delays and limited budgetary even complicate this further too. Additionally, the coordination gap between states and central agencies weakens policy and implementation.

India is now completely dependent on the state and the union policy makers and the government strategy makers. The framework of this is dependent on the implementation of those plans and schemes. Strengthening cooperative structural plans between state and the union offers the platform which can give base for better policy making, like a torch bearer. Several schemes like structured consultations, transparent data sharing, and improving policy framework along with the R&D of academic and research institutions can support this process too, via providing evaluation of their research analysis in order to support state government policy makers.

Conclusion

A brief review of state-wise energy sector performance and policies shows that Indian states have supported the Central Government's energy security goals to varying degrees. Many are proactive partners in the renewable energy transition, but critical gaps remain in utilities' financial health and oil/gas exploration. State support for major areas can be summarized in these two heads-

Exploration and Production

State support for E&P activities is mixed. Some resource-rich states support, but land acquisition and environmental clearances often delay the process. States could streamline regulatory approvals and mitigate local opposition to green field energy projects to unlock new basins' potential, accelerate development of oil and gas infrastructure and boost energy security.

Accessibility, affordability

States have supported energy access initiatives, with significant progress in household electrification. However, state-owned distribution companies' financial health, often due to tariff issues and subsidies, affects long-term affordability and reliability.

Lastly, it can be concluded that renewable energy is increasing rapidly towards future growth management, but state should support all major things too, in order for gaining optimum growth. The above assessment indicates the issues of national energy security and how India is tackling to overcome these problems and attain all the milestone. Various strategy including renewable energy deployment, strong policies and its real-time monitoring etc. all together helping to obtain a balance, reliable future option which is equipped with ideas of sustainable and clear-greener transition of Indian Energy scenario.



Renewable Energy Museum, 'Solar Dome'- India's first museum dedicated to sustainable energy, located in Kolkata, West Bengal



Dahej LNG Terminal- India's largest Liquefied Natural Gas (LNG) receiving and regasification terminal, located in the Bharuch district of Gujarat

Assessing State Energy Policies for Advancing India's Energy Security

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It is increasingly evident that a monolithic, centralized energy policy cannot address the granular complexities of the Indian subcontinent. A policy framework optimized for the solar-rich, arid geography of Rajasthan is functionally irrelevant for the land-constrained, coal-dependent economy of West Bengal, just as the hydropower-centric strategy required for Arunachal Pradesh bears little resemblance to the wind-repowering challenges faced by Tamil Nadu. Energy security, therefore, is no

longer solely about securing oil contracts in West Asia; it is about ensuring the financial liquidity of a state-owned Distribution Company (DISCOM) in Jaipur, managing the grid frequency in Bengaluru when wind generation drops, and navigating the socio-economic transition of coal mining communities in Jharkhand.

By conducting a rigorous analysis of region-wise energy mixes and critically assessing specific state policies, the following sections demonstrate that the "one size fits all" approach is an impediment to progress. Instead, security lies in empowering states to leverage their unique resource endowments while harmonizing regulatory mechanisms to create a unified, liquid, and resilient national energy market.

1. The Fallacy of Homogeneity: Limitations of Centralized Energy Planning

The central government's approach to energy transition has largely been driven by uniform targets, such as the Renewable Purchase Obligations (RPO), which mandate that all obligated entities across the country procure a minimum percentage of their consumption from renewable sources. While administratively convenient, this uniform application ignores the stark variance in the "Capacity to Pay" and "Capacity to Generate" across different states.

Centralized planning presumes a baseline homogeneity in infrastructure and resource availability that simply does not exist on the ground. The geological distribution of renewable energy potential is highly skewed. The National Institute of Wind Energy (NIWE) data indicates that wind potential is concentrated in just seven states, primarily in the Western and Southern regions. Similarly, solar irradiance is highest in the Northern and Western deserts, while the Eastern region faces lower irradiation levels and severe land constraints due to high population density and agricultural intensity.

When a uniform RPO is imposed on a state in the east, which lack significant local renewable potential, the local distribution utilities are forced to purchase Renewable Energy Certificates (RECs) or import power from renewable-rich states. This creates an additional financial burden on DISCOMs that are often already in financial distress. The cost of transmission, the Inter-State Transmission System (ISTS) charges (even if waived, the technical cost exists), and the market premium for green power act as a regressive tax on states that are historically dependent on cheaper pithead coal power. The Centre's ambition for a 500 GW target assumes that the grid can seamlessly transfer power from surplus zones to deficit zones. While the Green Energy Corridor (GEC) projects aim to facilitate this, the physical infrastructure often lags behind the policy mandates, leading to bottlenecks that result in the balkanization of energy markets rather than their integration.

The single most critical variable in India's energy security equation is the financial health of the State Distribution Utilities. The central government may sign treaties and announce targets, but the Power Purchase Agreements (PPAs) are signed by state DISCOMs. If these entities are insolvent, the entire value chain collapses. The Reserve Bank of India and Power Finance Corporation (PFC) reports consistently highlight the precarious financial position of DISCOMs, particularly in states like Tamil Nadu, Rajasthan, and Uttar Pradesh, which carry massive accumulated losses and outstanding dues to generators.

The "Panchamrit" goals rely on private capital investment. Investors require payment security. When states attempt to renegotiate signed PPAs or when a DISCOM delays payments for months, the risk

premium for the entire sector rises. Central schemes like UDAY (Ujwal DISCOM Assurance Yojana) and the more recent Revamped Distribution Sector Scheme (RDSS) have attempted to instill financial discipline through conditional transfers and reform-linked borrowing limits. Yet, the fundamental political economy of state-level electricity, where tariffs for agriculture are often subsidized by industrial consumers or direct state subvention, remains a stubborn obstacle. A centralized policy that demands rapid RE adoption without addressing the underlying state-level subsidy architecture risks exacerbating the financial fragility of the distribution sector, thereby threatening energy security rather than enhancing it.

A centralized push for decarbonization also fails to account for the asymmetric socio-economic impact of moving away from fossil fuels. For the Eastern states of Jharkhand, Odisha, and West Bengal, the coal ecosystem is not just a source of energy but a primary driver of employment, state revenue (through royalties and District Mineral Foundation funds), and railway freight earnings. A rapid, centrally mandated shift to renewables threatens the fiscal stability of these states. Unlike the Western states, which see the energy transition as an industrial opportunity (manufacturing solar panels and batteries), the Eastern states view it as a potential economic shock. A "one size fits all" policy that does not incorporate a funded "Just Transition" mechanism will face inevitable political resistance from these coal-bearing states, creating a fractured national energy policy landscape.

2. Region-Wise Energy Mix Analysis: A Granular Assessment

To understand the true state of India's energy security, one must move beyond national aggregates and dissect the energy mix of the five regional power grids. The data reveals distinct regional identities, each with its own set of security challenges and opportunities.

2.1 Northern Region: The Solar-Hydro Hybrid

The Northern Region, encompassing states such as Rajasthan, Punjab, Uttar Pradesh, Himachal Pradesh, and Uttarakhand, represents a complex interplay between the arid plains and the Himalayan ranges. As of late 2025, the region's installed capacity reflects a strategic pivot toward solar energy, anchored by Rajasthan, while relying on the hydro resources of the Himalayan states for grid balancing.

Rajasthan has emerged as the definitive leader in India's solar revolution, contributing a massive share to the national renewable capacity. The state's geography allows for the development of ultra-mega solar parks, such as Bhadla, which benefit from economies of scale that are impossible to replicate in other regions. This heavy reliance on solar, implies a generation profile that is strictly diurnal. The Northern grid faces a steep ramping requirement in the evening hours when solar generation collapses but demand (driven by lighting and air conditioning in summer, or heating in winter) remains high.

The presence of significant hydro capacity (over 21 GW) in the region provides a natural battery. Theoretically, the Northern grid is well-positioned to manage solar intermittency by ramping hydro generation up and down. The reality is more complex due to the seasonal nature of river flows and the priority often given to irrigation over power generation. Furthermore, the slow pace of hydro capacity addition compared to the exponential growth of solar has created a widening gap in flexibility reserves.

The primary security risk for the Northern Region is transmission congestion. The concentration of generation in the western part of the region (Rajasthan) and the concentration of load in the central and

northern parts (Delhi, NCR, UP) necessitates a massive throughput capacity. Delays in the Green Energy Corridor Phase-II have led to instances of solar curtailment, where available clean energy is wasted because the grid cannot evacuate it. Additionally, the region is heavily dependent on coal imports from the East to feed its thermal plants during the non-solar hours, creating a logistical vulnerability in the railway network.

2.2 Western Region: Industrial Load and Green Transition

The Western Region (Gujarat, Maharashtra, Madhya Pradesh, Chhattisgarh) is the industrial heartland of India, characterized by the highest electricity demand and the largest installed thermal capacity (over 84,000 MW).

Unlike the North, where demand is heavily influenced by residential and agricultural load, the West has a high baseload demand from heavy industries (steel, petrochemicals, textiles). This necessitates a high degree of reliability. Consequently, the region has maintained a robust thermal fleet while aggressively adding renewables. Gujarat and Maharashtra have pioneered the "Wind-Solar Hybrid" policy, aiming to optimize the utilization of transmission infrastructure. By co-locating wind and solar assets, these states achieve a higher Plant Load Factor (PLF) for the evacuation lines, effectively lowering the delivered cost of energy.

The region leads in installed capacity, with Gujarat and Maharashtra accounting for a significant portion of the national RE total. The availability of a long coastline facilitates wind energy, which complements solar generation. The Western Region is also the epicenter of India's emerging Green Hydrogen ecosystem, with states leveraging their port infrastructure to plan for export-oriented green ammonia production.

Energy security in the West is defined by *reliability* and *cost-competitiveness*. The industrial base is sensitive to power tariffs. The challenge lies in the financial health of the DISCOMs, particularly in Maharashtra (MSEDCL), which struggles with high arrears. While the generation capacity exists, the financial bottleneck prevents the seamless signing of new PPAs. Furthermore, the region faces the challenge of managing the "Duck Curve" where high solar penetration during the day hollows out net load, forcing thermal plants to cycle down to technical minimums, stressing the coal fleet and increasing wear and tear.

2.3 Southern Region: The Intermittency Testbed

The Southern Region (Tamil Nadu, Karnataka, Andhra Pradesh, Telangana, Kerala) offers the most advanced case study of high-renewable penetration in the developing world. With renewable energy contributing over 33% of the installed capacity, the South is effectively a laboratory for the grid management challenges that the rest of India will face in the coming decade.

Tamil Nadu, having been a pioneer in wind energy since the 1990s, now faces the issue of an aging fleet. Thousands of prime wind sites are occupied by low-capacity (250 kW - 500 kW) turbines that are inefficient by modern standards. The state's wind generation is highly seasonal, peaking during the monsoon months (May to September), which creates a massive surplus that the grid often struggles to absorb.

The Southern Region experiences the highest rates of renewable energy curtailment in the country. Grid congestion, combined with the inflexibility of the thermal fleet (which cannot ramp down quickly enough), forces State Load Despatch Centres (SLDCs) to order wind and solar farms to back down. This curtailment undermines the economic viability of RE projects and deters future investment. The region is structurally a net exporter of renewables during the monsoon but becomes dependent on coal imports during the rest of the year.

Security in the South is synonymous with *flexibility*. The region urgently requires energy storage solutions. Karnataka has taken the lead in promoting Pumped Storage Projects (PSP) and exploring battery storage markets to shift its mid-day solar surplus to the evening peak. Without a rapid deployment of storage and a resolution to the interstate transmission bottlenecks preventing export to the North, the South's renewable advantage risks becoming a financial liability.

2.4 Eastern Region: The Coal Conundrum

The Eastern Region (Odisha, West Bengal, Bihar, Jharkhand) presents a stark contrast to the West and South. It sits atop India's vast coal reserves, making thermal power structurally cheaper here than anywhere else.

The region's energy mix is overwhelmingly dominated by coal-fired generation (over 40,000 MW thermal capacity vs. negligible RE). The abundance of pithead coal plants means that the marginal cost of generation is low. Consequently, there has been little economic incentive for states to aggressively pursue renewables, which would require expensive imports or less efficient local generation.

The Eastern Region accounts for less than 4% of India's total renewable capacity. Physical constraints such as lower solar irradiance and a lack of high-wind sites further hamper RE deployment.

For the East, energy security is viewed primarily through the lens of *affordability* and *social stability*. High RPO targets mandated by the Centre can hamper the region's development. The transition away from coal poses an existential threat to the state economies that depend on mining revenues. Energy security here requires a nuanced policy that allows for a slower transition, supported by central funds for diversification, rather than a forced march to renewables that could destabilize the regional economy.

2.5 North-Eastern Region: The Stranded Battery

The North-Eastern Region (Arunachal Pradesh, Assam, Meghalaya, etc.) holds the key to India's long-term grid stability but remains the least integrated.

Arunachal Pradesh alone possesses an estimated 58,000 MW of hydropower potential, earning it the moniker of India's "future powerhouse". This large hydro capacity is essential for providing the baseload-like green power needed to balance the intermittency of the North's solar and the South's wind.

Despite the potential, the installed hydro capacity remains low (approx. 2,000 MW). The region is plagued by difficult terrain, geological risks (seismicity), and a severe lack of evacuation infrastructure. The "Chicken's Neck" corridor severely limits the transmission capacity available to transport power from the North-East to the rest of India.

The development of the North-East is a geopolitical imperative as much as an energy one. China's upstream activities on the Brahmaputra necessitate India's establishment of user rights through project

development. The security challenge here is logistical and financial, building the massive transmission highways required to unlock this "hydro battery" requires central investment far beyond the capacity of the state governments.

3. Conclusion

The trajectory of India's energy security is no longer linear. It is a complex, multi-dimensional puzzle that cannot be solved by central fiat alone. The details presented in this report confirms that a "one size fits all" policy is analytically flawed in a country of such stark regional diversity.

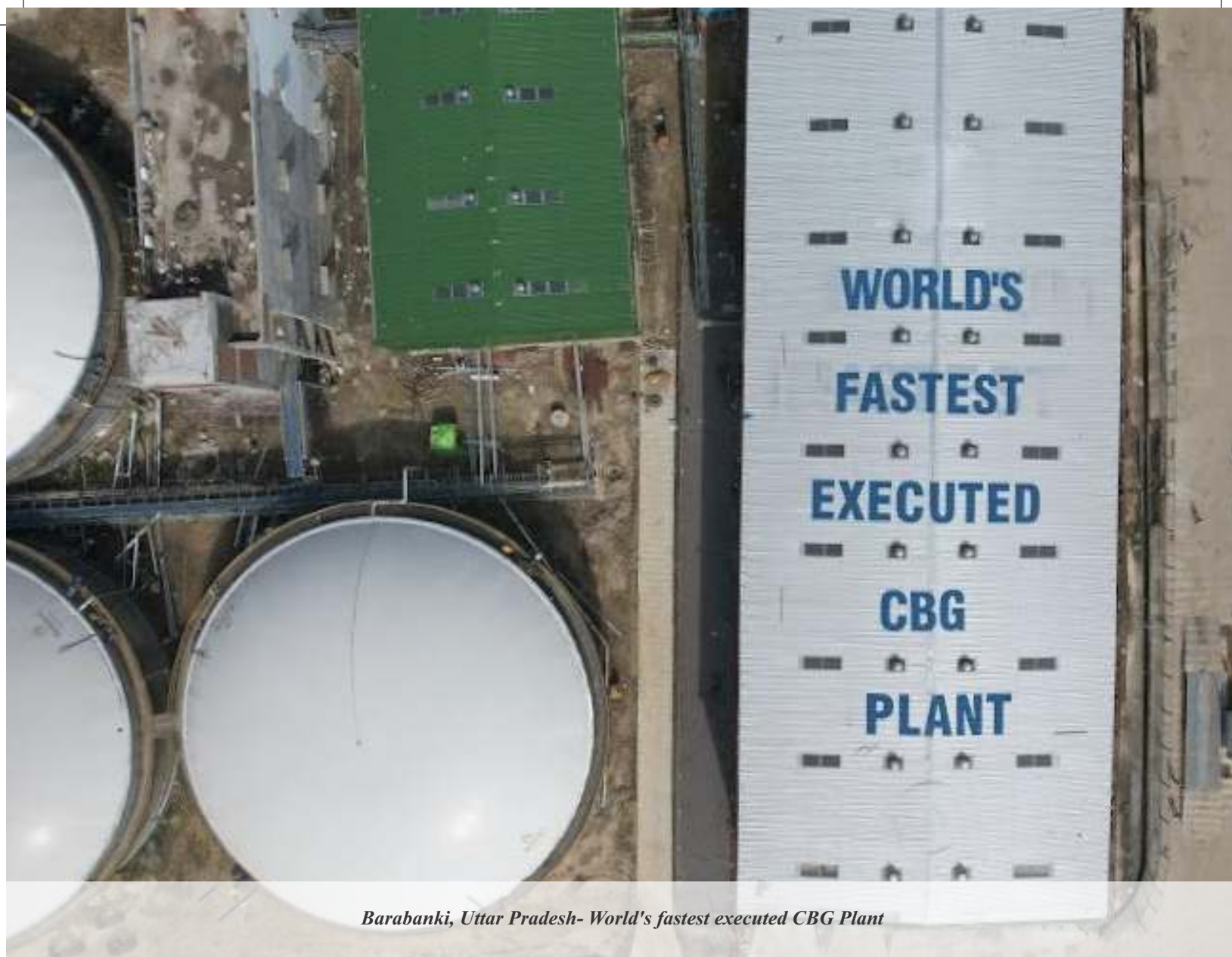
True energy security lies in embracing these differences. It requires a "Constructive Federalism" where the Centre provides the enabling framework, the transmission backbone, the financial liquidity rules, and the technical standards, while the States are empowered to design the implementation strategies that fit their unique political economies and resource endowments.

- **Northern Region:** Security lies in solving the transmission bottlenecks to unlock the Thar solar capacity.
- **Western Region:** Security lies in industrial decarbonization and grid reliability.
- **Southern Region:** Security lies in grid flexibility and the rapid deployment of storage.
- **Eastern Region:** Security lies in a financed, managed Just Transition that protects livelihoods while greening the grid.
- **North-Eastern Region:** Security lies in infrastructure investment to integrate its hydro reserves.

As India marches toward 2047, the measure of its energy independence will not just be the gigawatts installed, but the resilience of the federal compact that underpins them. The diverse state policies analyzed herein are not signs of fragmentation, but of a maturing democracy finding local solutions to a global challenge. Harnessing this diversity is the only viable path to a Net Zero India.



Raniganj CBM (Coal Bed Methane) Facility in Burdawan district of West Bengal



Barabanki, Uttar Pradesh- World's fastest executed CBG Plant

15

Compressed Biogas: An indigenous solution to India's rising clean fuel demand

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Abstract

India's natural gas market has been rapidly expanding. Renewed thrust on green and clean fuel has been well supported by increased focus on natural gas as a bridge fuel. The government has been continuously pushing for greater integration of natural gas infrastructure into the energy ecosystem. The sectoral regulator constantly strives to bring in regulations and regulatory reforms to expand natural gas penetration in the country. Consequent to these efforts, pan-India city or local natural gas networks are making fast progress. Further, to reduce import dependency and enhance domestic supply, enormous

efforts are made at multiple levels. Compressed biogas (CBG) emerges as one of the solutions to improve domestic supply and reduce natural gas import. It is pertinent to mention that integration of CBG into the existing natural gas ecosystem faces challenges across the CBG value chain that includes production, distribution and consumption. Further, financing the CBG value chain remains a bigger challenge than anticipated. Government has been taking necessary steps to mitigate challenges faced by the key stakeholders. By 2030, CBG would be reducing India's natural gas import and support energy security.

Introduction

India's conscious push for clean energy and sustainable transition depends on broad energy basket with increasing role of domestic energy production. Over dependence on fossil fuel import enforces the government to think about energy policies and strategies. Prime Minister Modi called for 10 % reduction in crude oil import and increase in domestic renewable energy production. India continues to examine the all possible renewable sources to meet rising domestic requirements. In the pursuit of new and renewable sources, multiple complementary alternative energy solutions emerge. Biofuel comes to the forefront of sustainable clean fuel that makes economic sense for the end users. India continues to expand its natural gas market. Natural gas consumption reached 72 billion cubic meter (BCM), out of which 37.7 BCM imported as liquefied natural gas, about 52% import dependency.

As per the Petroleum and Natural Gas Regulatory Board (PNGRB), under 'Good-to-Go' India's natural gas demand is expected to grow approximately at 8 percent to 297 million standard cubic meter per day (mmscmd) by 2030. Under the same scenario, total natural gas demand is projected to rise to 495 mmscmd by 2040. The rising natural gas demand has been fully supported through continuously expanding supporting infrastructure including cross country pipeline network of 33,478 KM (Fig. 1) and liquefied natural gas (LNG) terminal. Currently, India has seven onshore operational LNG terminals, with regasification capacity of 170 MMSCMD (47.7 MMPTA).

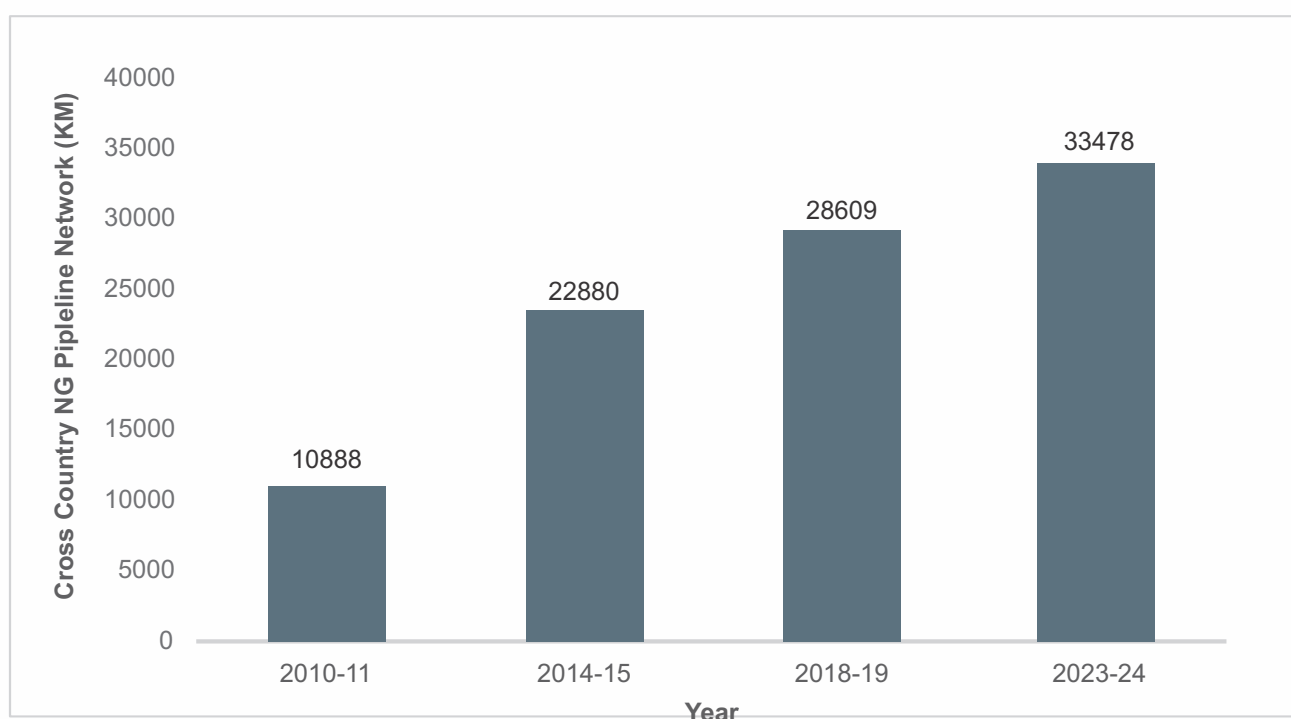


Figure 1: National Gas Grid Network

Source: Prepared by the author based on data collected from PNGRB

With over 336 geographical areas (GA) under City or Local Natural Gas Distribution Network, the gas market generates consistent demand for natural gas. Insufficient domestic gas production leaves greater scope for import, therefore, rising import dependency. Import of liquefied natural gas (LNG) has been rising in India. To reduce natural gas imports, options available include improving domestic production and exploring alternative option to supplement natural gas demand. Compressed biogas (CBG) is considered as the alternative domestic solution to rising domestic gas demand. Government targets to produce 5 million tons per annum (MMTPA) CBG to increase domestic alternative gas supply.

