



Renewables sector in India

Sector Report, April 2026

CHAKRA Centre of Excellence, Project Finance and Structuring SBU

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Preface

India is advancing a foundational energy shift with its commitment to installing 500 GW of non-fossil fuel capacity by 2030. The transition is anchored in two core technologies: solar and wind, which together are expected to comprise up to 80% of clean capacity by the end of the decade. This expansion is not only driven by decarbonization goals but also by energy security, growing electricity demand, and increasing corporate procurement of renewables. Policy reforms, digital grid upgrades, and the adoption of round-the-clock hybrid models are accelerating the sector's evolution from capacity procurement to dispatchable clean energy delivery.

At the heart of this growth lies the solar sector, which is set to add ~145 GW by 2030. Domestic manufacturing is scaling under the Production Linked Incentive (PLI) scheme, with planned capacity additions across the polysilicon, wafer, cell, and module value chain. While downstream module assembly is gaining maturity, upstream inputs remain import-dependent, exposing developers to cost volatility. Policy instruments like the Approved List of Models and Manufacturers (ALMM) and customs duties aim to encourage self-reliance, but cost gaps versus Chinese imports persist. Solar deployment continues to be led by utility-scale projects, with innovations like floating solar and agrivoltaics gaining traction to address land constraints.

Wind power, historically a stronghold in India's renewable mix, is set for a revival. Capacity is expected to double from ~56 GW to 100 GW by 2030, driven by hybrid tenders, repowering initiatives, and offshore wind policy frameworks. India maintains significant manufacturing capabilities across nacelles, blades, and towers, yet capacity utilization remains suboptimal due to weak domestic demand and limited tower infrastructure. Transmission congestion and delays in securing project approvals are key inhibitors. Addressing these bottlenecks through targeted investments in logistics-intensive components and faster permitting could unlock latent capacity and bolster export competitiveness.

Pumped Storage Projects (PSPs) are becoming essential for managing power supply changes and keeping the grid stable as we use more renewable energy. According to the Central Electricity Authority's (CEA) roadmap report published in January 2026, India has an estimated technical potential of about 267 GW, out of which ~96 GW of capacity is in various stages of planning and development. Because of this massive potential, PSPs are now being included in hybrid power projects to provide long-lasting energy storage. The business model for PSPs is improving, helped by benefits like must-run status, grid charge waivers, and viability gap funding. However, the sector still faces challenges like long building times, regulatory hurdles, and complex engineering needs at specific sites. To speed up PSP growth, the industry needs to shift toward closed-loop and modular reservoir designs, along with quicker approval processes.

Underpinning all segments is a broad policy architecture spanning central and state governments. Renewable Purchase

Obligations (RPOs), open access reform, storage-linked tendering, and manufacturing incentives are

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driving demand and de-risking investment. States like Gujarat, Tamil Nadu, and Karnataka are leading with tailored policies on land allocation, repowering, and single-window clearances. However, uneven implementation across states and ambiguity around long-term tariff frameworks continue to affect investor confidence. Strengthening inter-agency coordination and codifying a national renewable energy law could enhance predictability and streamline project development.

As the sector matures, environmental, social, and governance (ESG) performance is emerging as a key differentiator. Developers with strong ESG credentials benefit from lower-cost capital, faster land acquisition, and improved community alignment. Policy shifts such as SEBI's BRSR Core and blade recycling mandates are pushing ESG into mainstream compliance. Meanwhile, developers are addressing biodiversity risks, water usage, and material circularity through design innovations and local partnerships. Governance reforms around supply chain ethics, cybersecurity, and disclosure frameworks are reshaping stakeholder expectations.

Project bankability is improving as capital markets adapt to the unique contours of renewables. Financing instruments such as green bonds, sustainability-linked loans, and infrastructure investment trusts are gaining momentum. Project developers are de-risking cash flows through SECI-anchored power purchase agreements and payment security mechanisms, yet off-taker risk from state DISCOMs remains a concern. Manufacturing investments, particularly upstream, are still hindered by limited access to low-cost debt and tariff unpredictability, underscoring the need for capital structuring innovation and policy alignment.