Compressed Biogas: A Status Review

India's National Policy on Biofuels - 2018, outlines the use of domestic resources, especially, energy production from biomass and municipal waste. Government recognized the importance of CBG, therefore, it launched Sustainable Alternative Towards Affordable Transportation (SATAT) scheme in October 2018 to generate energy from waste/biomass resources. Conversion of waste to useful energy can greatly assist India's energy transition. SATAT scheme targets setting up 5000 CBG plants across the country. So, far this scheme has received significant interest from prospective project developers for setting up CBG plants. SATAT has 2227 active letters of intent (LOI) for establishing CBG plants. SATAT website confirms that 94 operational CBG plants sold 31422 tons of CBG in 2024-25^{xxxii}, with an average sales of 334.26 tons per annum per plant. Data from GAIL's website confirmed that GAIL sold 211000 SCMD (approx. 4804 tons; 160 tpd) in the month of March 2025. Higher growth is seen in 2025-26. In order to expand CBG market, government introduced a number of policies and schemes to enhance CBG production and offtake.

Policies and Schemes

India actively promotes CBG adoption in the country, which offers a viable complementary solution to insufficient domestic natural gas production and supply. Indian government has been putting enough efforts to create the enabling environment for the expansion of the CBG value chain. The government and its agencies have been making schemes and policies to develop investment climate to attract investors to install large number of CBG plants. Further, incentives are offered to stakeholders such as the farmers and municipality corporations to actively participate in the CBG value chain. The farmers are one of the important stakeholders as they are the suppliers of the agricultural biomass, a raw material for CBG production.

To facilitate timely availability of agricultural biomass, the government launched a scheme for procurement of biomass aggregation machinery. This scheme has financial outlay of Rs. 564.75 crore (\$67 million) for spending (FY 2023-24 to FY 2026-27). This scheme has a provision to provide financial assistance upto \$1 million for a plant capacity of 4tpd.

Also, the government allocated Rs. 994.50 crore^{xxxiii} (\$118 million) for pipeline infrastructure to evacuate gas from CBG plants and inject into City Gas Distribution (CGD) networks. The above allocated budget should be utilized for pipeline infrastructure creation during FY 2024-25 and FY 2025-26. This scheme intends to provide financial support to 100 CBG plants. Under the scheme plant size below 2 ptd is not eligible for financial assistance. The scheme encourages installation of relatively large scale CBG plants with capacity above 5 tpd. Under the scheme, government offers central financial assistance of Rs. 28.75 crore (\$3.4 million) per project for construction of CBG grid & pipeline (Steel/MDPE) up to 75 km.

In addition, government is enabling environment for greater acceptance of CBG. The CBG-CGD synchronization targets to enhance CBG integration into the CGD network. The CBG-CGD synchronization scheme mandates obligatory CBG blending in compressed natural gas (CNG) and piped natural gas (PNG). This move can ensure mandatory off-take of CBG, thereby supporting higher production. CBO targets are set for 1%, 3%, 4% & 5% of total CNG/PNG consumption for FY '25-26, '26-27, '27-28 and '28-29^{xxxiv}, respectively. It is looking at targeting 10%^{xxxv} CBG blending in the subsequent years. GAIL (India) Limited is the nodal agency for implementation of CBG-CGD synchronization scheme. According to GAIL (India) Limited, 249 CBG producers and 39 CGD entities are injecting CBG covering 86 geographical areas^{xxxvi}. So far 316 TPAs are active across India to ensure effective implementation of CBG-CGD synchronization scheme. GAIL India reported that 304000 standard cubic meter of CBG was sold in November 2025. A lucrative pricing structure has been in place to support off-take of CBG and Biogas (Table 1).

Table : Pricing Structure under CBG-CGD Synchronisation Scheme

Commodity	Delivery options		Purchase Price by GAIL from Producer	Sale Price by GAIL to CGD Entity
	Delivery Point	Mode of Transport		
CBG	Retail Outlet (RO) of CGD entity and/or CBG Plant	Through Cascades	Rs 1478/MMBTU + Compression charge (Rs.8/Kg)	UBP + Compression charge (Rs.8/Kg)
Biogas	Pipeline network of CGD entity	Through Tie-in Pipeline	Rs 1478/MMBTU + P/L Compression charge (Rs.2/Kg)	UBP + P/L Compression charge (Rs. 2/Kg)
		Cascade-Decompression (DCU)	Rs 1478/MMBTU + DCU Compression charge (Rs.8/Kg)*	UBP + DCU Compression charge (Rs.8/Kg)*

***Applicable from 01.06.2024 to 31.05.2026**

Source: <https://gailonline.com/cbgModalitiesPricing.html> accessed on 3 January 2026.

Transportation charges for supply through Cascades and through DCU arrangement are governed by the rates given as below:

- I. 0 – 50 km – Nil (as transportation charges upto 50km is included in the Biogas procurement price)
- II. >50 – 75 km-Rs. 1.5/kg
- III. >75 km-Rs. 2.5/kg

Bottlenecks

In spite of all possible government support, CBG industry continues to face many bottlenecks. To improve better access to funds from the banks, Reserve Bank of India puts CBG under priority lending sector. So far, policies and financial incentives to CBG industry prove inadequate for rapid expansion. Barriers exist across the CBG value chain. Very often the barriers such as lack of project financing, underdeveloped supply chain, and unavailability of good quality biomass hurt the CBG industry growth. Emergence of competing renewable investment options such as solar and green hydrogen attracted more investors than the CBG industry.

Low rate of plant commissioning compared to the letter of intent is a real concern for CBG industry. Investors need to come forward to support the sector for faster growth. In 2023-24, the union budgeted provision for 200 new CBG plants. The Ministry of Housing and Urban Affairs (MOHUA) targets to setup about 75 CBG plants by 2030. Urban wastes cause considerable environmental challenges but offer unique opportunities to generate energy from waste. CBG must be viewed from a prism that shows multiple benefits; therefore, consistent efforts and support from all stakeholders are essential.

Carrying the key stakeholders through

In the CBG value chain farmers play an important role in supplying the raw material for CBG plants. The local administration and the local institutions can come forward to bring the farmers on board. Educating the farmers about the potential benefits of waste-to-energy can help better implementation of government schemes.

Initially SATAT set a target of 5000 plants, which looks highly ambitious. But changing market conditions indicate that 1000-1200 plants may be targeted by 2030. As per feedback from policy makers and industry experts, the CBG industry will require additional investment of Rs.58,0000-Rs. 71,000 crores to achieve the above targets. The CBG industry can deploy additional core manpower of about 15000-17000 for plant operations and maintenance. In addition, 45,000-50,000 indirect workforce is deployed in the CBG value chain. CBG sector can enhance millions of farmers income through valorization of agri-biomass. Further, farmers can benefit from access to eco-friendly bio-fertilizer, which is a byproduct of CBG plant. To support a greater penetration of organic fertilizers such as Fermented Organic Manures (FOM) /Liquid FOM/Phosphate Rich Organic Manures, government provides financial assistance of Rs 1500 per metric ton to the Bio gas or CBG plants registered under GOBARdhan initiative. This kind of financial assistance for byproducts intends to improve viability of bio-gas/CBG plants.

Remedies

Commissioning of new CBG plants needs different market dynamics to create pull for the project developers. Affordable technological access with higher output will make the CBG proposition more acceptable across the value chain. A part of investment should be directed towards the technology development, innovation, incubation and start up ecosystem for CBG. The rudimentary supply chain for raw material collection needs improvement. Shortage of trained manpower to implement the CBG plant installations and operations is a massive challenge. Academic institutions, skill development councils, and industry should join hands to assess the skill gaps, reskill already employed professionals, and design new customized programs to address the manpower shortage.

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16

Technological Pathways to Enhance India's Long-Term Energy Security

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1. Introduction

India's long-term energy security is intrinsically linked to its ability to reduce import dependence, diversify energy sources, and transition towards low-carbon and sustainable energy systems without compromising economic growth. As India remains one of the world's largest importers of crude oil and natural gas, indigenous technological innovation assumes strategic importance. In this context,

IndianOil R&D plays a pivotal role by developing and deploying advanced technologies that convert domestic and renewable resources into clean fuels and high-value products. Among these, biomass-to-hydrogen pathways, novel compressed biogas (CBG) processes, and nano-enabled products emerge as critical technological pillars for enhancing India's long-term energy security.

2. Biomass to Hydrogen pathways

Hydrogen is a clean, high-energy fuel with only water as a combustion product, making it a key solution for decarbonization amid fossil fuel depletion. With a calorific value of 122 kJ/g, it far surpasses conventional fuels, yet most global hydrogen is currently produced via carbon-intensive fossil-based processes. Biomass-to-hydrogen offers a sustainable alternative by utilizing India's abundant agricultural, forestry, and organic wastes, reducing import dependence and supporting the National Green Hydrogen Mission. Hydrogen can be produced from biomass through thermochemical, biological, electro-biochemical, and hybrid conversion routes, collectively enabling a decentralized and carbon-neutral hydrogen economy.

2.1 Biomass gasification

Biomass gasification is a thermochemical process that converts biomass feedstocks such as woody biomass, forest residues, and agricultural wastes into a combustible gaseous mixture through partial oxidation using gasification agents like air, oxygen, and steam. The resulting gas, known as syngas, mainly contains hydrogen and carbon monoxide, along with methane, carbon dioxide, and nitrogen. Syngas also carries impurities such as tars, particulates, and sulfur- and nitrogen-containing compounds, which must be removed before downstream utilization. After appropriate cleaning and conditioning, syngas can be used for power generation, heating, or the production of hydrogen, synthetic methane, liquid biofuels, and chemicals.

Hydrogen generation from biomass gasification typically involves three major steps. In the first step, biomass reacts with oxygen and steam at high temperatures in a gasification reactor to produce syngas. In the second step, the hot syngas is cooled and subjected to cleaning processes to remove particulates, tars, and other contaminants. This is followed by syngas conditioning, where the hydrogen content is enhanced through the water–gas shift (WGS) reaction, in which carbon monoxide reacts with steam to produce additional hydrogen and carbon dioxide. In the final step, hydrogen is separated from the conditioned syngas using suitable gas separation technologies. The hydrogen yield obtained from biomass gasification depends on the type of biomass feedstock and operating conditions of the gasifier.

Air-blown biomass gasification has been widely practiced for power generation applications; however, its use for hydrogen production faces several limitations. The presence of large amounts of nitrogen dilutes the syngas, leading to lower hydrogen concentration and reduced efficiency. Additionally, variations in biomass feedstock quality affect syngas composition, and the removal of heavier hydrocarbons and other impurities becomes challenging. To overcome these limitations, oxy-steam biomass gasification has emerged as a more suitable and economically attractive option for hydrogen production, as it avoids nitrogen dilution and enhances hydrogen yield.

IndianOil R&D, in collaboration with the Indian Institute of Science (IISc), Bengaluru, has developed an advanced oxy-steam biomass gasification-based hydrogen generation technology capable of producing fuel cell grade hydrogen. The process integrates high temperature oxy-steam gasification

with Vacuum Pressure Swing Adsorption (VPSA) for efficient hydrogen separation. In this technology, biomass is gasified with oxygen and steam at temperatures above 850°C to generate hydrogen-rich syngas. The syngas undergoes rigorous cleaning to remove particulates, tars, and sulfur compounds before entering the VPSA unit, which separates hydrogen with a purity exceeding 99.97%. The off-gas from the VPSA system is effectively utilized to generate the steam required for the gasification process, improving overall energy efficiency. Schematic of the biomass gasification-based hydrogen generation technology is shown in figure 1.

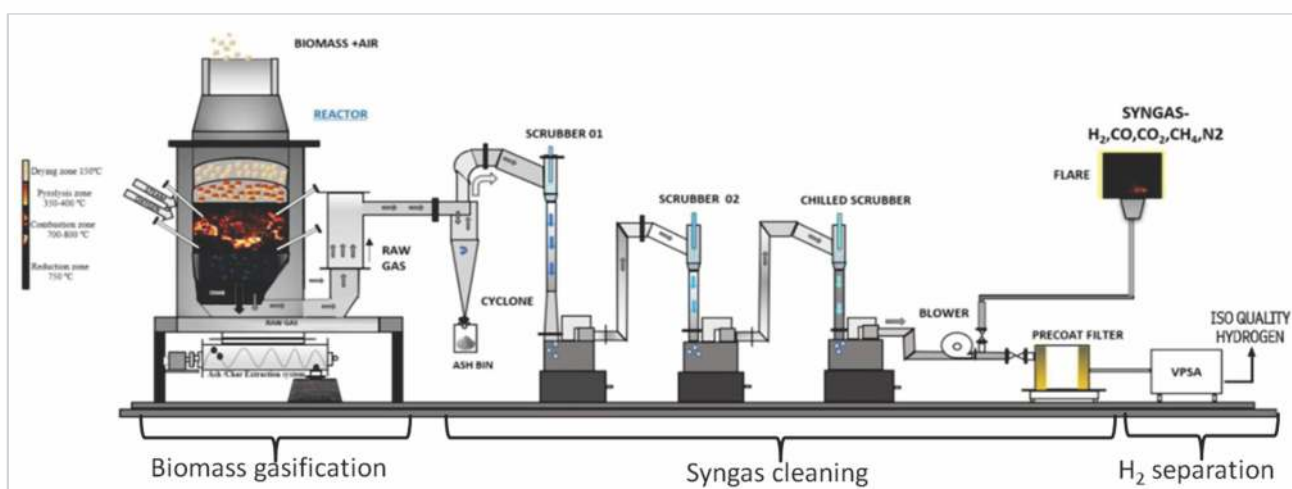


Fig 1 : Schematic of the biomass gasification based hydrogen generation technology

The developed technology has been successfully demonstrated at a scale of 5 kg/h at IISc for different biomass feedstocks such as woody biomass and agro residue briquettes. Pictures of the 5 kg/hr hydrogen generation unit comprising of 100 kg/hr biomass gasifier and VPSA system located at IISc, Bengaluru, Karnataka are shown in figure 2. Building on this success, IndianOil plans to establish a biomass gasification-based hydrogen generation plant of approximately 100 kg/h capacity at one of its refineries, reinforcing the role of indigenous technologies in advancing clean and sustainable hydrogen production.

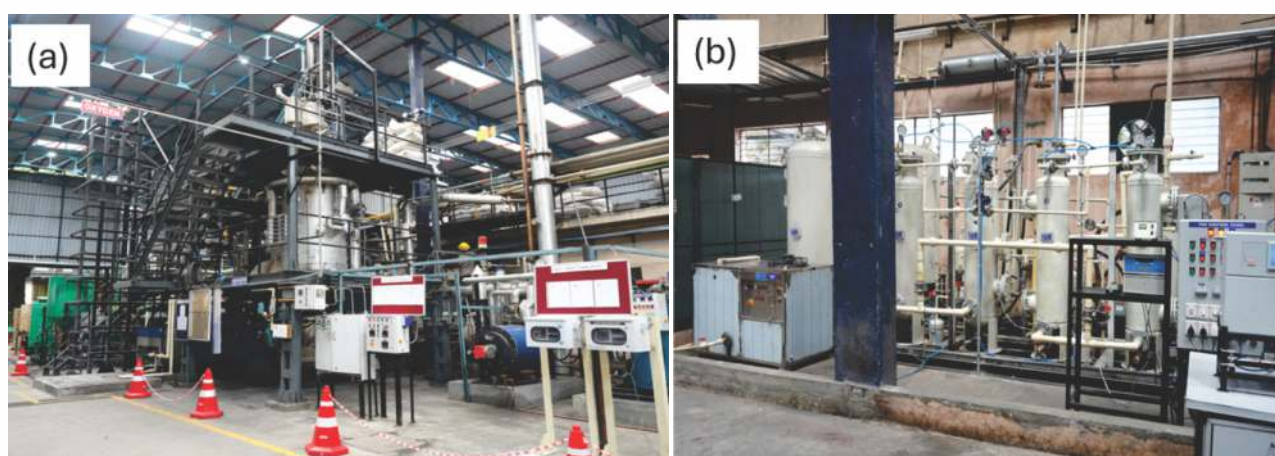


Fig 2: 5 kg/hr hydrogen generation unit : (a) 100 kg/hr biomass gasifier, (b) Vacuum Pressure Swing Adsorption system at Indian Institute of Science (IISc), Bengaluru, Karnataka

2.2 Dark fermentation

Dark fermentation is an anaerobic biological process in which microorganisms produce hydrogen without the need for light. It involves hydrolysis, acidogenesis, and acetogenesis, where complex organic matter such as carbohydrates, proteins, and lipids is broken down into simpler compounds and then converted into volatile fatty acids and hydrogen by fermentative bacteria. Hydrogen is released as a metabolic byproduct during this process. Dark fermentation is practically viable due to its robustness and ability to process diverse biomass and organic wastes, including agricultural residues, food waste, and sludge, making it a sustainable and adaptable pathway for renewable biohydrogen production.

2.3 Microbial electrolysis cell (MEC)

Microbial Electrolysis Cell (MEC) is a hybrid system combining electrochemistry and biotechnology that enhance dark fermentation by supplying small external energy inputs from renewable sources. Electro-active bacteria transfer electrons from biomass degradation to electrodes, enabling hydrogen production at lower energy input than conventional electrolysis. Protons and electrons combine at the cathode under mild applied potential, allowing hydrogen generation at low redox potential. MECs can process high organic loads and complex substrates with improved conversion efficiency. Their simple, membrane free single chamber designs make them suitable for evaluating wastewater biodegradability, though scalable and efficient reactor designs are essential for large-scale applications.

3. Novel CBG Process and Products to enhance economics

A large fraction of organic waste and biomass residues in India is currently dumped in open land or burnt in fields, significantly contributing to greenhouse gas emissions and climate change. Compressed Biogas (CBG) production has emerged as a sustainable solution that simultaneously addresses waste management challenges and enhances energy security. Government initiatives such as SATAT and GOBARdhan have provided strong policy support for scaling up CBG infrastructure across the country.

Despite growing interest, many existing CBG plants face technical and economic challenges, including low and inconsistent biogas yields, low methane content, long hydraulic retention times, high purification costs, large reactor sizes, feedstock variability, scum formation, and limited digestate valorization. These issues collectively hinder large-scale adoption. To overcome these limitations, IndianOil R&D has developed innovative CBG processes and bio-products through advanced microbiological and biotechnological interventions, improving biomethanation efficiency, feedstock flexibility, and overall plant economics, thereby enabling faster and more sustainable growth of the CBG sector.

3.1 Innovative CBG process:

IBG-Max is an IndianOil R&D–developed two-stage anaerobic digestion technology designed for efficient biomethanation of food waste and other biodegradable organic wastes to produce high-quality biogas/ CBG. By separating acidogenesis and methanogenesis into optimized stages, it achieves higher gas yields, better process stability, and faster waste conversion than conventional single stage digesters.

IBG-Plus is IndianOil R&D's compact, modular, single stage biogas production technology where anaerobic digestion is carried out in reactors hydraulically linked in series or parallel especially for

agriculture residues and biomass. It integrates rapid hydrolysis and methanogenesis in a chain of optimized reactor, enabling faster digestion, simplified operation.



Fig 3: 100 TPD cattle dung based CBG plant in Hingonia, near Jaipur, Rajasthan

IBG-Max and IBG-Plus provides a compact and scalable solution for urban organic waste, agriculture residue waste treatment, waste-to-energy plants, and SATAT-aligned CBG projects. These processes have been successfully implemented at commercial scale. A 100 tonnes per day (TPD) cattle dung based CBG plant has been set up at the Hingonia Cattle Rehabilitation Centre in Hingonia, near Jaipur, Rajasthan and photograph of the plant shown in figure 3. Another 200 TPD paddy straw based CBG plant has been set up in Gorakhpur, Uttar Pradesh and photograph of the plant is shown in figure 4.



Fig 4: 200 TPD paddy straw based CBG in Gorakhpur, Uttar Pradesh

3.2 Innovative bio-products for CBG plants

IndianOil through its dedicated R&D Centre in Faridabad and collaborative innovation ecosystem, strategically working on CBG and biomass valorization. IOC R&D developed a diverse product portfolio for sustaining the CBG yields in any existing CBG plants. This includes the proprietary feed agnostic microbial blend (BioXeed) suitable for any feedstock, innovative formulation, IBG-Booster, for sustained biogas yields and smooth operation of CBG plants during shock loads, operational updowns, etc., IBG-F5 for feedstock quality management over storage and IBG-SRA for scum reduction in operating digesters and other troubleshooting options. CBG is being sold through Indian Oil retail outlets under the brand name IndiGreen. The bio-products also include Agri-Elite that helps in faster & efficient conversion of digestate to premium quality manure. The enriched manure using Agri-Elite from Indian Oil based CBG plants is being sold as BhuSuvarna. The bio-products of Indian Oil CBG technology consists of the following.

- Efficient bioinoculant (BioXeed): A feed agnostic, robust, patented bioinoculant to increase biogas yield.
- Formulation for sustained biogas yield (IBG-Booster): It is a formulation for sustained release of micronutrients required for early start-up CBG plant as well as Quick restoration of CBG plant from shock loads offering protection from unexpected operational variations.
- Microbial blend for enrichment of manures (Agri-Elite): The microbial blend to “enrich the solid/liquid manure from CBG plant” and improve the commercial viability of CBG plant.
- IBG-F5 for feedstock quality preservation: Formulation for preserving the feedstock quality to reduce the in-situ deterioration of biomass quality during long term storage. The formulated chemicals sprayed on the surface of the biomass to prevent their degradation and to minimize the potential biogas production ability of the stored biomass.
- IBG-SRA for scum reduction in digesters: This is a formulation to reduce the scum formation and reduction in the commercial biogas digesters. The SRA acts as a surfactant, reducing the surface tension and breaking down the scum layer, and preventing scum buildup.

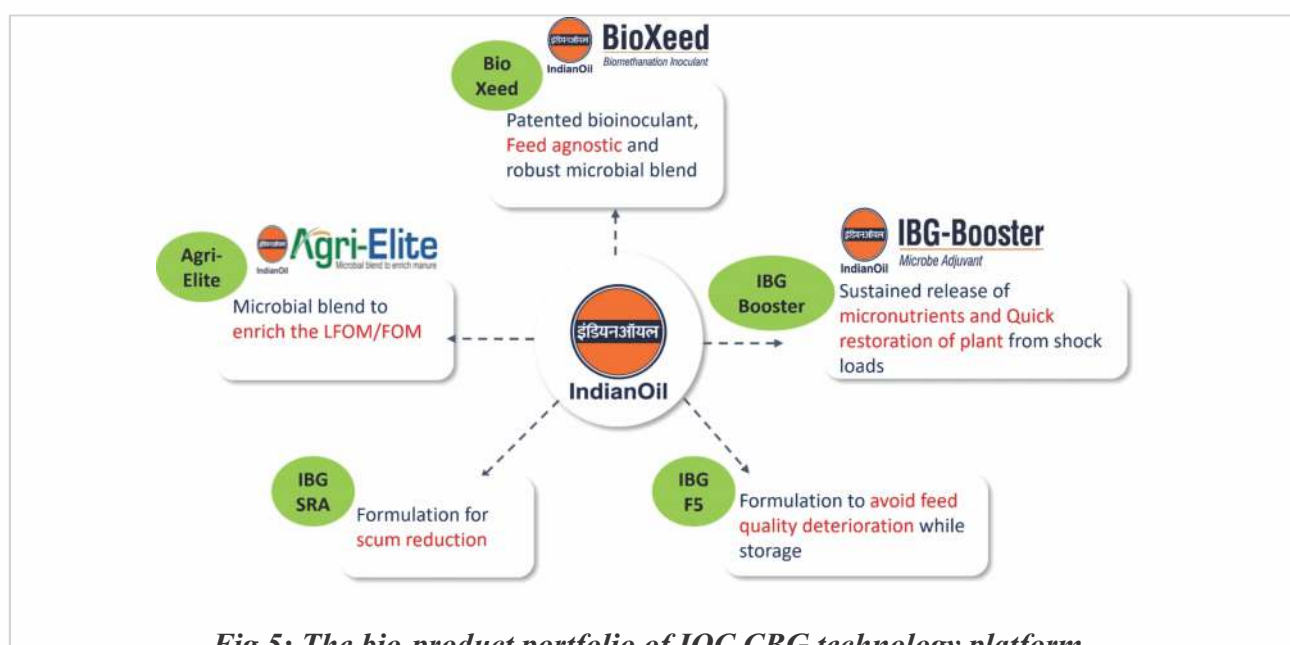


Fig 5: The bio-product portfolio of IOC CBG technology platform

These bio-products have been commercially implemented at different scales, locations and modes, and is currently being commercialized. They have been retrofitted successfully in existing CBG plants like, IAVB, Namakkal, Anaerobic energy India Pvt. Ltd., Haridwar, Banaskantha CBG plant, Banaskantha, etc., apart from Indian Oil owned CBG plants.

4. Nano enabled products in India's Long-Term Energy Security

Technology Pathways for long-term energy security requires resilient, diversified, and sustainable process or products; with key focus on either reducing dependence on fossil fuel imports or by improving energy efficiency of the system. With majority of energy management in the hydrocarbon industry deals with management of heat either in the form of better utilization of process heat or extracting more heat from energy system at the customer place. Nanotechnology interventions in Indian Oil aims for improving energy efficiency and conservation of energy to secure future energy needs.

4.1 Differentiated LPG for improving fuel efficiency and to reduce import dependency

LPG has been traditionally used as fuel for domestic and commercial cooking, heating, and other industrial applications constituting a larger part of gaseous fuel. However, about 80% of LPG in India is imported to cater for these needs. There is a need to improve combustion and in turn improve fuel efficiency and emission to reduce this import dependency. Differentiated product solutions are an energy efficient approach by IOCL as these products are innovative and first of its kind for the existing in-use. Array of differentiated LPG products have been introduced in the market based on patented additives developed by Indian Oil.

Indane NANOCUT is an additized LPG with higher Flame temperature, specific use for metal cutting and related high temperature applications with an aim to reduce import of hazardous carbides used for generating acetylene; traditionally used for metal cutting application. **Indane XTRATEJ** is an additized LPG with higher Flame temperature, specific use for commercial cooking and industrial applications. The product helps in reducing the LPG consumption by at least 5 %, and reduction in cooking time by around 14%. **XtraBoost**, is a new age Automotive LPG with improved performance and benefits complying BS VI norms. The Indane **XtraBoost** has excellent attributes in drivability, pickup as well better engine performance with enhanced fuel economy of ~3%. **Propane Plus**, the additized fuel based on patented nano additive, achieves a flame temperature that is 400°C higher than regular propane, resulting in reduced fuel consumption, cleaner combustion, and more heat output suitable for users, who use propane for heat generation.

All of these products not only help improve the efficiency of application, but also help in reducing import dependency owing to their better fuel economy. Moreover, gaseous fuels are one of the enablers for reducing CO₂ emissions.



4.2 Improving energy efficiency by advanced Coating formulation

Performance coatings are critical for the entire energy sector for asset management and provide solutions for enhancing energy security by maximizing operational efficiency. Advanced functional coatings, such as thermal insulating coatings improve energy efficiency in industrial processes by managing heat transfer, and associated energy consumption. Furthermore, specialized anti-reflective coatings boost the energy yield of PV solar panels. The cost of corrosion in India is estimated 4.2% to 5-7% of the nation's GDP and Anti corrosion coatings can help the country by protecting the infrastructure and saving the GDP and securing energy needs. Through these diverse applications, innovative nanocoatings help prevent costly downtime, minimize environmental risks, and support the reliable and sustainable generation, storage, and transmission of energy, thus contributing significantly to India's energy resilience.

Indian Oil is working on array of problems in order to improve energy efficiency and came up with few solutions, which being implemented for captive use first and to be extended to the industry further. **Nanokoat-I** is one of such coating formulations which has been validated to address the issue of corrosion under insulation. This coating would enhance the life span of the process pipelines and reduce the downtime due to unwarranted shutdowns. The nanocoating is also suitable for high temperature process pipelines which reduces thermal loss and improves energy efficiency by acting as thermal barrier. **NanoKoat-A** is a coating formulation developed by Indian Oil designed for resistance against corrosion due to acids and related harsh corrosive environment. This coating formulation is designed to cover infrastructure handling acid at ambient temperature and large battery storage areas. This would lead to reduce downtime and improve system efficiency for long-term energy sustainability. Additionally Indian Oil also validated & benchmarked its developed antireflective and self cleaning coating for solar panels with 5% enhanced power generation to ensure the long-term energy security.

IndianOil strongly believe in power of innovation through its nanotechnology activities to ensure energy efficiency in this paradigm shift across the entire energy value-chain ranging solar power generation, maintaining integrity of process and transportation infrastructure and most importantly protecting critical energy infrastructure present in coastal corrosion zone of our country.

5. Conclusion

The integration of biomass-to-hydrogen, advanced CBG technologies, and nano-enabled products offers a comprehensive pathway to enhance India's energy security by improving sustainability, affordability, and resilience. IndianOil R&D's emphasis on indigenous technology development reduces dependence on critical imports while building domestic intellectual property and manufacturing strength. These innovations align with national priorities such as Atmanirbhar Bharat, the National Bio-Energy Mission, and the National Green Hydrogen Mission. Overall, India's long-term energy security will rely on scalable, cost-effective technologies that harness domestic resources. IndianOil R&D's advances in biohydrogen, value-added CBG processes, and nano-products together support a cleaner, self-reliant, and future-ready energy system.



Kudankulam Nuclear Power Plant, Tamil Nadu

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NPCIL's role in developing India's nuclear power sector and advancing clean energy goals

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Nuclear Power Corporation of India Limited

Introduction

Nuclear energy being an environment friendly, clean source, available 24x7 as a baseload reliable power, has long been a cornerstone of India's vision for energy independence and sustainability. At the heart of this journey stands the **Nuclear Power Corporation of India Limited (NPCIL)**, a public sector enterprise under the Department of Atomic Energy entrusted with the design, construction, and operation of nuclear power plants besides developing relevant technologies. Thus, NPCIL has been the operational backbone for deploying commercial nuclear power plants expanding India's nuclear

capacity base, nurturing technology development, and supporting industrial ecosystems that underpins a low-carbon transition strengthening the country's clean energy credentials.

NPCIL and India's Clean Energy Journey

Though the India's civil nuclear journey began soon after independence with research reactors and a nuclear power programme conceived to use indigenous resources, its foundation was realized in the 1940s under the visionary leadership of Dr. Homi J. Bhabha. Recognising the nation's limited fossil fuel reserves but abundant Thorium deposits, India adopted a three-stage sequential nuclear power programme envisaging use of Uranium-235 in the first stage, Plutonium and Uranium-233 (obtained from irradiated Thorium) in the subsequent stages.

Accordingly, over the decades the country moved from research reactors to commercial PHWRs. While achieving maturity and expertise in the Stage-I, the country is now poised to enter Stage-II while technology development is underway for Stage-III. In the meantime, for faster capacity addition, large capacity Light Water Reactors (LWRs) with international collaboration are also being pursued as additionalities.

Nuclear power in India is thus more than a set of reactors and cooling towers. It is a story of long-term vision, technical grit, and institutional patience. At the heart of that story sits the NPCIL, which has carried the country's nuclear ambitions of achieving low-carbon electricity generation. Over decades, the operational footprint of NPCIL has grown from operating a handful of reactors to managing multiple sites, commissioning new units, and partnering on international collaborations.

This article traces NPCIL's role in building India's nuclear sector, the landmark accomplishments during the journey, the hurdles it has faced and overcome over several decades, the industrial ecosystem it has nurtured, and the path ahead as India pursues Viksit Bharat by 2047 and Net Zero by 2070.

The beginning, landmark accomplishments, and present position

India's nuclear programme which began with research reactors and an emphasis on self-reliance in technology and fuel, overtime grew indigenously in terms of scale, capacity and capability.

NPCIL emerged as the operational backbone of this vision, translating research into commercial deployment. The nuclear power plant journey began way back in 1969 with the commissioning of the Tarapur Atomic Power Station, Units-1&2 as a turnkey project with the help of USA and subsequently in 1973 with Rajasthan Atomic Power Station, Units-1&2 with the help of Canada marking the beginning of India's civil nuclear power era. Following this multiple units of capacity of 220 MW, 540 MW and subsequently 700 MW based on indigenous PHWR technology were set up by NPCIL. Parallely, with the cooperation of the Russian Federation, 2 Pressurized Water Reactors (PWRs) of 1000 MW capacity each have already become operational at Kudankulam while 4 more such units are being established at the same site. It is important to note that Kudankulam nuclear power plants are the largest unit size power utility in the country.

Today, NPCIL operates 24 reactors (excluding RAPS-1) with a capacity of about 9 GW. Seventeen more units are under different stages of implementation while many more are planned to be setup, both based on indigenous technology and international cooperation. With this kind of expansion in place, NPCIL

envisages to reach to a capacity of about 22 GW by 2031-32 and about 54 GW by 2047 contributing to more than 50% of the Government's target of 100 GW.

During the journey of development interwoven with several constraints, NPCIL resolute dedication and determination resulted not only enhancing the capacity of indigenous PHWRs, it also obtained expertise in other technologies viz. Boiling Water Reactors (BWRs) and Light Water Reactors (LWRs). The company assets grew from Rs. 1313 crores to over 1.9 lakh crores. NPCIL is a profit making, dividend paying company with consistent safety rating of AAA. NPCIL is probably the only organisation in the world which is into various aspects of a nuclear power cycle viz. siting, designing, construction, commissioning, operation & maintenance, renovation and modernization, life extension & upgradation, waste management and quality assurance.

NPCIL has an impeccable safety record of over 650 reactor-years averting over 825 million tonnes of CO₂ equivalent emissions into the environment with remarkable operational performance, making it an organisation to aspire for. There have been several noteworthy accomplishments in the name of NPCIL including, one unit (KGS-1) making world record in 2018 for continuous operation of 962 days, two units (TAPS-1&2) became the oldest operational nuclear power plant in the world, so far 53 times nuclear power plants of NPCIL operated for more than a year uninterruptedly, among many. Of the top 9 nuclear power plants in the world with longest continuous run, 4 are of NPCIL demonstrating the kind of maturity and expertise it has gained over the period of time. NPCIL is a learning organisation which has a motto of SAFETY FIRST-PRODUCTION NEXT. Safety is accorded utmost importance at all levels. The reactors are maintained up-to-date based on the experience gained across globe and thus India has among the safest nuclear power plants besides being economically competitive.

NPCIL has also mastered the intensive in-core intricate jobs which only a few countries are capable of and that too at very competitive cost. Be it En-masse Coolant Channel Replacement, En-masse Feeder Replacement, etc. Thus, it will be prudent to say that NPCIL has placed itself firmly on the global nuclear power map.

Decades of development and constraints

India's nuclear journey has been shaped by steady technical progress and recurring constraints. The development trajectory began from the first commercial units in the 1960s–70s to the more recent indigenously designed PHWRs and LWRs with international collaborations, India steadily expanded its nuclear fleet across multiple states, while building domestic manufacturing, regulatory, and human-resource capabilities.

The growth trajectory was not without constraints and bottlenecks. Subsequent to the Pokhran-I peaceful explosion and thereafter Pokhran-II, the sector faced strict global technology denial and embargo regime. There was a long phase of fuel shortage, lack of technical support added with public perception regarding safety and livelihood concerns. To address the public perception, NPCIL has since long setup a large scale community outreach through an exhaustive and structured framework to build public confidence.

These constraints shaped a cautious, capability-building approach that emphasised self-reliance in every aspect of the technology. Despite these challenges, we pursued a cautious but resilient path, focusing on indigenous development and gradual capacity addition.

Industry handholding and ecosystem development

There have been consequential benefits resulted from the above constraints which paved the way for Atmanirbhar approach since then. As one of the important steps, NPCIL hand-held the industry through its multi-pronged approach, comprising of transferring technical know-how, qualifying domestic vendors, and creating long-term procurement pipelines that incentivize investment in heavy engineering, instrumentation, and nuclear-grade materials. This has led to the emergence of specialized suppliers, testing facilities, and nuclear exacting standard manufacturing utilities that support construction, commissioning, and operations. NPCIL's project contracts and vendor development programs have been instrumental in building a resilient domestic supply chain capable of meeting nuclear quality and safety standards.

NPCIL's programmes helped catalyze allied establishments thereby strengthening the national nuclear power infrastructure facilitating development of a conducive ecosystem. This ecosystem reduced dependence on imports and strengthened India's technological sovereignty while creating various job opportunities.

Way forward in light of the Nuclear Energy Mission (NEM) and clean energy objectives

NPCIL has been a driving force behind indigenizing reactor technology, scaling Pressurized Heavy Water Reactors (PHWRs), and exploring Small Modular Reactors (SMRs) and advanced designs under national missions. Leadership statements and strategic plans position NPCIL at the core of the **Nuclear Energy Mission**, which aims to expand nuclear capacity and integrate it with India's long-term clean energy targets. NPCIL's operational experience, vendor ecosystem, and growing portfolio of reactor designs make it the natural lead agency to deliver the expansion responsibly and safely

To contribute to the twin goals of **Viksit Bharat by 2047** and **Net Zero by 2070**, NPCIL plans a strategy which is combination of multi elements including, emphasis on scale, flexibility, and innovation. The capacity is planned to be scaled up by accelerating construction of large reactors, development of new technologies (including Bharat Small Modular Reactors-BSMRs), strengthen indigenization, increased investment in human capital, expanding international collaboration for technology exchange, setting up joint ventures, opportunities that support export potential and strategic partnerships, etc. As regards to BSMRs, NPCIL is collaborating with BARC for development on three variants, 200 MW & 55 MW for captive use, remote area deployment and repurposing of old thermal power plants while 5MWth is focused for industrial applications. Further NPCIL plans to setup Bharat Small Reactors (BSRs), the proven small sized improved PHWRs, with industry support to decarbonize hard-to-abate sectors like metal, cement, etc.

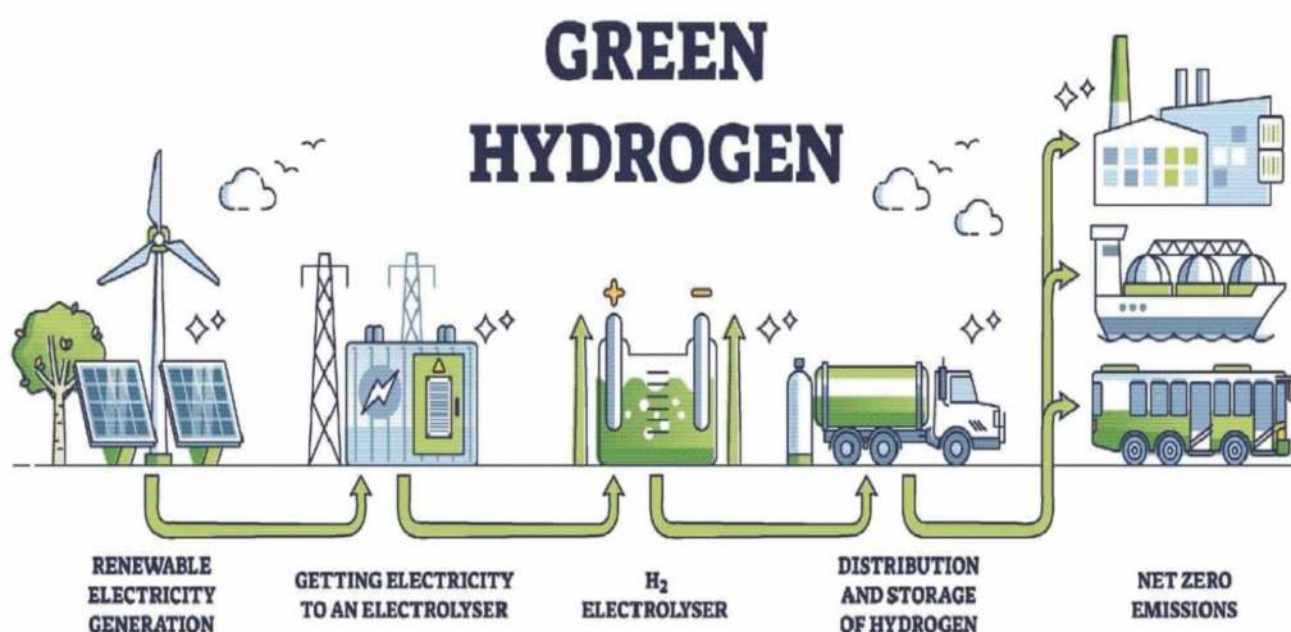
India's nuclear energy trajectory is set for a transformational change under the recent **Sustainable Harnessing and Advancement of Nuclear Energy for Transforming India (SHANTI) Bill, 2025**, which modernizes the civil nuclear framework. NPCIL is poised to contribute to the cause of this legislative shift, leveraging its expertise and experience, positioning nuclear power as a reliable backbone for India's clean energy mix, complementing renewables and reducing dependence on fossil fuels.

These steps align NPCIL's operational strengths with national climate and development targets, positioning nuclear energy as a reliable backbone for a low-carbon, industrialized India.

Conclusion

NPCIL's multi-faceted role, be a conceptualizer; a project developer; technology custodian; industry enabler; and public-safety steward, has been central to India's nuclear power progress. Overcoming decades of constraints, the organization and its partners have built a resilient nuclear ecosystem that can now scale more rapidly under modern policy reforms and contribute materially to the country's clean energy and development ambitions

As India pursues its clean energy transition, nuclear power will remain indispensable for balancing sustainability with energy security and NPCIL will continue to play a motherly role.





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Exploring the Influence of State CGD Policies Promoting a Gas-Based Economy for Energy Security fulfilling India Vikshit Bharat @2047 Aspirations

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Abstract

The article discusses the impact of state policies on the City Gas Distribution (CGD) sector in India, which is crucial for promoting a gas-based economy and ensuring energy security and energy transition to achieve the Vikshit Bharat @2047 goals. With a projected CAGR of 10.4% between April 2021 to

March 2025 and an average natural gas (NG) consumption of approximately 44 MMSCMD, the CGD sector accounts for 23% of total NG consumption. Nonetheless, the sector faces challenges such as infrastructure bottlenecks, gas sourcing, pricing issues, and demand switching. State policies are vital for the sector's growth by offering regulatory frameworks, fiscal incentives, and administrative support. Key strategies include streamlining approvals, tax rationalization, infrastructure support, and promoting demand through mandatory switching. Infrastructure development enhance long-term energy security while supporting cleaner energy access and sustainable socio-economic growth. The article also highlights the role of alternate supply sources like bio-methane in fostering a circular economy and the importance of the National Bio-Fuel Policy to promote compressed biogas (CBG) for energy security and India's decarbonization commitments.

Introduction

India is the third-largest primary energy consumer globally, with a vision to become a “Vikshit Bharat” by the centenary of its independence in 2047. Its total primary energy consumption (PEC) is 40.81 EJ, behind the USA (96.5 EJ) and China (176.35 EJ). While India's PEC per capita is only 26.7 GJ, against the world average of 72.56 GJ per capita, its PEC grew by 4.7% between 2014 and 2024, compared with 3.8% for China, 0.3% for the USA, and 1.7% globally [1]. The accelerated PEC manifests all-round rapid economic development, urbanization, population growth, and the raising of the standard of living of Indian citizens, along with the country's expanding role in global manufacturing supply chains, which heightens its energy intensity. However, India faces a challenge in maintaining uninterrupted and dependable access to energy sources, guaranteeing their availability without disruption and at a price deemed reasonable. This notion of Energy Security in the Indian context underscores the importance of ensuring a steady energy supply to promote economic stability and security, while also addressing concerns about the sustainability and diversity of energy sources.

India's Primary Energy Consumption Mix

An analysis of India's PEC mix data for 2024, published by the Energy Institute, shows that fossil fuels comprising oil, (26.7%), Natural Gas(NG) (6.2%) and coal (56.3%) account for 89.2% of total consumption, while biofuels consumption is 77,000 barrels of oil equivalent per day, registering a 31.8% growth between 2014 and 2024. This highlights the importance of both energy availability and affordability, asserting that a robust energy framework and state policies are essential for consumers and industry alike. However, India is heavily dependent on fossil fuel imports, with annual foreign exchange outgo amounting to approximately USD 150 billion to meet rising energy demand and sustain its economic development. India imports 88-89% of its crude oil and over 50% of its NG as liquefied Liquefied Natural Gas (LNG) from multiple global sources. Despite being a significant coal producer, India fulfils approximately 20% of its coal requirements through imports, primarily to serve the steel and power industries. This persistent reliance on imported fossil fuels highlights both energy security concerns and the challenges of transitioning sectors such as heavy industry and power generation, where alternatives are still developing.

Long Term Low Carbon Development Strategy (LT-LEDS)

To address the issue, the Indian government has diversified its energy supply imports and increased its focus on renewable energy sources, such as solar, wind, bioenergy, and Green Hydrogen, to enhance

energy security and accelerate the energy transition. Amid such a situation, under its LT-LEDs [2] India aspires to a gas-based economy by increasing the share of NG in its PEC mix to 15 % by 2030, enhancing bio-gas and green hydrogen consumption as cleaner energy alternatives to coal and oil, thereby enhancing sustainability, reducing emissions, creating jobs, and improving urban air quality standards'—[3]. Fuel switching, driven by the enhanced use of NG and the promotion of Bio-Gas and compressed bio-gas (CBG) under the National Policy on Bio-Fuels, will contribute to achieving India's net-zero carbon goals by 2070.

Natural Gas Transition Fuel

NG is the preferred fuel globally, accounting for 23.4% of the global PEC mix[1]. It is a transition fuel [4] because it emits roughly half the CO₂ of other fossil fuels, while renewable energy technologies are developing to address their production challenges for secure, sustained energy[5]. Using NG as a bridge fuel, India aims to meet its climate commitments [2] "[6] while also promoting energy security and sustainability issues[7]. Accordingly, necessary infrastructure[8], such as LNG Regasification terminals, cross-country pipelines, and City Gas Distribution (CGD) networks, as well as CBG plants, is being constructed to provide easy access to NG and achieve a target of a 15% gas share in India's PEC mix by 2030'—[3]. The infrastructure details for NG are in Table 1.

Table 1. Natural Gas Infrastructure[8], [9]

1.	LNG Terminal	:	8 Nos.
2.	Regasification Capacity	:	52.7 MMTA
3.	NG Operational Pipelines	:	24,510 Km
4.	NG Pipelines under construction	:	8681 Km
5.	Geographic Areas	:	307 Nos.
6.	Domestic PNG Connections	:	156,27,037 Nos
7.	Industrial PNG Connections	:	20,964 Nos
8.	Commercial PNG Connections	:	46,633 Nos
9.	CNG Stations	:	8340
10.	CBG Plants operating under SATAT	:	132 Nos.
11.	Retail Outlets for CBG Sale	:	423 Nos.

The CGD Sector

Analysis of the NG sectoral consumption reveals that the CGD sector is the fastest-growing, registering a CAGR of 10.4%, from April 2021 to March 2025, with average NG consumption of approx. 44 MMSCMD, accounting for 23% of total NG consumption. However, the CGD sector faces several challenges related to infrastructure and operations, such as Right-of-Way and Permissions, Last-Mile Delivery, Third-Party Damage, and Spatial limitations in setting up CNG stations. To overcome such challenges, robust state policies are required to ensure that CGD infrastructure is developed rapidly without incurring cost or time overruns.

In light of the above deliberations, this article explores a few CGD State Policies to assess their role in promoting LT-LEDS and thereby enhancing NG and CBG consumption, accelerating India's 2030 gas-based economy targets for Vikshit Bharat@2047.

CGD Policies in India

The Ministry of Labour and Employment has granted CGD projects "Public Utility Status". The Ministry of Housing and Urban Affairs directed State Governments to standardize road restoration charges, earmark land for CNG Stations in urban planning, and modify building by-laws for gas pipeline infrastructure associated with CGD. To promote the expansion of CGD networks and increase NG consumption in the CNG and PNG domestic segments, the government has allocated domestic NG, which is more affordable than imported LNG, to fully meet customer demand in the PNG Domestic and CNG Transport segments, ensuring it remains in the no-cut category. Additionally, there are facilitation measures for NG distribution, including the allocation of domestic gas through swapping and transportation by LNG tankers and Cascades. Additionally, some state governments have issued policy guidelines to accelerate the nationwide implementation of CGD infrastructure. Accordingly, a few state policies are detailed.

Karnataka

The Government of Karnataka has initiated a strategic policy to expand the CGD, aligning with national goals to reduce carbon emissions[10]. The policy includes a structured institutional framework comprised of a Special Desk and high-level committees to streamline permissions and standardize infrastructure charges. Key objectives are to promote PNG domestic CNG transport and the development of CBG plants. The policy standardizes permissions, with governance led by state- and district-level committees to monitor progress and resolve issues. "Ease of doing business" measures include standard charges, time-bound clearances, and mandatory integration of gas infrastructure into urban planning. Adoption strategies for PNG and CNG include reserved CNG buses for state transport, conversion mandates for government vehicles, and incentives for reducing pollution in industrial areas. Overall, this policy aims to create a sustainable and efficient energy supply across Karnataka, akin to a circulatory system that promotes economic and environmental health.

Madhya Pradesh

The Madhya Pradesh CGD network development and expansion policy aims to enhance clean energy infrastructure by increasing access to PNG and CNG across all 55 districts[11]. This initiative is expected to attract Rs. 40,000 crore in investment over the next 6-8 years, seeks to establish 60 lakh domestic PNG connections and 1207 CNG stations. Key features include a single-window online system for permits, a governance structure with state and district monitoring committees, and a focus on skill development for local employment. The policy also highlights environmental and economic benefits, aiming to reduce pollution, create job opportunities, and ensure a safe and reliable gas supply through standardized procedures and safety frameworks.

Rajasthan

The Rajasthan CGD Policy 2025 aims to expand clean energy infrastructure throughout the state by establishing a streamlined application process for pipeline laying and gas station setups via a digital

portal[12]. It mandates timely clearances, encourages private investment through land leasing, and focuses on transitioning transport and industry to NG for environmental sustainability. The policy supports India's goal to increase natural gas's share to 15% by 2030. Key objectives include developing a robust CGD network, establishing a unified framework for clearances, promoting collaboration for setting biogas plants, and ensuring access to PNG and CNG. The policy specifies binding infrastructure targets, emphasizing a strong regulatory framework that enhances investor confidence. Governance structures establish accountability, facilitating the monitoring and execution of the policy through state and district committees. Provisions for financial transparency and stakeholder obligations further solidify a supportive ecosystem for implementation and future adaptations.

Bihar

The Bihar CGD Policy 2025 outlines a framework to enhance clean energy infrastructure in the state[13]. It establishes a governance model with state- and district-level monitoring committees to oversee the deployment of PNG connections and CNG stations. Key features include technical standards for road restoration, a digital approval process, and a grievance redressal mechanism, all aimed at ensuring public safety and operational reliability. The policy seeks to operationalize India's national energy strategy by expanding NG infrastructure across all 38 districts of Bihar, creating approximately 8,000 jobs, and attracting an investment of ₹10,772 crores. It promotes NG as a cleaner fuel and implements strict safety protocols. The anticipated impacts include economic growth, enhanced quality of life through a reliable energy supply, and significant environmental benefits from reduced carbon emissions. Overall, the policy presents a comprehensive approach to transitioning Bihar toward a sustainable gas-based economy.

Puducherry

The Government of Puducherry has introduced the "Puducherry CGD Policy 2023," aiming to promote the use of NG as an environmentally friendly fuel while enhancing the development of CGD infrastructure[14]. Key objectives include ensuring safe operations, reliable gas supply, and an efficient permissions process, alongside regulations for the gradual adoption of natural gas across multiple sectors. The policy emphasizes the use of CNG and LNG as transportation fuels. It encourages converting diesel generators to gas generators, with details on fees and conditions to be provided as CGD networks evolve. A High-Level Committee will oversee infrastructure development and procedural optimization, while a Nodal Agency will manage project implementation and coordination among stakeholders. The policy establishes a standardized methodology for obtaining permits for pipeline installations across jurisdictions, safeguards existing utilities and public safety during construction, and outlines directives for collaboration with local authorities. Restoration rates and procedures for pipeline installation will be framed, with costs linked to the nature of the work and local conditions. Ultimately, the policy is designed to expedite CGD projects, promote cleaner fuel usage, and address environmental challenges, contributing to national energy goals and commitments to mitigate climate change.

Tamil Nadu

The Tamil Nadu CGD Policy 2023 outlines a strategic initiative to promote NG in the state, as part of India's goal to increase its share of the energy mix to 15% by 2030[15]. The key objectives include

accelerating the adoption of PNG and CNG, ensuring operational safety, streamlining permissions and regulations, and enhancing NG use across sectors, including industrial, commercial, and household. A structured governance framework is proposed, comprising a State-Level Committee chaired by the Chief Secretary, a State Nodal Agency (TIDCO), and District-Level Monitoring Committees (DLMCs) led by District Collectors. This multi-tier approach aims to oversee the rollout of City Gas Distribution (CGD) infrastructure, address land and utility issues, and enhance the training and integration of renewable gas sources, such as biogas, into networks. Several statutory permissions are outlined to regulate land use and operational clearances, involving multiple authorities such as the NHAI and local governing bodies. The initiative plans to establish 2.28 crore PNG connections and 2,785 CNG stations across all 38 districts of Tamil Nadu, projected to attract an investment of ₹35,000 crore and create approximately 20,000 jobs. Safety regulations emphasize compliance with service norms and the implementation of emergency response plans. Overall, the policy aims to foster a robust governance structure that supports economic growth and promotes a cleaner energy future.

Tripura

The Tripura CGD Policy 2022 aims to promote the use of NG in Tripura, thereby enhancing clean, affordable energy access across the domestic, commercial, industrial, and transportation sectors[16]. Key objectives include accelerating infrastructure growth through the establishment of CGD networks with PNG for homes and CNG for vehicles, enhancing environmental sustainability by reducing urban pollution from liquid fuels and LPG, and ensuring energy security by utilizing the state's estimated 28.18 billion cubic meters of local gas reserves by 2024. The policy outlines several important highlights: it mandates the conversion of state-owned buses to CNG, promotes PNG usage in high-emission industries such as tea estates and brick kilns, and introduces a Single Window System to facilitate timely permissions for pipeline laying and other project needs. Additionally, it encourages local employment by requiring CGD service providers to employ 80% of their workforce from within Tripura and mandating planning for land earmarked for future CNG station development. Operationally, the policy identifies major authorized operators, such as the TNGCL and North East Gas Distribution Company Limited (NEGDCL), and delineates service areas (GAs), including Agartala and surrounding districts. It also incorporates safety standards mandated by national bodies and establishes a grievance redressal mechanism that requires CGD providers to address public complaints within three working days.

Punjab

The Punjab policy, established in 2018 and updated for 2025, outlines the framework for laying gas pipelines on government and local authority lands[17]. Key components include guidelines for RoU, with licensed entities approved by the PNGRB allowed to lay pipelines. Applications for permission must be processed within 90 days, and Ground Penetrating Radar (GPR) surveys are required. Financially, a rent of ₹50 per running meter for government land is mandated, along with restoration costs that escalate by 5% annually. A single-window system aims to streamline approvals, and the licensee is responsible for public safety during pipeline installation. The policy also emphasizes clean energy integration, with a focus on CBG, and mandates that industries switch to PNG while reducing VAT on NG to promote adoption.

West Bengal

West Bengal's Policy applies to all state departments and local authorities that approve and facilitate the expansion of city gas networks by licensed CGD operators[18]. The policy aims to streamline the deployment of PNG and CNG pipelines, ensuring uniformity in permission granting, restoration charges, and land-use fees across different towns. The key objectives include facilitating the delivery of cleaner fuel, reducing urban pollution, and aligning with broader environmental goals. Key provisions of the policy include a single-window process for obtaining necessary approvals, the establishment of RoU framework for public land access, and defined charges for road restoration when pipelines are installed. Implementation guidelines mandate that licensed CGD operators comply with specific licensing and technical requirements, while permissions granted are only enabling and do not extend beyond what is specified in the licenses. The policy aligns with PNGRB directives and supports India's initiative to establish an NGG. It supports national clean energy initiatives, such as the Urja Ganga project and the Ujjwala Yojana. It facilitates CGD growth in underserved urban and semi-urban areas by establishing a clear, transparent framework for pipeline rollout and management.

Assam

The scope and objectives of Assam's CGD policy introduce infrastructure as a utility service, aimed at promoting a gas-based economy[19]. The initiative focuses on providing eco-friendly, cost-effective supplies of PNG and CNG across domestic, industrial, commercial, and transport sectors. It applies statewide, excluding areas under the Sixth Schedule until local authority concurrence is obtained. The implementation relies on coordinated efforts from state-level nodal authorities and district magistrates to handle permissions and ensure smooth operations. Service providers can apply through a single-window system, necessitating timely authorization and adherence to defined timelines for road usage and restoration procedures. Pipeline installation methodologies are detailed, specifying open-cut techniques for minor roads and HDD for larger thoroughfares. Restoration options are categorized, and associated fees are subject to periodic review. The policy emphasizes the establishment of utility corridors for streamlined planning and pipeline installation, supported by monitoring committees and grievance redressal mechanisms to facilitate access to clean energy. A governance framework ensures transparency and efficiency, helping expedite CGD deployment in Assam.

Haryana

Haryana's proposed CGD Policy focuses on expanding NG infrastructure by attracting public-private investment and streamlining approvals through a single-window system. Key objectives include accelerating the installation of PNG pipelines, establishing CNG stations, promoting cleaner energy alternatives, and enhancing energy security. The policy will be implemented by the Industries and Commerce Department, offering incentives, ensuring fair competition among distributors, and providing a transparent operational framework. Overall, this initiative aims to create a robust gas network, making cleaner energy more accessible while positioning Haryana as an attractive energy investment hub.

These policies are designed to expand PNG use in households and establish CNG stations, promoting NG as a cleaner alternative to more polluting fuels. Additionally, the initiatives aim to attract investment and create employment opportunities within the energy sector. Collectively, the states involved

represent a substantial portion of India's population and households, underscoring their importance in the nation's transition to clean energy.

National Biofuel Policy

The National Biofuel Policy 2018 classifies CBG as an "Advanced Biofuel," qualifying it for specific financial support and contributing to energy security by replacing fossil fuels such as LNG and crude oil. The policy promotes a circular economy by converting organic waste into clean fuel, thereby reducing greenhouse gas emissions. Initiatives like SATAT aim to establish approximately 5,000 CBG plants, targeting a production goal of 15 million tonnes. The mandatory CBG blending obligation has fixed a 5% CBG blending target for NG by 2028-29. This would potentially drive ₹37,500 crore in investments and establish around 750 CBG plants. Financial assistance is available for biomass aggregation and pipeline infrastructure to support the growth of CBG production. OMCs are actively partnering with entrepreneurs to launch CBG plants, with significant LOIs already issued. The strategic impacts of this initiative include reducing imports and GHG emissions, improving scientific waste management, and supporting rural economies. This is manifested by the fact that in FY 2024-25, 31.9 TMT of CBG blending was achieved, while in the current FY till November 2025, a total of 42.4 TMT of blending occurred. As such CBG substantiates the domestic production thereby promoting energy security and energy transition.

Overall, the policy fosters a sustainable waste-based fuel economy, enhances India's energy security by reducing fossil fuel dependency, diversifies energy sources through domestic and advanced biofuels, supports rural economies, and advances climate goals—thus driving a long-term energy transition while enhancing India's energy independence.

Conclusion

Energy security[20] and energy transition within India have emerged as pivotal components of the nation's leadership agenda to achieve Vikshit Bharat @2047. However, energy security and sustainability are interrelated, as energy consumption emissions significantly contribute to global climate change. Energy security comprises two primary dimensions: long-term and short-term[21]. The long-term dimension addresses investments in energy supply and their relationship to timely economic developments and environmental requirements. As such, investment in NG infrastructure supports this dimension. The short-term dimension primarily addresses the energy system's capacity to respond swiftly to abrupt fluctuations in the energy supply and demand cycle. It is seen that there has been a sudden rise in sale of CBG from 11.2 TMT in FY 2022-23 to 41.5 TMT in current FY 2025-26 till Oct 2025, reflecting systems capacity and customers acceptance to adopt this new source of gas.

The Indian energy security concerns centre on energy-producing raw materials, emphasising national and human security. It employs the 4-A framework comprising Availability, Accessibility, Affordability, and Acceptability to delineate energy security[22]. Various factors negatively impact energy security and influence access to energy supplies. Physical factors include the geological availability of fossil fuels, which is often difficult to assess. The cost of exploitation affects the feasibility of production. Technology plays a critical role, as advancements such as fracking in the USA have boosted energy supplies, while advances in renewables, storage, and efficiency improve security. Political factors, including war, geopolitics, political instability, and supply chain disruptions, can also devastate energy

resources or divert investments away from energy initiatives. Additionally, government policies that ensure reliable access to energy resources, reduce dependency on foreign energy sources, and promote sustainable energy practices enhance energy security. These policies often include investments in renewable energy technologies, incentives for domestic production, and strategic partnerships to diversify energy supplies.

The government's vision to transform India into a self-reliant and prosperous economy for Viksit Bharat @2047 focuses on economic growth, technological advancement, infrastructure development, social empowerment, sustainability, and a robust, transparent policy framework with energy security playing a significant role. Accordingly, this article established that state and national policies, in tandem, promote the Long Term Low Carbon Development Strategy, supporting the gas-based economy while setting the stage for an energy transition with NG [6], [23] as a bridge fuel and opening different pathways for Viksit Bharat @2047.

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Omkareshwar Floating Solar Project, Khandwa, Madhya Pradesh

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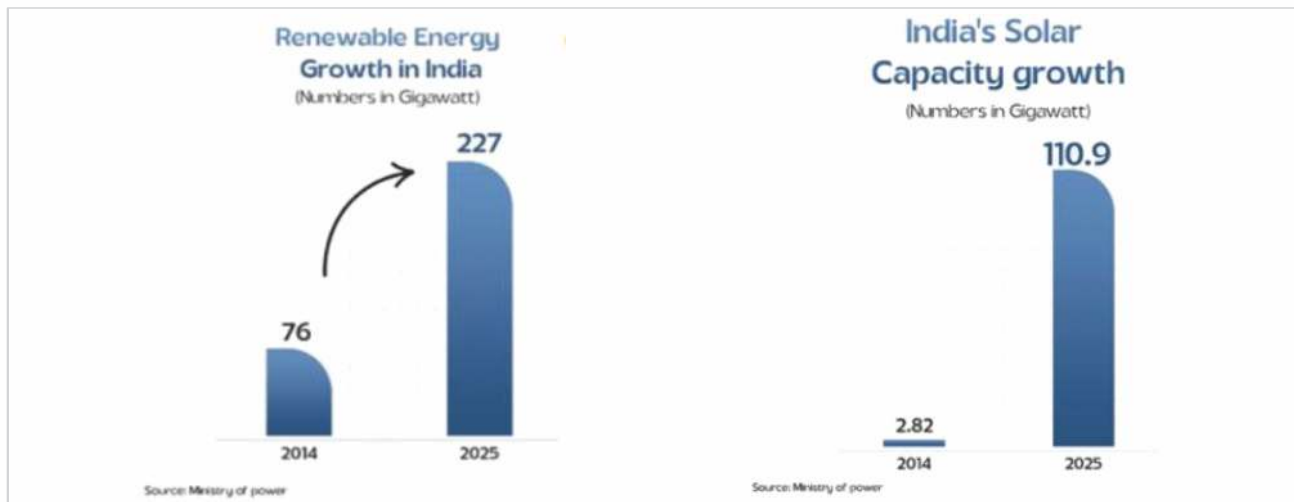
Strong Policy Support for Solar Energy is Advancing India's Energy Security

Solar Energy Corporation of India Limited (SECI)

India's Evolving Energy Landscape: Solar Becomes a Central Pillar

A decisive shift in India's energy landscape has been marked by the steady rise of renewable energy, with solar power having a major share, which has moved from an emerging option to a central pillar of the nation's clean-energy transition, driven by our Nationally Determined Commitments (NDCs).

This transformation has been shaped by deliberate policymaking, strong institutional coordination, and consistent efforts across central and state levels. As solar installations continue to expand, the influence of State Solar Policies has become increasingly visible in guiding investments, supporting project development, and strengthening India's long-term energy security.



Over the years, India's renewable energy sector has benefited deeply from a stable policy environment created by the Government of India, complemented by state governments that have framed their own solar-specific policies to match local needs and resource conditions. This dual approach, has allowed each state to design solar programs aligned with its geography, infrastructure, and economic priorities, while aligning itself with National priorities.

India's solar expansion has been powered not just by demand-supply dynamics, but by a strong, multi-layered policy ecosystem that operates at both the national and state levels. Over the past decade, forward-looking policies have simplified procedures, accelerated approvals, facilitated land access, improved transmission readiness, and created market confidence, enabling solar deployment at a pace and scale unmatched globally.

Policies Driving India's Solar Momentum

India's clean-energy journey was anchored by the National Solar Mission (NSM) launched in 2010, initially targeting 20 GW and later revised to 100 GW by 2022, a milestone that marked India's transition from solar emergence to solar leadership.

As solar adoption grew, national frameworks continued reinforcing demand. The Renewable Purchase Obligation (now Renewable Consumption Obligation) mandated increasing renewable consumption across discoms, industries, and major consumers, ensuring a strong market for developers. To reduce import reliance and build domestic capability, the Production Linked Incentive (PLI) Scheme catalysed gigawatt-scale investments in high-efficiency PV manufacturing.

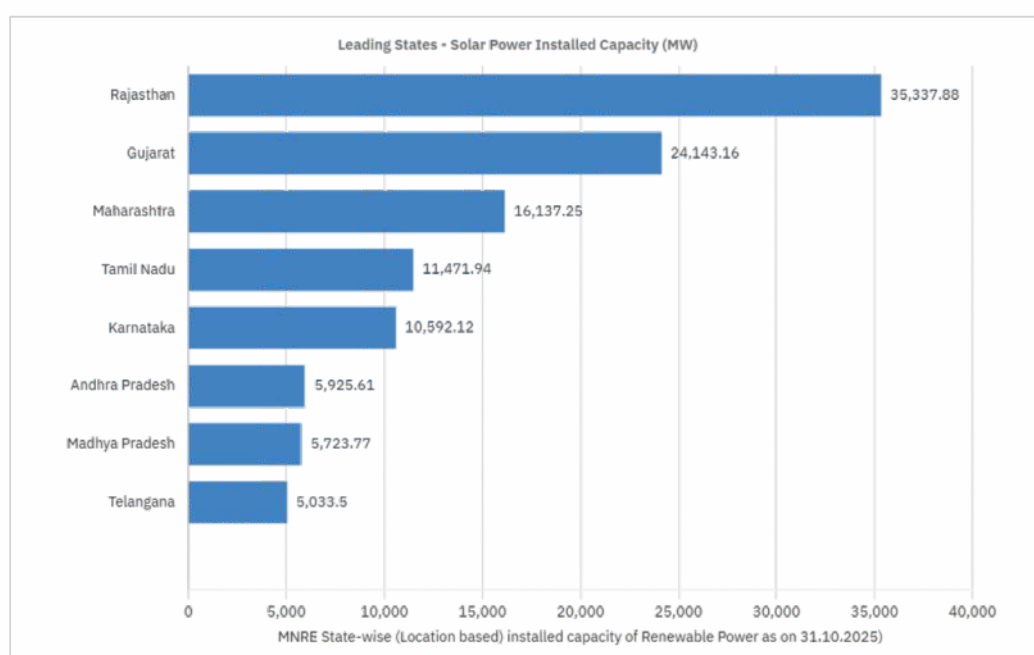
Aligned with its Paris-era climate commitments, India's "Panchamrit" announced at COP26 in 2021 sets ambitious medium-term goals under its updated NDCs. The goals include achieving 500 GW of non-fossil energy capacity by 2030, sourcing 50% of India's energy requirements from renewable energy, reducing the carbon-intensity of GDP by 45% (from 2005 levels), and cumulatively cutting 1 billion tonnes of carbon emissions. These commitments were formally reflected in India's revised NDCs, providing a clear policy framework and long-term direction for clean-energy investments.

Of these goals, India has already crossed a major energy-transition milestone. As of 31 October 2025, more than 50% of the country's installed electricity capacity now comes from non-fossil sources, achieved five years ahead of the 2030 timeline.

To deliver cleaner and more predictable power, the government introduced FDRE (Firm and Dispatchable Renewable Energy) and blended renewable models integrating wind, solar, and storage. FDRE refers to renewable power that can be supplied reliably on demand by combining solar, wind, and storage solutions, ensuring round-the-clock, predictable electricity comparable to conventional power. These frameworks mark India's next phase of renewable evolution, encompassing hybrid systems, standalone and co-located battery storage, pumped hydro, offshore wind integration, and green hydrogen-linked renewable supply.

At the state level, policies designed to encourage both utility-scale and rooftop solar have also played a crucial enabling role. Leading states such as Rajasthan, Gujarat, Karnataka, Andhra Pradesh, Madhya Pradesh, Telangana etc. that have implemented clear frameworks for land allocation, clearances etc. have enhanced ease of doing business for utility-scale project execution and have also demonstrated clean-energy growth on the back of carefully structured policies.

REIAs as Critical Enablers for India's Renewable-Energy Ambitions



The Renewable Energy Implementing Agency (REIA) model forms the backbone of India's large-scale renewable-energy rollout. Under this model, a designated agency is responsible for designing, tendering, contracting, and overseeing renewable-energy projects on behalf of the government. By ensuring transparent auctions, standardised documentation, bankable offtake structures, and coordinated execution between developers, discoms, and state agencies, REIAs significantly reduce counterparty risks and enhance investor confidence. This model has enabled India to scale renewable deployment rapidly while maintaining cost competitiveness and market stability.

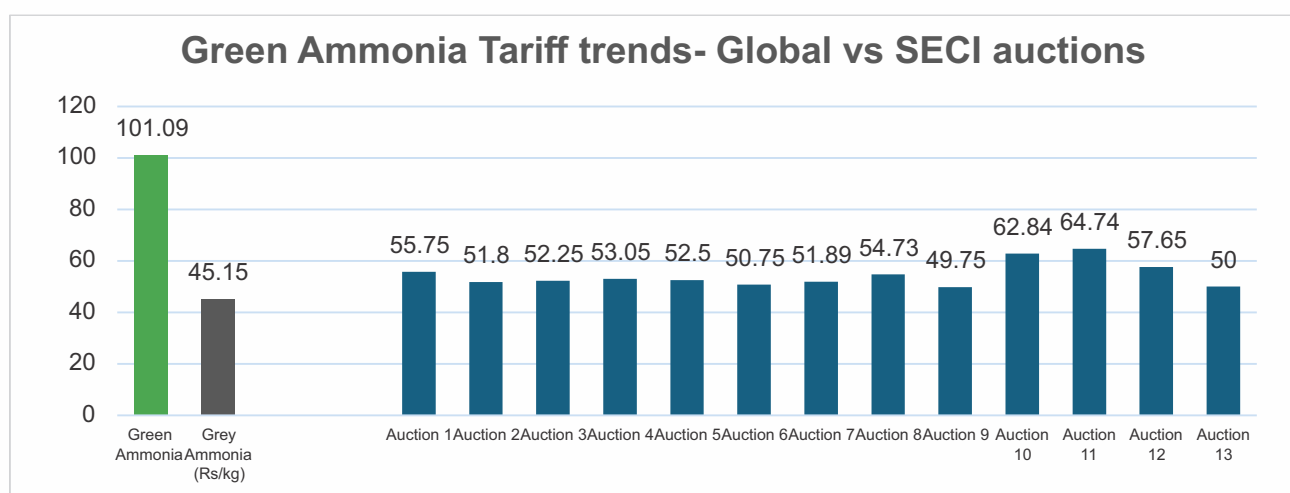
At the centre of this multi-tiered policy ecosystem stands SECI, the country's leading Renewable-Energy Implementing Agency. SECI's activities encompass solar, wind, wind-solar hybrids, Round-The-Clock (RTC) RE, FDRE models, energy storage, green hydrogen, green ammonia, and more. SECI has been consistently delivering some of the world's most competitive renewable tariffs and attracts top global investors into the RE sector. A major contributor to this momentum has been SECI's transparent, technology-agnostic tendering framework, long-term offtake assurance, and strong payments track

record, which have further reduced counterparty risk for developers and financiers—deeply strengthening market trust.

Outlook: Strong Policy-push as the Backbone of India's Solar Future

As India advances toward its long-term clean-energy milestones, including the national commitment to achieve Net Zero by 2070, renewable-energy, especially solar policies will remain central to shaping on-ground outcomes. The country's progress toward a resilient power ecosystem, clean, stable, affordable, and domestically anchored, depends on continued synchronisation between state-level frameworks and the national vision. As Renewable Energy attains a larger share in the country's electricity generation, policy-driven initiatives for strengthening grid integration, such as energy storage, hybrid/FDRE projects, transmission growth alignment, market-based supply models and greening of energy-intensive segments such as transport and industries etc. are enabling the next phase of renewable growth.

A strong push in that direction has come through SECI's recent Green Ammonia auctions, which were designed to accelerate the production of domestically sourced, low-carbon ammonia for India's fertiliser sector. Through these tenders, SECI discovered competitive tariffs (as low as ₹ 49.75/- per kg) that reflect the falling cost of renewable-energy-based hydrogen and ammonia production. These auctions not only secure a cleaner feedstock supply for multiple fertiliser industries but also create early market demand that is essential for scaling India's green-hydrogen ecosystem.



SECI's experience across India's diverse geographies and regulatory environments has repeatedly shown that predictable and transparent policies reduce project risks, accelerate commissioning, and foster a more competitive and innovation-driven renewable-energy market. Supportive policies around land allocation, right-of-way, transmission connectivity, banking, open access, and hybridization have made it possible for large-scale tenders to translate into real-world assets at speed and scale.

Looking ahead, India's transition toward energy self-reliance and Net Zero will advance with continued momentum, strengthened by SECI's market-making role. As the anchor institution shaping India's renewable pipeline from electrons to molecules, SECI remains at the forefront of building a cleaner, more resilient, and globally competitive energy future for the country.



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Does Economic Growth Still Drive POL Product Consumption in India? Evidence from a State-Level Assessment

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Shri Hrithik Sen (Corporate Strategy)

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Introduction

Ensuring energy security in a large and diverse economy like India requires looking beyond national averages to understand how state-level economic growth shapes petroleum product demand. While the relationship between Real Gross State Domestic Product (GSDP) and petroleum product (POL) consumption is generally strong and well established, national trends can mask important regional differences. Over FY15–25, India recorded average real GDP growth of about 6%, alongside POL

consumption growth of around 3.7%, reflecting the continued importance of petroleum products in supporting economic activity, even as POL consumption grew at a slower pace than overall economic growth. This divergence at the national level highlights the need to examine how economic growth translates into POL consumption across states.

The analysis shows that patterns of economic growth across states shifted significantly between the pre-COVID period (FY 15-19) and the post-COVID recovery phase (FY 23-25). Growth, which was earlier concentrated in a limited number of states, became more dispersed in the post-COVID period, supported by higher capital expenditure and infrastructure-led expansion. The central objective of this study is to assess whether this shift in economic growth is reflected in a corresponding shift in petroleum product consumption across states.

2. How Closely Does a State's POL Products Consumption Follow Its Gross State Domestic Product (GSDP)?

This section examines how closely petroleum product (POL) consumption follows GSDP across Indian States and Union Territories. The analysis covers **33* States and UTs over the period FY15 to FY25**, using POL consumption as an indicator of energy demand and Real Gross State Domestic Product (GSDP) as a measure of economic activity. A **panel regression approach** is used to account for differences across States and UTs as well as changes over time.

The results indicate a **very strong and consistent relationship** between Real GSDP and POL consumption. Nearly **88% of the variation in POL consumption across States and UTs is explained by changes in GSDP**, showing that POL demand moves closely in line with GSDP. In simple terms, when a State or UT's economy expands, its consumption of petroleum products almost always increases.

Panel Regression Results: (POL Consumption in TMT and GSDP in Lakhs)

Description	Result	What it Means
Model used	Random Effects Panel Model	Accounts for differences across States and UTs over time
Time period	FY15 to FY25	10 Year
States & UTs	33*	Balanced panel
R-squared	0.88	About 88% of changes in POL consumption are explained by GSDP
Relationship between Real GSDP and POL	Highly Positive	Higher economic output leads to higher POL consumption
Statistical strength	Very strong	Relationship is highly reliable
Overall model significance	$p < 0.001$	Statistically significant - Results are not due to chance

Source: Author's Calculation using R. Data Source: PPAC, RBI.

** Note: Ladakh, Dadra & Nagar Haveli and Daman & Diu, and Lakshadweep are not included in the analysis due to the non-availability of GSDP data.*

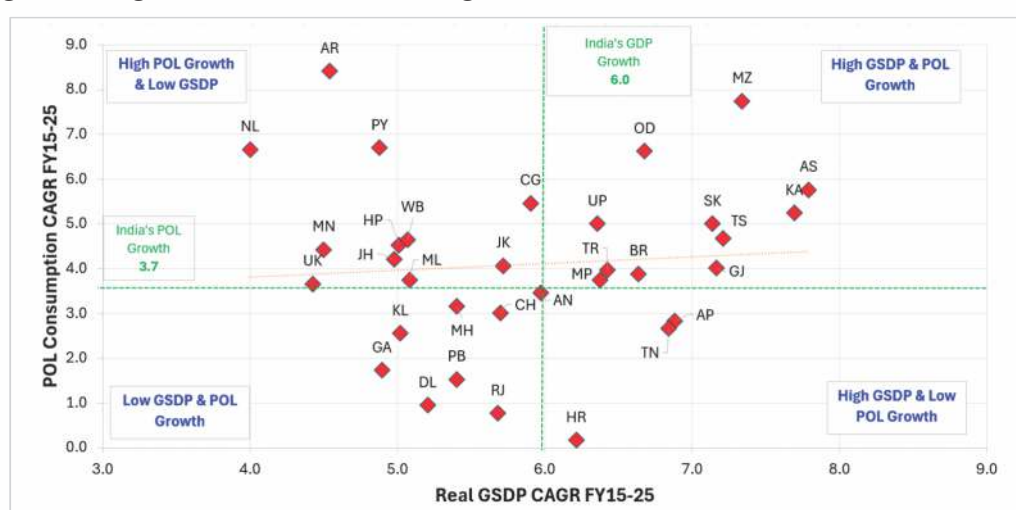
This strong link reflects the continued reliance of economic activity on petroleum fuels. As economies grow, higher transport demand, industrial production, and construction activity lead to increased POL consumption. Overall, the analysis confirms that **POL consumption remains closely aligned with GSDP across Indian States and UTs.**

3. Did Economic Growth Become More Evenly Distributed Across States post-COVID?

India's state-wise assessment compares FY15–25 CAGR of petroleum product (POL) consumption with real GSDP growth, benchmarked against national averages of 3.7% for POL consumption and 6.0% for GDP.

State-wise Real GSDP and POL Consumption Growth Matrix (FY 15-25)

Positioning States Against the All-India Average



Source: Author's Calculation, Data Source: PPAC, RBI

India's economic growth story has undergone a visible shift over the past decade, not just in pace, but in **who is driving the growth**. A comparison of state-wise growth patterns pre and post COVID shows a clear movement away from growth being concentrated in a few large states toward a more **broad-based and dispersed growth structure**.

To understand this shift, states are grouped by two dimensions:

- **Economic base** (share of GSDP), and
- **GSDP Growth rate** (CAGR – FY 15-19 vs FY 23-25).

This framework helps distinguish between **large economies growing steadily** and **smaller economies catching up rapidly**.

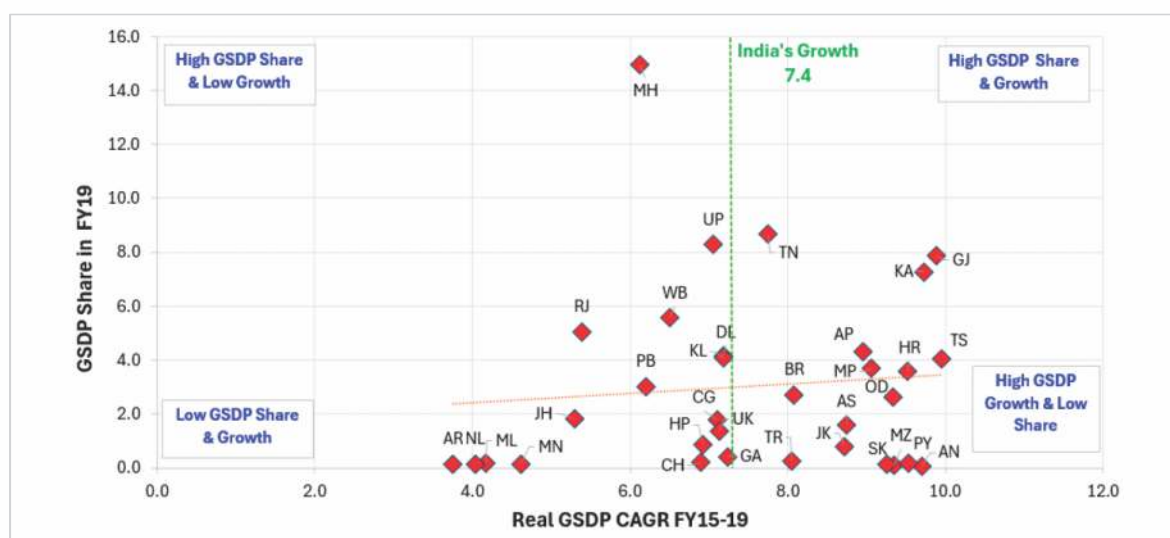
Pre-COVID Growth Pattern: Concentrated and Predictable (FY15–19)

All India GDP CAGR: 7.4%

In the pre-COVID period, economic growth was largely anchored in a limited set of high-base states. Large contributors to national output such as Maharashtra, Tamil Nadu, Uttar Pradesh, Gujarat, and Karnataka dominated both in terms of size and growth momentum.

Big states grew steadily, small states followed, and the growth hierarchy remained largely unchanged.

Positioning States' GSDP Share Against GSDP Growth Relative to the All-India Average



Source: Author's Calculation, Data Source: RBI

India's GDP CAGR FY 15-19 - 7.4%				
Share of GSDP in Total vs GSDP Growth (FY 15-19)		Gross State Domestic Product (GSDP Growth)		
		High Growth ($\geq 8\%$)	Moderate Growth (6-8%)	Low Growth ($\leq 6\%$)
Share of GSDP	High Base ($\geq 5\%$)	Gujarat, Karnataka	Maharashtra, Tamil Nadu, Uttar Pradesh, West Bengal	Rajasthan
	Moderate Base (2-5%)	Andhra Pradesh, Bihar, Haryana, Madhya Pradesh, Odisha, Telangana	Delhi, Kerala, Punjab	
	Low Base ($< 2\%$)	Andaman & Nicobar, Assam, Jammu & Kashmir, Mizoram, Puducherry, Sikkim, Tripura	Chandigarh, Chhattisgarh, Goa, Himachal Pradesh, Uttarakhand	Arunachal Pradesh, Jharkhand, Manipur, Meghalaya, Nagaland

Source: Author's Calculation,

Data Source: RBI

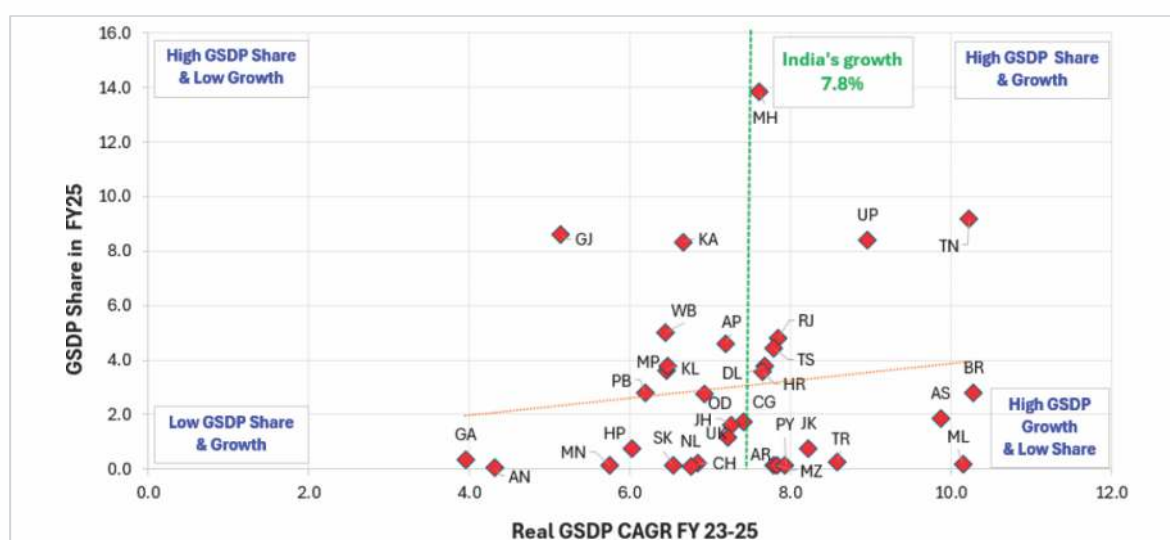
Post-COVID Recovery Growth Pattern: Broader and More Evenly Spread (FY 23-25)

India GDP CAGR: 7.8%

In the post-COVID recovery period, economic growth became more evenly distributed across states. Growth extended beyond a few high-base states, with several moderate- and low-base states recording strong expansion alongside larger economies, indicating a shift toward a more balanced growth pattern.

Big states continued to grow, but smaller and mid-sized states closed the gap, making growth more evenly distributed.

Positioning States' GSDP Share Against GSDP Growth Relative to the All-India Average



Source: Author's Calculation, Data Source: RBI

India's GDP CAGR FY 23-25 - 7.8%				
Share of GSDP in Total vs GSDP Growth (FY 23-25)		Gross State Domestic Product (GSDP Growth)		
		High Growth ($\geq 8\%$)	Moderate Growth (6-8%)	Low Growth ($\leq 6\%$)
Share of GSDP	High Base ($\geq 5\%$)	Tamil Nadu, Uttar Pradesh	Karnataka, Maharashtra	Gujarat
	Moderate Base (2-5%)	Bihar	Andhra Pradesh, Delhi, Haryana, Kerala, Madhya Pradesh, Odisha, Punjab, Rajasthan, Telangana, West Bengal	
	Low Base ($< 2\%$)	Assam, Jammu & Kashmir, Meghalaya, Tripura	Arunachal Pradesh, Chandigarh, Chhattisgarh, Himachal Pradesh, Jharkhand, Mizoram, Nagaland, Puducherry, Sikkim, Uttarakhand	Andaman & Nicobar, Goa, Manipur

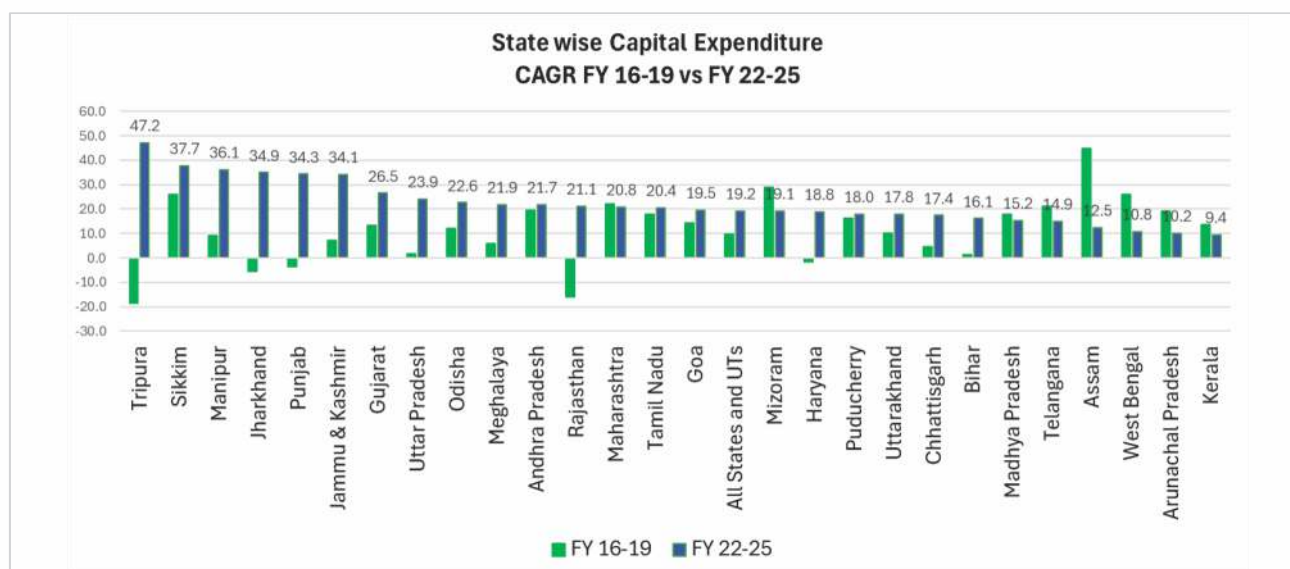
Source: Author's Calculation,

Data Source: RBI

4. What Drove This Shift? The Role of Capital Expenditure

Post-COVID growth dispersion closely aligns with a sharp rise in **state-level capital expenditure**. Investment in roads, infrastructure, and connectivity increased across states, with several smaller and mid-sized economies recording faster capex growth than larger states.

This investment push helped narrow inter-state growth gaps, making **public spending a key driver of more balanced growth.**



Source: Author's Calculation, Data Source: RBI

How State-Level Capital Expenditure Growth Varies by Economic Size (FY22–25)

Share of GSDP in Total vs Capital Expenditure (FY 22-25)		Capital Expenditure Growth		
		CAGR ($\geq 30\%$)	CAGR (20-30%)	CAGR ($\leq 20\%$)
Share of Gross State Domestic Product (GSDP)	High Base ($\geq 5\%$)		Gujarat, Maharashtra, Tamil Nadu, Uttar Pradesh	Karnataka
	Moderate Base (2–5%)	Punjab	Andhra Pradesh, Odisha, Rajasthan	Bihar, Delhi, Haryana, Kerala, Madhya Pradesh, Telangana, West Bengal
	Low Base ($< 2\%$)	Jammu & Kashmir, Jharkhand, Manipur, Sikkim Tripura	Meghalaya	Andaman & Nicobar Islands, Arunachal Pradesh, Assam, Chandigarh, Chhattisgarh, Goa, Himachal Pradesh, Mizoram, Nagaland, Puducherry, Uttarakhand

Source: Author's Calculation, Data Source: RBI

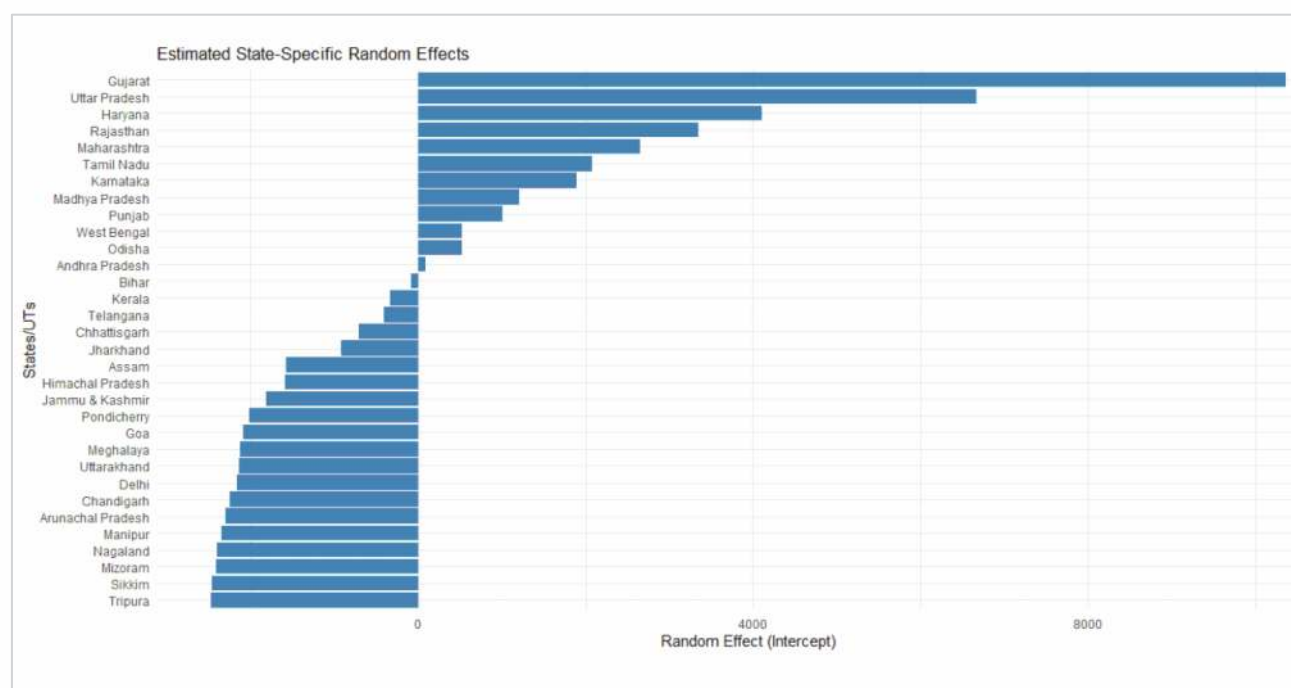
5. What Growth Dispersion Means for POL Consumption

As economic growth becomes more evenly distributed across states, it is important to assess whether petroleum product consumption has shifted in the same way. The study shows that this is only partly true. Nearly **88%** of the variation in POL consumption across States and UTs is explained by changes in Real GSDP, and states with larger and faster-growing economies generally consume more fuel.

However, states with similar economic size often show very different fuel consumption levels. **This indicates that POL Consumption depends not only on economic growth, but also on state-specific structural factors such as industrial mix, transport intensity, infrastructure, geography, energy policies, and the penetration of alternative fuels.**

As a result, even with more balanced economic growth, petroleum consumption continues to be shaped by state-specific structural characteristics and policy factors, rather than economic growth alone.

State-Specific Variations in Petroleum Consumption after adjusting GSDP (in TMT): Analysis Using a Random Effects Panel Regression*



Source: Author's Calculation, Data Source: PPAC, RBI.

#The random effects intercept (in TMT) shows whether a state uses more or less petroleum than average, beyond what economic size alone would suggest.

The chart shows how each state's petroleum consumption differs from the national average after adjusting for economic size. States above the zero line consume more fuel than expected, reflecting higher industrial activity and transport intensity, while states below the line consume less due to structural and geographical factors. This indicates that petroleum demand is influenced not only by economic growth, but also by state-specific structural and policy characteristics.

6. Association Between GSDP Growth and POL Consumption Growth of Indian States

To assess whether changes in the distribution of economic growth across states have been accompanied by a similar shift in petroleum consumption growth, Spearman's rank correlation is used. This approach compares state rankings rather than absolute values, allowing us to examine whether states that have grown faster economically have also experienced faster growth in fuel consumption.

Correlation results:

Study variables	Spearman's Rank Correlation	Interpretation
Proportional GSDP Growth vs Proportional POL Consumption Growth	0.45	Moderate positive relationship.

Source: Author's Calculation, Data Source: PPAC, RBI

The rank correlation of 0.45 indicates a moderate association between state-level GSDP growth and POL product consumption growth, suggesting that faster economic expansion is generally accompanied by higher POL product consumption, though the relationship is not uniform across states.

The wide dispersion around this trend indicates that economic growth alone does not fully explain inter-state variations in POL product consumption. Differences in economic structure, urbanisation and transport intensity, the pace of clean energy adoption, and state-specific policy frameworks play a significant role in shaping POL product consumption patterns.

Conclusion

The study shows that petroleum product consumption across Indian States and UTs is strongly linked to the level of economic activity. States with larger economies consume more petroleum products, but the rate at which petroleum demand grows differs across states. This indicates that economic growth alone does not fully explain changes in fuel consumption.

Differences in industrial structure, transport use, infrastructure, energy transition progress, state VAT and state policies influence how petroleum demand evolves. These findings highlight the scope for further studies to examine state-level factors and sector-specific drivers in order to improve petroleum demand estimation and support more effective fuel planning and long-term energy security.

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Puga Valley, Ladakh- Geothermal Site

21

Assessing State Energy Policies for Advancing India's Energy Security

Shri Nikhil Moghe

Partner – Oil & Gas & Low Carbon Fuels, KPMG

1. Executive Summary

India's energy sector has undergone a remarkable transformation over the past decade, underpinned by robust demand growth and a series of decisive policy interventions aimed at scaling up non-fossil energy capacity. Official statistics underscore a sustained upward trajectory in Total Primary Energy Supply (TPES), which has increased at a CAGR of $\sim 4\%^2$ over the last ten years. Per capita energy consumption has also risen steadily, from 22,434 MJ/person in FY 2014-15 to 27,574 MJ/person in FY 2023-24.³

² IEA, years considering from 2013-2023, India - Countries & Regions - IEA

³ Energy Statistics India 2025_27032025.pdf

On the supply side, renewable electricity capacity has expanded from 76.37 GW in March 2014 to 226.79 GW in June 2025, reflecting the country's commitment to a cleaner energy mix.⁴ However, despite these advances, India remains acutely exposed to the volatility of global fuel markets. Crude oil import dependence exceeds 85%, LNG imports account for approximately 50%⁵ of domestic gas consumption, and coal imports though a smaller proportion (21%)⁶ relative to domestic production tend to spike seasonally.

This context highlights the imperative for a more resilient energy system, anchored in state-led execution that expands clean, indigenous energy sources, builds flexible grids and storage solutions, and accelerates both efficiency and electrified mobility.

2. Powering India's Progress: Unpacking the Forces Fueling the Nation's Surging Energy Demand

India's energy landscape is in the midst of a profound transformation, shaped by rapid economic growth, ambitious industrialization, accelerating urbanization, large-scale infrastructure expansion, and a sweeping digital revolution. State energy policies are pivotal in translating these macro trends into actual energy demand, ensuring that growth remains sustainable, secure, and inclusive. The following section highlights the principal drivers of energy consumption and the policy responses required at the state level.

2.1. Industrialization and “Make in India”

The industrial sector is the single largest consumer of electricity in India, accounting for a significant share of total energy demand. The Government of India's “Make in India” initiative aspires to position the country as a global manufacturing powerhouse by fostering investment, innovation, and infrastructure development across 27 sectors including electronics, automotive, renewable energy, and data centers. State-level incentives and tailored policies are instrumental in attracting investment and nurturing industrial clusters, which in turn drive up energy consumption for manufacturing, logistics, and value-added services. The government's emphasis on self-reliance (Atmanirbhar Bharat) and production-linked incentives for sectors such as solar PV, batteries, and green hydrogen is further accelerating industrial energy demand, particularly in states with proactive policy frameworks and robust infrastructure.

2.2. Urbanization

India is experiencing one of the fastest rates (35% in 2024)⁷ of urbanization globally. According to IEA, migration from rural to urban areas is driving increased demand for electricity across residential, commercial, and municipal segments.⁸ Urban households are adopting more energy-intensive appliances, air conditioning, and electric vehicles, while commercial buildings and smart cities require reliable, high-quality power supply. National schemes such as Saubhagya Yojana and Deendayal Upadhyaya Gram Jyoti Yojana have accelerated electrification, but the resulting urban load growth now

⁴ Press Note Details: Press Information Bureau

⁵ Consumption | Petroleum Planning & Analysis Cell | Government of India

⁶ Press Note Details: Press Information Bureau

⁷ Urban population (% of total population) - India | Data

⁸ Urbanisation and industrialisation in India India Energy Outlook 2021 Analysis - IEA

necessitates enhanced grid management, demand-side management, and energy efficiency measures. State energy policies must address urban energy poverty, promote efficient building codes, and support distributed renewable energy solutions in cities.

2.3. Infrastructure Development

India's infrastructure drive spanning roads, highways, railways, airports, ports, and dedicated freight corridors has emerged as a major catalyst for energy demand. The National Infrastructure Pipeline (NIP) and PM Gati Shakti Master Plan are enabling large-scale investments in physical, digital, and social infrastructure. Construction activity increased vehicular traffic and expanded logistics networks are collectively raising demand for electricity, diesel, and alternative fuels. States play a critical role in project execution, land acquisition, and policy alignment. The government's focus on public-private partnerships and urban infrastructure funds is empowering states to invest in critical infrastructure, thereby locking in higher energy demand for decades to come.

2.4. Data Centers and Digitalization

The exponential growth of India's digital economy is fueling a surge in data center construction and operations. Data centers are among the most energy-intensive facilities, requiring uninterrupted power for servers, cooling, and backup systems. According to the Institute for Energy Economics and Financial Analysis (IEEFA), the IT sector's energy footprint is rising rapidly, and electricity consumption by data centers is projected to increase by more than 200 times by 2030⁹. The government is finalizing a national data center policy, and several states including Tamil Nadu, Uttar Pradesh, Telangana, West Bengal and Odisha¹⁰ have introduced dedicated data center policies to attract investment. State energy policies must facilitate reliable grid connections, promote open access to renewable energy, and incentivize energy-efficient data center design and operation.

2.5. Exports and Global Integration

India's export-oriented growth strategy, underpinned by the “Make in India” and “Make for the World” initiatives, is expanding industrial output and logistics. Export zones, logistics parks, and integration with global supply chains are increasing localized energy demand and raising the need for reliable, high-quality energy. States such as Karnataka, Rajasthan and Gujarat that have aligned their energy policies with global standards, and sustainability requirements will be better positioned to attract investment and drive export-led growth.

3. Bridging Ambition and Action: The State-Central Blueprint for India's Sustainable Future

India's ambitious economic and social development agenda demands a robust, diversified, and sustainable energy supply. To meet the rising demand outlined above, the Government of India has enacted a comprehensive suite of enabling policies spanning renewables, biofuels, and emerging technologies such as green hydrogen. States are pivotal in operationalizing and localizing these policies, ensuring that national objectives are achieved with regional relevance and effectiveness.

⁹ *Indias power-hungry data centre sector at a crossroads | IEEFA*

¹⁰ *data-centre-policies-in-india-a-statewise-comparison.pdf*

3.1. Renewable Energy

India's renewable energy expansion is anchored by central policies such as the National Solar Mission, Renewable Purchase Obligations (RPOs), and Green Energy Open Access Rules. States are instrumental in translating these frameworks into action. For instance, Rajasthan and Gujarat have not only met but exceeded their RPO targets, leveraging state solar and wind policies that provide land, single-window clearances, and transmission incentives. Karnataka's solar policy supports both rooftop and utility-scale projects, aligning with central goals while tailoring incentives to local conditions. Tamil Nadu's leadership in wind energy is a direct result of proactive state policies that complement central schemes with state-specific feed-in tariffs and grid integration support. States like Maharashtra and Uttar Pradesh have launched solar agricultural feeder programs, directly supporting the central KUSUM scheme for solarizing agriculture. In many cases, state nodal agencies (e.g., GEDA, RRECL, KREDL) serve as the operational arms for central schemes, ensuring effective on-ground implementation and stakeholder engagement. Where states possess unique renewable resources such as offshore wind in Tamil Nadu or solar parks in Madhya Pradesh, they have developed independent policies that nonetheless contribute to national targets.

3.2. Biofuels

The National Policy on Biofuels sets ambitious blending targets for ethanol and biodiesel, but its success is contingent on state-level facilitation. Maharashtra, Uttar Pradesh, and Karnataka India's leading sugarcane producers have streamlined licensing for ethanol distilleries, provided fiscal incentives, and promoted contract farming for feedstock, directly supporting the central Ethanol Blended Petrol (EBP) Programme. Several leading states have introduced progressive biofuel policies with strong, quantifiable incentives to promote Compressed Biogas (CBG) as part of their clean energy transition. Uttar Pradesh's Bio-Energy Policy 2022 offers a capital subsidy of up to ₹75 lakh per tonne of CBG capacity (capped at ₹20 crore per project), 100% exemption on stamp duty and electricity duty, and government land at nominal lease rates to incentivize CBG plant development. Bihar's amended biofuel policy provides a 15% capital subsidy on plant and machinery for CBG projects, with land made available in industrial areas and incentives granted on a first-come, first-served basis to encourage private sector participation and rural waste-to-wealth conversion. Andhra Pradesh's Integrated Clean Energy Policy 2024–2029 targets the establishment of 10,000 TPD of Bio-CNG/CBG capacity, offering single-window clearance, deemed non-agricultural status for CBG projects, exemption from statutory land conversion charges, capital subsidies for clean energy manufacturing, and off-take guarantees to ensure market access. Collectively, these state policies not only align with central government objectives but also create enabling environments for rapid CBG sector growth, rural development, and sustainable waste management. These state actions not only help meet national blending targets but also create rural employment and reduce air pollution.

3.3. Green Hydrogen

The National Green Hydrogen Mission provides an overarching framework for scaling up green hydrogen production and electrolyzer manufacturing. States are rapidly aligning their industrial and energy policies to attract investment in this emerging sector. Gujarat and Maharashtra have announced dedicated green hydrogen policies, offering land, water, and infrastructure support for pilot projects and manufacturing hubs directly supporting the central mission's targets. Andhra Pradesh and Tamil Nadu

are developing port-based green hydrogen clusters, leveraging their coastal advantages and aligning with central export ambitions. Rajasthan's renewable energy surplus is being positioned to supply green hydrogen projects, with state-level facilitation for grid connectivity and water access. These state initiatives are not only in sync with central policy but are also fostering regional competition and innovation, accelerating India's green hydrogen roadmap.

4. Powering Progress: How State-Central Synergy is Shaping India's Energy Security

India's journey toward energy security and sustainability is a compelling demonstration of the power of cooperative federalism and strategic foresight. Over the past decade, the nation has not only achieved a remarkable expansion in energy supply and access but has also shown an exceptional ability to adapt to the evolving contours of global energy markets and domestic aspirations. The interplay between robust central policy frameworks and dynamic, locally tailored state initiatives has been the bedrock of this transformation.

At the heart of India's energy evolution is the recognition that the drivers of demand industrialization, urbanization, infrastructure growth, digitalization, and global integration are both opportunities and challenges. The central government has responded with a suite of forward-looking policies: scaling up renewables through the National Solar Mission and RPOs, accelerating biofuel adoption, pioneering the National Green Hydrogen Mission, and modernizing the regulatory and investment environment for conventional energy. Yet, it is at the state level where these ambitions are translated into reality. States have not only operationalized central schemes with agility and innovation but have also set new benchmarks by exceeding targets, piloting new business models, and addressing region-specific needs be it through solar parks in Rajasthan, ethanol clusters in Maharashtra, green hydrogen hubs in Gujarat, or digital infrastructure corridors in Karnataka.

This synergy is not merely administrative; it is strategic and catalytic. States act as laboratories for policy experimentation, adapting central guidelines to local resource endowments, industrial strengths, and social priorities. Where central policies provide scaffolding, state actions fill in the detail streamlining approvals, incentivizing investment, and building capacity on the ground. The result is a virtuous cycle: central vision inspires state action, and state innovation, in turn, informs and elevates national policy.

Moreover, the Indian energy policy ecosystem is increasingly characterized by its inclusivity and adaptability. Mechanisms such as joint working groups, regular intergovernmental consultations, and shared funding platforms ensure that best practices are disseminated, and challenges are addressed collaboratively. States are empowered to set more ambitious targets, offer additional incentives, and innovate independently where warranted demonstrating leadership in areas such as electric mobility, distributed renewables, and advanced biofuels.

Looking ahead, India's path to energy security will require continued commitment to this model of partnership and mutual reinforcement. The challenges of import dependence, price volatility, and climate imperatives are formidable, but so too is the nation's capacity for coordinated action and creative problem-solving. By leveraging the strengths of both central and state actors, India is not only securing its energy future but is also laying the foundation for a resilient, inclusive, and globally competitive economy. The Indian experience offers a compelling blueprint for other nations seeking to balance national priorities with regional dynamism in the pursuit of sustainable development.



Diu: India's First daytime 100% renewable energy- Powered city

22

Ensuring Energy Security: Role of Energy Policies of States

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Energy security lies at the core of India's energy trilemma, underpinning long-term economic growth and strategic autonomy while balancing the imperatives of affordability and environmental sustainability. For a fast-growing economy such as India, ensuring uninterrupted access to affordable, reliable, and cleaner energy is much more than a choice but a national imperative. While national-level policies provide the overarching vision and direction, the effective realization of energy security outcomes increasingly depends on the design and execution of energy policies at the state level.

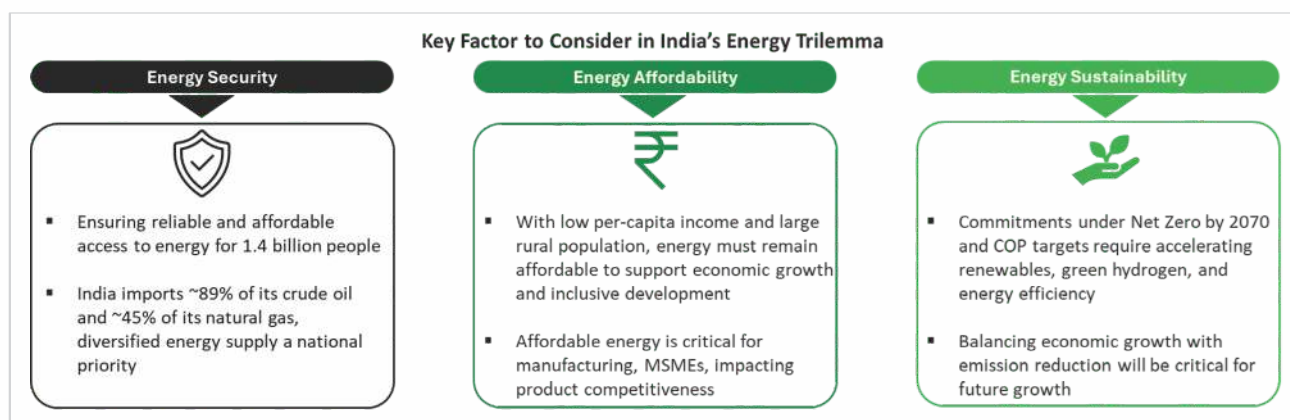


Figure 1: India's Energy Trilemma

India's energy landscape is undergoing a fundamental transformation to align with India's commitments for energy transition along with meeting the rising energy demand. India is seeing rapid growth in electricity demand, transport fuel use, and industrial activity, while also committing to energy independence by 2047 and net-zero emissions by 2070—bringing the challenges of energy security, affordability, and sustainability into sharper focus. This transition is unfolding in a context marked by high import dependence for crude oil, natural gas, and coking coal, exposure to global price volatility, and regional disparities in energy access and infrastructure.

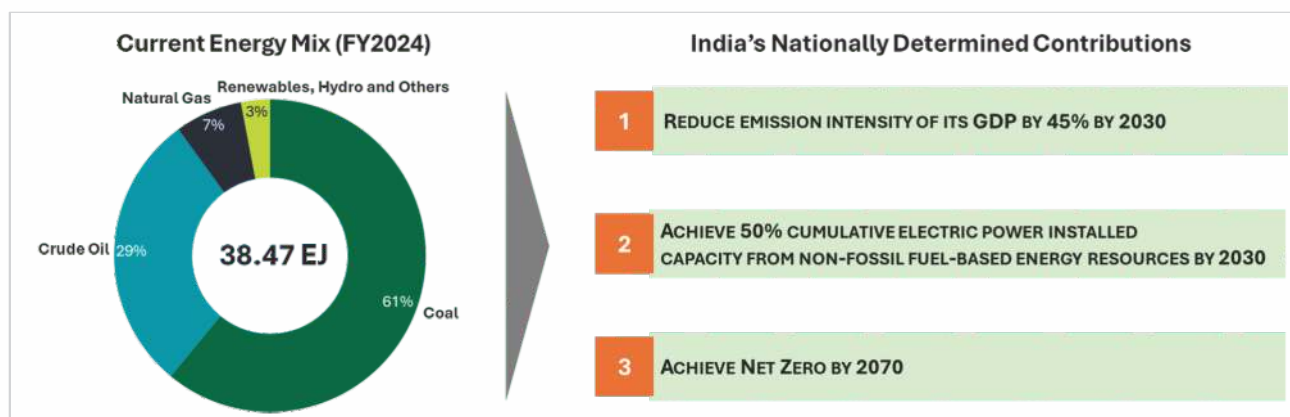


Figure 2: India's Energy Mix and NDC Goals¹

In this evolving scenario, state governments are emerging as key enablers of energy security. States influence energy outcomes through land allocation, power distribution utilities, industrial and fiscal policies, and the implementation of clean energy and alternative fuel programmes. More importantly, states are increasingly tailoring policies to leverage local resources such as solar, wind, biomass, hydrocarbon infrastructure, and industrial demand profiles. This has been instrumental in shaping region-specific energy pathways, policies and regulations.

In this article, we shall examine the overall energy landscape, role of state-level energy policies and key challenges in strengthening India's energy security. We will be drawing on select state-wise case studies, we will highlight how innovative policy frameworks, institutional mechanisms, and public sector participation are contributing in solving India's energy trilemma.

¹ Ministry of Statistics and Program Implementation Publication of Energy Statistics India 2025, BP Energy Statistics, IEA publications

A. India's Evolving Energy Landscape:

India's energy demand has been expanding steadily, driven by urbanisation, industrialisation, rising incomes, and increased electrification. Electricity demand is expected to more than double over the next two decades, while energy requirements from transport, refining, steel, cement, and chemicals are set to grow in tandem with economic activity. At the same time, India remains significantly dependent on imports for its primary energy needs, particularly crude oil and natural gas, exposing the economy to external supply disruptions and price shocks.

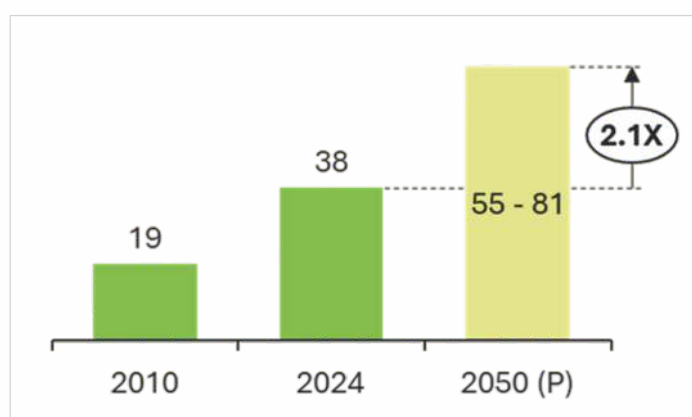


Figure 3: India's Energy Demand (in EJ)²

Recognising these structural challenges, the Government of India has developed a comprehensive policy framework aimed at enhancing energy security. Key initiatives include the National Energy Policy, National Electricity Plan, National Bio-Energy Mission, City Gas, Ethanol Blending Programme, National Policy on Biofuels, National Green Hydrogen Mission, CBG - SATAT and the expansion of Strategic Petroleum Reserves. Collectively, these initiatives seek to diversify the energy mix, promote domestic energy sources, improve efficiency, and accelerate the transition towards cleaner fuels.

Sr. No.	Policy	Sector	Details
1	SATAT ³	Bio-energy - CBG	Incentives to build CBG ecosystem through assured offtake of CBG
2	Green Hydrogen Mission ⁴	Green hydrogen & derivatives	Sets a targets 5 MMT green hydrogen production by 2030. Includes financial incentives for manufacturers of electrolyzers and green hydrogen production
3	National Energy Policy ⁵	Overall energy transition	Prioritizes 50% non-fossil electricity capacity by 2030 and net-zero by 2070.
4	National Electricity Plan ⁶	Electricity transmission & generation	Transmission to support renewables by 2030+, connecting national grid, planning network requirements up to 2032

² Current Energy Consumption – MOSPI Statistics, Projection BP Energy Outlook 2025

³ SATAT (Link)

⁴ Ministry of New and Renewable Energy Publication (link)

⁵ Ministry of New and Renewable Energy Publication (link)

⁶ Ministry of Power Central Electricity Authority (link)

Sr. No.	Policy	Sector	Details
5	National Bio-Energy Mission ⁷	Bio-energy	Aims to convert surplus biomass/urban-industrial waste into energy
6	Ethanol Blending Programme ⁸	Bio-fuels	Aims to reduce dependence on fossil fuels and cut emissions by setting blending mandates for ethanol with petrol across India

However, the diversity of India's geography, resource availability, and economic structure implies that energy security cannot be achieved through a uniform policy approach. Solar-rich desert states, wind-intensive coastal regions, biomass-abundant agrarian states, and industrialised energy-consuming clusters face distinct challenges and opportunities. Consequently, the role of state governments in translating national objectives into actionable and regionally relevant policies has become increasingly critical.

B. Role of State Governments in Strengthening Energy Security

State governments occupy a central position in India's energy ecosystem. They exercise direct or indirect control over land acquisition, power distribution companies (DISCOMs), state electricity regulators, and industrial development agencies. States also influence energy markets through local taxation, fiscal incentives, and demand-side mandates.

Over the past decade, the role of states has evolved from being primarily power allocators to becoming energy system architects. State policies now determine the pace of renewable energy deployment, the commercial viability of clean fuels such as biofuels, compressed biogas (CBG), methanol, and hydrogen, and the attractiveness of states as destinations for energy-intensive investments. Through competitive power tariffs, assured fuel availability, policy stability, fiscal incentives, and timely infrastructure development, states directly influence industrial location decisions in sectors such as refining, chemicals, fertilisers, steel, cement, and emerging clean energy manufacturing. As a result, states shape up the localized energy demand. Industrial procurement policies, public transport electrification, blending mandates, and public sector offtake commitments have emerged as powerful tools to anchor new energy value chains. In this context, state-level innovation is becoming a decisive factor in strengthening India's overall energy security. Commercial outcomes increasingly demonstrate this linkage. Ethanol-focused policies in Maharashtra (e.g. dual feed policy for ethanol production) and UP (Uttar Pradesh State Bio-Energy Policy-2022) have catalysed large-scale investments by sugar mills and distilleries, directly reducing petrol import dependence. Similarly, EV policies in most of the states such as UP, Delhi, Gujarat, etc. support EV adoption through declared targets for new vehicle sales. Few cases studies highlighting the key state level incentives through policy and regulation are shared below.

⁷ Ministry of New and Renewable Energy Publication (Link)

⁸ Ministry of New and Renewable Energy Publication (Link)

Case Studies

Rajasthan: Renewable Energy as a Strategic Asset

Rajasthan Renewable Energy Policy, 2023⁹

The Rajasthan Renewable Energy Policy, 2023 aims to position the state as a leading renewable energy hub by leveraging its strong solar and wind resource base. The policy sets an ambitious target of ~90 GW of renewable capacity by 2030, with a clear focus on large-scale solar, wind-solar hybrid projects, storage solutions (BESS and pumped storage), and decentralized renewable energy. It is aligned with national objectives of energy security, clean energy transition, and India's 2030 and 2070 climate commitments.

A key strength of the policy lies in its investment-oriented incentive framework. Rajasthan offers significant reductions in land-related and project security charges, exemptions or waivers on transmission and cross-subsidy surcharge for eligible projects, and relief on electricity duty and land taxes. Solar parks and renewable energy parks are supported through concessional land allotment and infrastructure facilitation, reducing execution risks. The policy also promotes open access and third-party sale of renewable power, improving project bankability and enabling industrial decarbonisation.

Beyond utility-scale renewables, the policy supports rooftop solar, decentralized systems, and emerging technologies. Simplified approvals, net/gross metering provisions, and DISCOM facilitation encourage residential, commercial, and agricultural solar adoption. Importantly, the policy complements Rajasthan's Green Hydrogen and bioenergy initiatives, creating a broader “new energy” ecosystem.

Policy Aspect	Key Benefit
Financial incentives (tax/charges)	Lowers cost of power generation
Land & infrastructure support	Improves project feasibility
Decentralized & rooftop solar push	Expands access & energy security
Storage & hybrid support	Grid reliability & variability handling
Synergy with green H ₂ & bioenergy	Future energy ecosystem development

Overall, Rajasthan's approach addresses the energy trilemma by strengthening energy security through scale, improving affordability via cost reductions, and advancing sustainability through diversified clean energy deployment.

Uttar Pradesh: Leveraging Biomass to achieve energy security

Uttar Pradesh State Bio-Energy Policy, 2022

The *Uttar Pradesh State Bio-Energy Policy, 2022*¹⁰ is a targeted initiative by the Government of Uttar Pradesh to accelerate the **development of bioenergy enterprises** particularly *Compressed Bio-Gas (CBG)*, *bio-coal*, and *bio-diesel* production in the state. It aligns with broader goals of promoting clean, waste-to-energy solutions, boosting rural incomes, reducing agricultural residue burning, and

⁹ RAJASTHAN RENEWABLE ENERGY POLICY, 2023 ([link](#))

¹⁰ Invest UP Publications ([Link](#))

strengthening energy sustainability through locally available feedstocks. The policy's tenure is five years, and incentives under the policy apply throughout the life of eligible projects.

The policy's core incentives aim to attract investment and lower operating costs for bioenergy developers. To further stimulate production, the policy provides production-linked subsidies in addition to central incentives. These funds can be used for plant machinery, infrastructure, power supply, and related systems. Additionally, the policy includes infrastructure support such as financial assistance for approach roads (up to 5 km for investments over ₹50 crore) and facilitation of land use through nodal agency UPNEDA.

Policy Dimension	Key Benefit
Target Segments	Focuses on scalable, waste-to-energy pathways aligned with SATAT and rural economy
Capital Cost Support	Improves project viability and accelerates financial closure
Operating Cost Relief	Enhances long-term project cash flows
Land & Transaction Incentives	Reduces upfront investment and land acquisition costs
Feedstock & Logistics Support	Strengthens feedstock supply chains and reduces procurement risk
Infrastructure Support	Improves last-mile connectivity and plant accessibility
Institutional Facilitation	Reduces approval timelines and execution risk
Environmental Benefits	Reduces stubble burning and local pollution

Uttar Pradesh's Bio-Energy Policy creates a **holistic investment framework** by combining capital subsidies, operating cost relief, logistics support, and institutional facilitation making bioenergy projects commercially viable while delivering environmental and rural-economic benefits.

Maharashtra: Promoting EV through conducive policies

Maharashtra EV Policy 2025

The Maharashtra Electric Vehicle (EV) Policy 2025¹¹ (effective April 1, 2025 – March 31, 2030) builds on the earlier EV policy and aims to transform Maharashtra into a leading electric mobility hub by accelerating adoption across vehicle segments, strengthening charging infrastructure, supporting EV manufacturing and supply chains, promoting R&D, and improving energy security and sustainability through reduced petroleum dependence.

The policy sets clear adoption and infrastructure targets by 2030 e.g., a sizeable share of EV registrations across two-wheelers, three-wheelers, cars, buses, and goods carriers, and widespread charging stations along highways and in public/commercial spaces. It supports EV adoption with purchase incentives, market stimulation measures, and enabling infrastructure standards. By encouraging zero-emission mobility and backward linkages such as battery recycling hubs and D+ category manufacturing incentives, the policy promotes economic growth, technological investment, and emissions reduction.

¹¹ Maharashtra Government GR on Maharashtra Electric Vehicle Policy 2025 ([link](#))

Policy Dimension	Key Benefits
Adoption Targets (by 2030)	Establishes measurable demand goals, guiding private sector and public fleets toward electrification.
Purchase Incentives	Lowers upfront cost barriers, enhancing affordability for buyers.
Charging Infrastructure	Improves range confidence and deployment speed of EV charging, reducing infrastructure risk.
Built-Environment Standards	Mainstreams infrastructure readiness in buildings to sustain long-term EV growth.
Supply-Side Incentives	Attracts manufacturing investment and supports circular economy development.
R&D & Skills	Builds local innovation and workforce capabilities.
Energy & Environmental Impact	Aligns EV growth with decarbonisation and cleaner urban air goals.
Institutional Mechanisms	Provides governance backbone to execute targets and streamline inter-agency actions.

Aligned with energy security and environmental goals, the policy's comprehensive measures aim to reduce local air pollution, cut GHG emissions, and help Maharashtra reduce oil import dependency while fostering new industrial opportunities. These incentives and targets are designed to stimulate demand, support supply-side growth, and establish Maharashtra as a strategic EV ecosystem

C. Challenges in State level policies

Despite notable progress, several challenges persist at the state level. These include:

Sr. No.	Policy	Sector	Details
1	No uniform policies for RoU (Right of Use) for CGDs across Local bodies	States do not have a uniform policy for land for RoU across local bodies such as municipal corporations. This impacts laying of pipelines (in case of CGDs) and other assets	Develop and implement a uniform policy across all the local bodies in a state to mitigate the challenges arising from non uniform policies especially in case of RoUs
2	Absence of supportive frameworks for feedstock for biofuels	There is a lack of frameworks that support on ground Used Cooking Oil (UCO) collection for biodiesel, segregated waste collection at municipal/local body level for CBG production. This limits the availability of feedstock for biofuel production (e.g. Biodiesel, CBG)	Develop frameworks strengthen implementation of the same to support grass root level feedstock collection especially for UCO and segregated MSW for biofuel producers

Sr. No.	Policy	Sector	Details
3	Financial stress in DISCOMs	Weak balance sheets of distribution utilities constrain their ability to invest in network upgrades, storage, and long-term power procurement, thereby affecting reliability and integration of clean energy	Accelerate DISCOM reforms through targeted subsidy rationalisation, timely government dues settlement, loss reduction programmes, and promotion of market-based procurement mechanisms
4	Policy Uncertainty and Frequent Revisions	Changes in tariffs, incentives, or contractual terms increase regulatory risk and deter long-term private capital in energy projects	Provide stable, long-tenure policy frameworks with clear transition mechanisms, grandfathering provisions, and predictable regulatory processes.
5	Centre–State Coordination Gaps	Coordination Gaps between central schemes and state-level implementation can delay approvals, funding flows, and project execution.	Strengthen institutional coordination through joint planning platforms, standardised guidelines, and regular centre–state review mechanisms
6	Land and Environmental Clearances	Delays in land acquisition and statutory approvals continue to be critical bottlenecks, particularly for large energy infrastructure projects.	Streamline approval processes through single-window systems, early stakeholder engagement, and advance identification of energy corridors and zones

Addressing these challenges requires sustained institutional strengthening, predictable policy frameworks, and enhanced centre–state collaboration.

D. States as Architects of India's Energy Future

Energy security in India is increasingly shaped by the effectiveness of state-level policies and institutions. While national strategies provide direction, states determine outcomes through execution, innovation, and stakeholder engagement. As India advances towards its goals of energy independence and net-zero emissions, state governments will play a defining role in building a resilient, sustainable, and self-reliant energy system.

A future-ready state energy policy framework can be anchored on five pillars:

- **Resource-Aligned Strategy:** Aligning policies with local resource endowments and demand profiles.
- **Demand Creation:** Using mandates, procurement commitments, and public sector offtake to anchor new energy markets.
- **Integrated Planning:** Coordinating power, fuels, transport, and industry policies.
- **Institutional Strengthening:** Enhancing the capacity of DISCOMs, regulators, and PSUs.
- **Private Capital Enablement:** Providing long-term policy visibility and risk-sharing mechanisms.

India's energy security will depend not just on national policies, but also on how effectively states design and implement their own policies, making strong cooperation between the Centre and states essential to India's energy transition.



23

Ensuring Energy Security: Role of State Energy Policies in India

Shri Lav Kumar

Additional Director, Centre for High Technology

1. Introduction

Energy Security, along with Energy Sustainability and Affordability, has emerged as a cornerstone of India's development strategy, industrial growth and citizen welfare. As India's GDP expanded at 6.5% in 2024–25, energy consumption grew proportionally, with electricity generation rising from 1,168 billion units in 2015–16 to an estimated 1,824 billion units in 2024–25.

In 2023–24, the industrial sector led the Total Final Consumption (TFC) of energy growth at 13.2%, followed by transport (10.7%) and commercial/public services (6.6%). Industry alone accounts for

41–42% of TFC, fueling sectors such as steel, cement, and chemicals. Installed capacity reached 509.74 GW by November 2025, up from 305 GW in 2015–16, with renewables now comprising 50%—a milestone achieved five years ahead of the 2030 goal.

The Ethanol Blended Petrol (E20) target was also met early, reaching 20% blending by 2025 five years ahead of the original target of 2030, strengthening energy security, cutting imports and emissions, and benefiting farmers and biofuel producers. However, notable state-level disparities persist in energy access, quality, and affordability.

2. Importance of Energy, Development, and Industrialization

Energy and Development are inseparable in India's economic trajectory. Per capita electricity consumption remains at 1,395 kWh/year in 2023–24, marking a 45.8% increase (438 kWh) from 957 kWh/year in 2013–14—much less than the global average of 3,800 kWh/year and a fraction of developed economies' levels. This indicates enormous latent demand as incomes rise and manufacturing expands.

Energy access statistics demonstrate that electrification and electricity consumption improvements align strongly with gains in human development indicators, urbanization rates, and formal sector employment. However, the current energy mix remains carbon-intensive and vulnerable to external shocks.

India's non-fossil electricity capacity, though rapidly expanding, requires acceleration from 254 GW (as of November 2025) toward 500 GW by 2030. This transition must be managed at the state level, where distribution infrastructure, regulatory frameworks, and fiscal capacity vary dramatically. Without strong state policies, energy security will remain elusive, and industrialization will be constrained by unreliable or expensive power.

3. Energy Transition and State-Wise Applicability

India's energy transition cannot rely on any single technology. Instead, each state must develop a differentiated portfolio aligned with its resource endowments, industrial structure, and geographic characteristics.

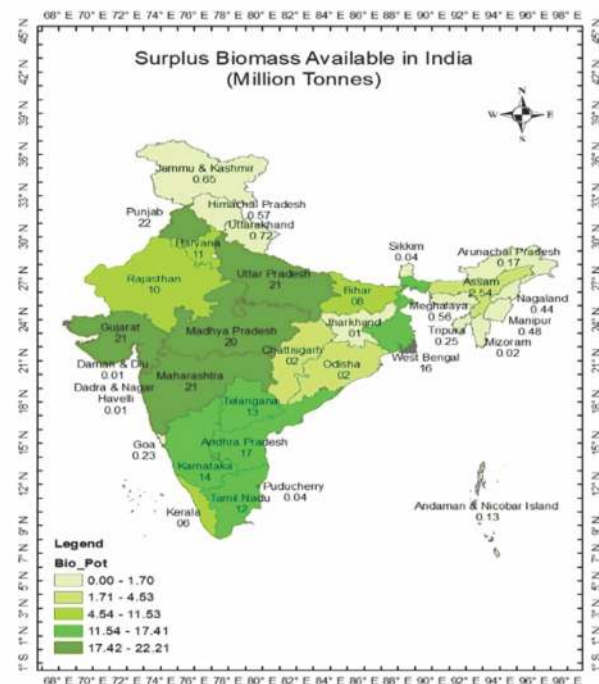
a. Renewable Power: Solar, Wind, and Hydropower

Solar power is central to India's energy transition, especially in high-irradiance states such as Rajasthan, Gujarat, Andhra Pradesh, Madhya Pradesh, Karnataka, and parts of Maharashtra, which receive 250–300 sunny days and 5.5–6.5 kWh/m²/day, favoring utility-scale projects. Indo-Gangetic states such as Uttar Pradesh and Bihar have strong rooftop and distributed solar potential for agriculture and MSMEs. Solar capacity has grown from 2.82 GW in 2014 to 133 GW by 2025, with 23.83 GW added in 2024–25. Wind resources in Tamil Nadu, Gujarat, Karnataka, Maharashtra, and Andhra Pradesh, plus Himalayan hydropower, support balancing through hybrid and flexible clean generation.



Source: MNRE
Copyright © 2026, India's Climate and Energy Dashboard

Solar potential in India. Source: ICED, Niti Aayog



Biomass potential in India. Source: MNRE

b. Bioenergy: Biogas and Biomass Power

Bioenergy harnesses agricultural residues, forestry waste, and animal dung, making it ideal for agrarian states. Punjab, Haryana, Uttar Pradesh, Bihar, Madhya Pradesh, and Rajasthan can deploy biomass power plants, sugarcane bagasse cogeneration, and decentralized biogas systems. Feedstock-rich regions in Gujarat, Uttar Pradesh, and Rajasthan are suited to compressed biogas (CBG) plants that aggregate dung, replace fossil fuels, and create rural income.

The National Bioenergy Programme provides central support that states can amplify with incentives and streamlined approvals.

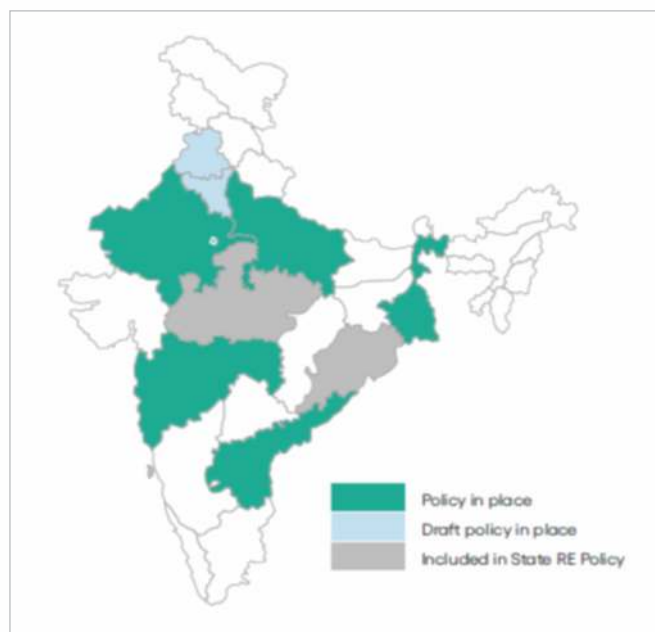
c. Biofuels for Road and Aviation Transport

Conventional biofuels use sugarcane ethanol (Uttar Pradesh, Maharashtra, Karnataka), grain-based ethanol (Punjab, Haryana, Madhya Pradesh), and biodiesel from non-edible oilseeds and used cooking oil (urban hubs in Maharashtra, Gujarat, Tamil Nadu). Sustainable Aviation Fuel (SAF) represents a critical new pathway. SAF is a drop-in replacement for jet fuel produced from used cooking oil, non-edible oilseeds, agricultural residues, and advanced waste feedstocks, offering lifecycle CO₂ reductions of 70–80%.

India's national SAF policy targets 1% blending in domestic aviation, progressing toward ICAO CORSIA compliance and net-zero by 2070.

- Aviation hub and refinery states (Maharashtra, Gujarat, Delhi-NCR, Karnataka, Telangana) can integrate SAF biorefineries with existing airports and petroleum infrastructure.
- Feedstock-rich agrarian states (Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan) can supply crop residues, oils, and used cooking oil through organized farmer producer organizations, creating rural income while meeting aviation blending mandates.

d. **Green Hydrogen** Green hydrogen produced through renewable-powered electrolysis, targets hard-to-abate sectors such as steel, fertilizers, chemicals, heavy transport, and aviation. Industrial states (Gujarat, Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh) can develop hydrogen hubs for refineries and chemical clusters, reducing carbon intensity. Solar/wind-rich Rajasthan can host utility-scale electrolyzers for hydrogen/ammonia export subject to availability of adequate water. Punjab can explore biomass gasification linking farm waste to decarbonization. The central SIGHT (Strategic Interventions for Green Hydrogen Transition) scheme provides production incentives; states must build regulatory frameworks and hydrogen pipeline infrastructure.



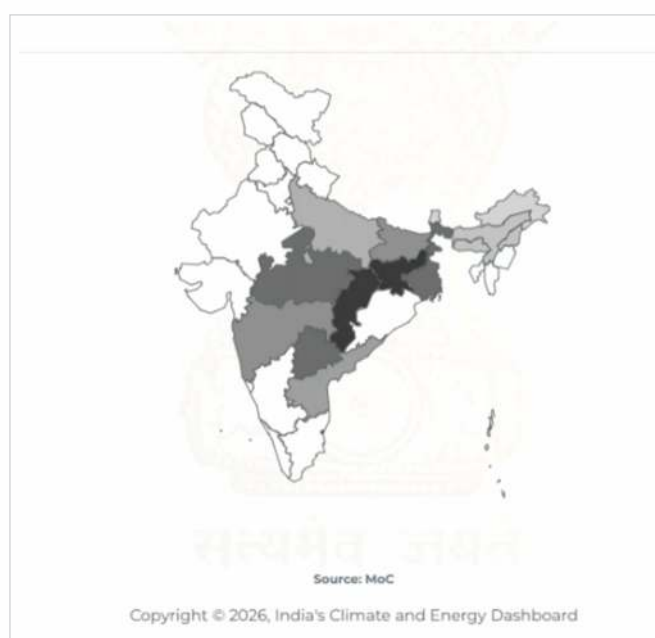
Green Hydrogen policy in States. Source: ICF report

e. **Coal Gasification**

Coal gasification converts coal into syngas for synthetic natural gas, chemicals, and fertilizers. Coal-rich states—Jharkhand, Odisha, Chhattisgarh, and Madhya Pradesh—can use domestic coal more efficiently with lower pollution than direct combustion. Coal-bearing states can adopt coal gasification in two forms:

- Surface coal gasification (SCG), such as the Mahanadi Coalfields Limited plant in Odisha.
- Underground coal gasification (UCG), demonstrated by the pioneering Kasta coal block pilot in Jharkhand's Jamtara district, launched in 2024. UCG has advantages for deep, economically unviable coal reserves—approximately 40% of India's coal reserves lie too deep for conventional mining.

The Ministry of Coal exempted pilot UCG projects from environmental clearance, and the 14th commercial coal mine auction included 21 UCG-potential mines. States must enforce strict environmental safeguards and carbon capture, treating gasification as a transition technology. However, the capital expenditure requirement for coal gasification is high, and capital support is required to make the final product financially viable.



Coal Producing States. Source: ICED, Niti Aayog

f. Sustainable Marine Fuels

Shipping decarbonization in India is progressing through LNG as a transition fuel and future low-carbon options including green methanol, ammonia, and hydrogen-based fuels. Coastal states—Gujarat, Maharashtra, Tamil Nadu, Andhra Pradesh, Odisha, Kerala, and West Bengal—are developing green ports with LNG bunkering, shore power, and green fuel pilot projects. Paradip and Kandla ports are emerging as green maritime hubs, supporting domestic coastal shipping.

4. Types of Support from States

States command diverse instruments to accelerate energy transitions while managing social and fiscal dimensions.

a. Financial Support Mechanisms

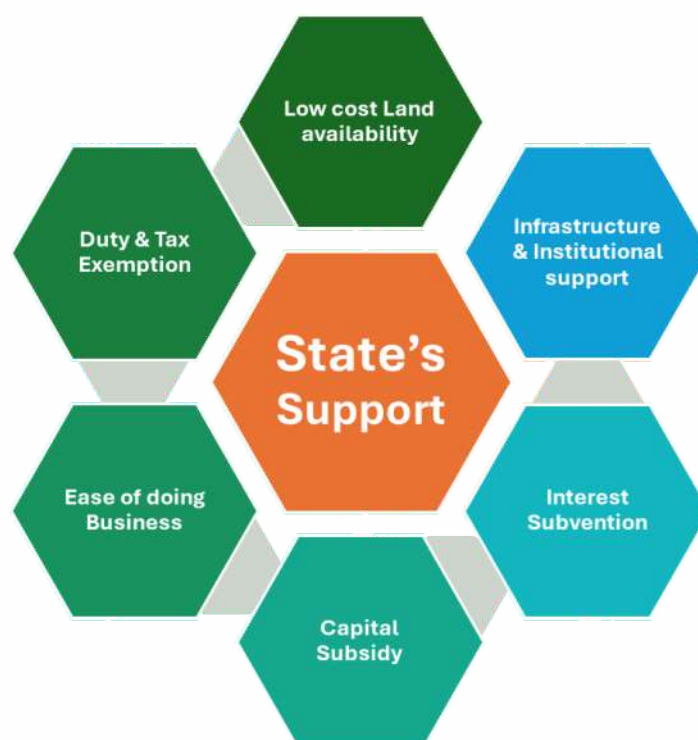
States can deploy capital subsidies, viability gap funding for high-risk renewable and green hydrogen projects, accelerated depreciation benefits, waivers on inter-state transmission system charges, reduced wheeling costs for renewable power, and exemptions on electricity duty and stamp duty. For SAF and green hydrogen, states can offer land and capital subsidies for biorefineries and electrolyzers. These incentives, combined with central government schemes such as PM-KUSUM, PM JI-VAN, SATAT, National Bioenergy Program, and National Green Hydrogen Mission, improve project viability.

b. Regulatory Frameworks

State Electricity Regulatory Commissions (SERCs) establish Renewable Purchase Obligations, progressively increasing non-fossil power requirements on distribution companies. The Draft Electricity Amendment Bill 2025 introduces penalties for non-compliance (35–45 paise per unit), strengthening renewable adoption signals. SERCs can simplify grid connection procedures, establish open access norms enabling direct renewable purchases, introduce time-of-day pricing to incentivize flexible demand, and issue sector-specific policies (rooftop solar, hydrogen, EVs) signaling long-term commitment.

c. Infrastructure and Institutional Support

Investment in transmission lines, green energy corridors, smart metering, and grid modernization is essential for integrating high renewable penetration. States can create dedicated renewable energy corporations or hydrogen cells with technical expertise and



financial autonomy, streamlining project development. For SAF, states can support feedstock aggregation through farmer producer organizations and supply chain coordination. For marine fuels, port authorities must upgrade bunkering infrastructure and shore power systems.

5. Best Model Practices

- **Develop integrated energy transition roadmaps:** States should create comprehensive, time-bound plans setting technology-wise capacity targets aligned with national 500 GW and 5 MMT hydrogen goals etc. These roadmaps must identify priority regions, integrate central schemes (PM-KUSUM, SAF subsidies, hydrogen tenders), and specify financing strategies.
- **Scale distributed and demand-side solutions:** Beyond utility-scale projects, states should aggressively promote rooftop solar via simplified approvals and net metering, support biogas and biomass projects via biomass clusters, and implement industrial energy efficiency programs.
- **Develop feedstock supply chains:** For SAF, biofuels, and biogas, states should organize farmer producer organizations to aggregate crop residues, oilseeds, and dung, negotiating long-term contracts with producers.
- **Invest in skills:** States should design explicit transition strategies, including miner retraining, social protection, and industrial diversification. All states should fund vocational training in renewable installation, hydrogen technology, biofuel production, and maritime decarbonization.
- **Establish dedicated agencies:** Creating dedicated renewable energy corporations, hydrogen cells, or green ports authorities—with technical expertise, financial autonomy, and single-minded focus—accelerates project deployment and reduces administrative delays.

6. Success Stories

- **Rajasthan's integrated renewable strategy:** Rajasthan, with 34.14 GW capacity (15.51% of India's total as of March 2025), demonstrates how aggressive targets, mega solar and hybrid parks, streamlined land policies, and transmission corridor investment create leadership. Other solar-rich states can adopt this model.
- **Gujarat's hybrid parks and industrial integration:** Gujarat's 30 GW Khavda Hybrid Renewable Energy Park on wasteland combines solar-wind to optimize capacity factors.
- **Tamil Nadu's wind leadership:** Tamil Nadu's early wind policies and industrial manufacturing base demonstrate policy stability benefits. Coastal states can adapt this for onshore and future offshore wind.
- **State-level feedstock aggregation (Bioenergy model):** States aggregating agricultural residues via FPOs for CBG/ethanol/ Power generation create rural income while Indore's waste segregation model benefits both CBG production and urban cleanliness.
- **Coal gasification in transition:** Jharkhand and Odisha's coal gasification pilots illustrate how coal states can plan long-term transition while improving coal efficiency.

7. Way Forward

Energy security in modern India transcends mere fuel sufficiency; it requires building resilient, diversified, low-carbon systems capable of powering rapid industrialization while protecting public health and meeting climate commitments. Because electricity distribution, local regulation, port and airport management are state responsibilities, state-level policy design and execution will ultimately determine India's energy future.

Each state must craft a differentiated strategy integrating renewable power, bioenergy, biofuels, green hydrogen, SAF, marine fuels, and—where appropriate—cleaner coal technologies in proportions suited to its resource base and economic structure. Through targeted financial incentives, coherent regulatory frameworks, infrastructure investment, dedicated institutions, and explicit transition planning, states can attract investment, create green employment, reduce pollution, and ensure reliable, affordable energy.

By learning from frontrunner states—Rajasthan's renewable scaling, Gujarat's hybrid integration, Tamil Nadu's manufacturing prowess, and emerging e-SAF and green hydrogen initiatives—India's states can transform energy policy into a development opportunity. When state policies align with national targets and international climate commitments, energy security becomes a catalyst for shared prosperity, environmental protection, and India's emergence as a clean energy superpower by 2070.

Disclaimer: *The views and opinions expressed are personal to the author and do not represent the views or positions of the Ministry of Petroleum and Natural Gas (MoPNG) or the Centre for High Technology (CHT) in any manner.*



24

India's Energy Pivot: Securing Today, Decarbonising Tomorrow

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Introduction: Energy Security as a National Imperative

India's energy security challenge is underscored by its heavy reliance on imported crude oil — **88.2% of total consumption in FY 2024–25**, with imports reaching **234.3 MMT** and a record import bill of **\$137 billion**.¹ This dependency is compounded by global price volatility and geopolitical risks. Simultaneously, the country is accelerating its clean energy transition, with **renewable capacity at**

¹ Ministry of Petroleum and Natural Gas (MoPNG) 2025, Basic Statistics on Indian Petroleum & Natural Gas, Petroleum Planning & Analysis Cell (PPAC), Government of India, <https://ppac.gov.in/>.

237.49 GW as of July 2025² and a target of **500 GW by 2030.³** While **nuclear energy** presently contributes around 3% to the nation's electricity generation mix, supported by an installed capacity of approximately **8.8 GW**.

The central challenge is twofold:

1. **Securing affordable, reliable energy** to sustain economic growth.
2. **Accelerating the energy transition** to meet climate commitments and ensure long-term sustainability.

2. The Policy Engine: States as Co-Architects

While the **Union Government** articulates the national energy vision, **state governments** are pivotal in translating strategy into tangible outcomes. Their influence spans:

- **Infrastructure Deployment** – e.g., Gujarat's streamlined land acquisition for solar parks and LNG terminals.⁴
- **Regulatory Alignment** – Tamil Nadu's harmonization of state electricity regulations with national renewable purchase obligations (RPOs).
- **Investment Facilitation** – Andhra Pradesh's single-window clearance for renewable projects.
- **Demand-Side Management** – Karnataka's EV adoption incentives and industrial energy efficiency programmes.

3. India's Five-Pillar Energy Security Strategy

Pillar	Key Action	Illustrative Example	Impact
Supply Diversification	Importing from Russia, USA, Middle East and Africa	Post-2022, India increased Russian crude intake to secure discounted supplies. And maintaining global supply vs demand dynamics	Reduces geopolitical risk concentration
Domestic Boost	OALP, DSF reforms, deep-water exploration	ONGC's KG-DWN-98/2 deep-water project. Andaman Explorations ⁵	Cuts import dependency
Clean Transition	Achieving 50% non-fossil capacity ahead of 2030	Rajasthan's 10GW solar park expansion	Aligns with net-zero 2070
Resilience	Expanding Strategic Petroleum Reserves (SPR)	New caverns in Odisha and Rajasthan ⁶	Shields from prices shocks

² Ministry of New and Renewable Energy (MNRE) 2025, Renewable Energy Installed Capacity Data, Government of India, <https://mnre.gov.in/>.

³ International Energy Agency (IEA) 2021, India Energy Outlook 2021, IEA, Paris, <https://www.iea.org/reports/india-energy-outlook-2021>.

⁴ Government of Gujarat 2023, Gujarat Renewable Energy Policy 2023, Energy & Petrochemicals Department, Government of Gujarat, <https://guj-epd.gujarat.gov.in/>.

⁵ Oil and Natural Gas Corporation (ONGC) 2024, KG-DWN-98/2 Project Overview, ONGC, <https://ongcindia.com/>.

⁶ Indian Strategic Petroleum Reserves Limited (ISPRL) 2024, Strategic Petroleum Reserves Expansion Plans, ISPRL, <https://isprlindia.com/>.

India's energy security framework has been traditionally rested on above four pillars. However, given the imperative for firm, low-carbon baseload power, **nuclear energy merits recognition as a complementary fifth pillar.**

Pillar	Key Action	Illustrative Example	Impact
Nuclear Energy	Scaling existing pressurised heavy water reactors and advancing Small Modular Reactors (SMR). ⁷	Accelerating the commissioning of additional Kudankulam units. Focusing on thorium-based power generation. ⁸	Reduce storage and grid-balancing costs associated with high renewable penetration.

4. Energy Freedom: Reducing Strategic Vulnerabilities

Energy freedom entails **minimizing external leverage** over domestic policy.

Key enablers include:

- **Domestic Oil Production Incentives** – Rationalizing royalties to attract E&P investment (e.g., marginal field incentives in Assam).
- **Technology Partnerships** – Collaborations with global majors for enhanced oil recovery and deep-water drilling.
- **Critical Minerals Mission** – Securing lithium from Australia and cobalt from Africa to support EV and battery manufacturing.⁹ Enhance energy independence through domestic uranium and thorium resources development.

5. Sustainability for Citizens: Equity and Access

Energy security must be **inclusive**:

- **City Gas Distribution (CGD)** – Expanding PNG and CNG access; Indore and Surat as model cities.
- **LPG Penetration** – *Pradhan Mantri Ujjwala Yojana* achieving near-universal household coverage.¹⁰
- **Rural Electrification & Rooftop Solar** – Saubhagya scheme and PM Surya Ghar Muft Bijli Yojana.
- **Compressed Biogas (CBG)** – Turning agricultural waste into fuel; Satara district's CBG plant as a replicable model.

⁷ World Nuclear Association (WNA) 2025, *Nuclear Power in India*, World Nuclear Association, <https://world-nuclear.org/information-library/country-profiles/countries-g-n/india.aspx>.

⁸ Department of Atomic Energy (DAE) 2024, *Annual Report 2023–24*, Government of India, <https://dae.gov.in/annual-reports-of-dae/>.

⁹ Ministry of Mines 2024, *KABIL: Securing Critical Minerals for India*, Government of India, <https://mines.gov.in/>.

¹⁰ Press Information Bureau (PIB) 2025, *PMUY Achieves 10.33 Crore LPG Connections*, Government of India, <https://pib.gov.in/>.

Figure 1: Compressed Biogas (Anaerobic Digestion)

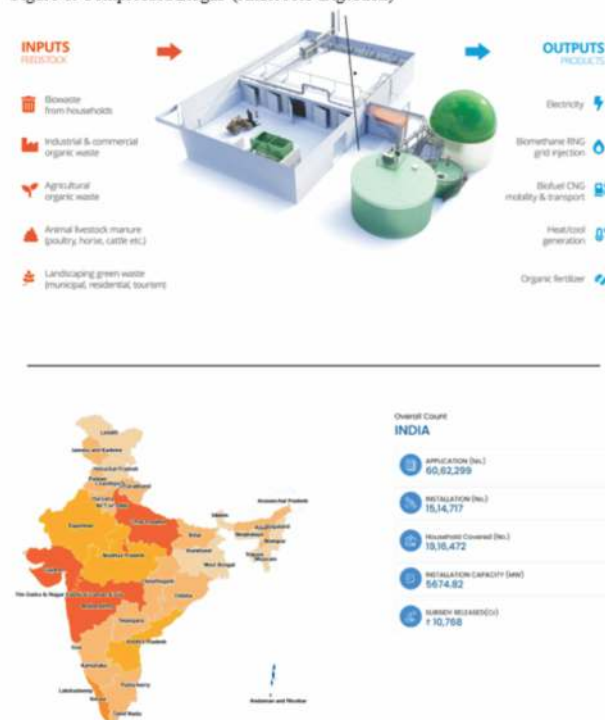


Figure 2: PM Surya Ghar Program

Figure 3: Small Modular Reactor Program



Figure 4: Green Hydrogen Program



Source: Figure 1 – Compressed Biogas Plant, Anaerobic Digestion, Renergon GmbH

Figure 2 – Government of India, National Portal, PM Surya Ghar: Muft Bijli Yojana, Ministry of New & Renewable Energy

Figure 3 – Government of India, Bharat Small Modular Reactors, Department of Atomic Energy

Figure 4 – Government of India, National Green Hydrogen Mission

6. Policy Recommendations

To strengthen Centre–State synergy:

1. **Harmonize State RPOs** with national targets to avoid compliance gaps.
2. **Fast-Track Clearances** for upstream, midstream, and downstream projects via digital single-window systems.
3. **Fiscal Incentives** for marginal fields and enhanced oil recovery.
4. **State-Level Hydrogen Hubs** linked to industrial clusters (e.g., Gujarat - Jamnagar). It will produce 7 MTPA of green ammonia and 1.4 MTPA of green hydrogen.¹¹
5. **Integrated Energy Planning** at state level, factoring in local resources, demand, and climate resilience.¹²
6. Develop a **National SMR Roadmap** with a clear regulatory pathway, pilot projects and public-private financing models at **state-level** energy strategies, ensuring alignment with local industrial and grid needs.¹³

¹¹ NITI Aayog 2023, National Green Hydrogen Mission: Strategic Roadmap, Government of India, <https://niti.gov.in/>.

¹² Central Electricity Authority (CEA) 2024, Report on Renewable Energy – Round the Clock (RE-RTC) Supply, Government of India, <https://cea.nic.in/>.

¹³ NITI Aayog 2023, The Role of Small Modular Reactors in the Energy Transition, NITI Aayog, Government of India, <https://www.niti.gov.in/>.

7. Conclusion

India's pursuit of **energy security, freedom, transition, and sustainability** is a **national mission with local execution**. By aligning **state energy policies** with the **national strategic vision**, India can insulate itself from global shocks, meet its climate commitments, and ensure equitable access to clean, reliable energy for all citizens.

The **policy choices made today**—both in the national capital and in state capitals—will determine whether India remains energy-vulnerable or emerges as an **energy-secure, climate-resilient powerhouse**.



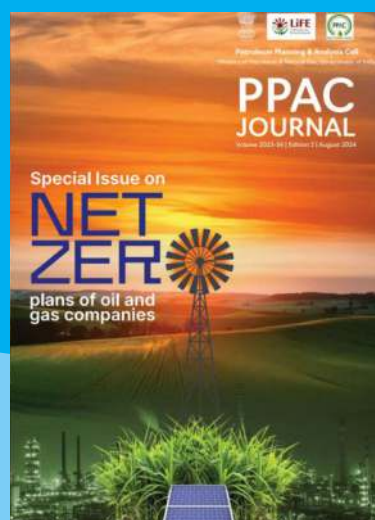
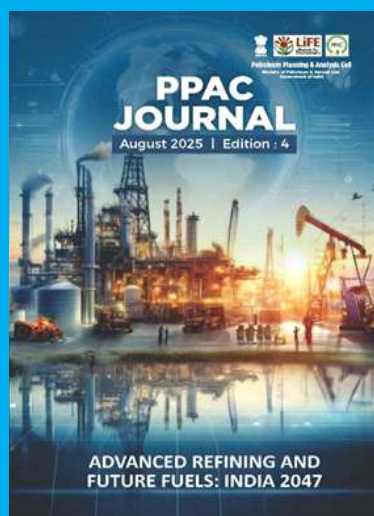
Numaligarh Refinery Limited (NRL) in Assam operates India's first bamboo-based biorefinery.

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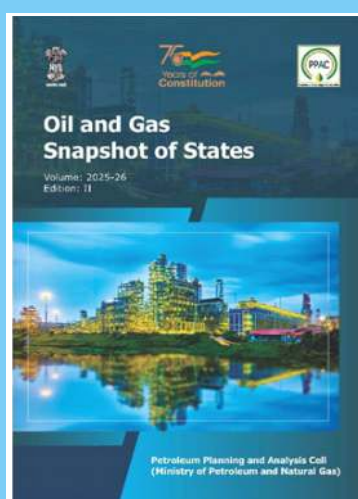
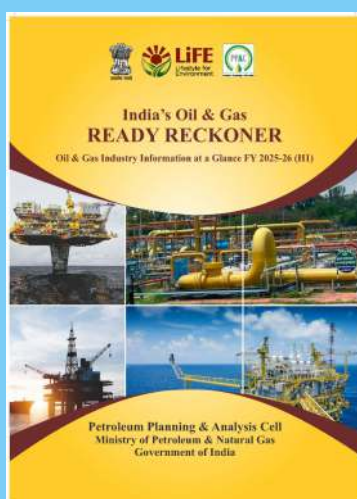


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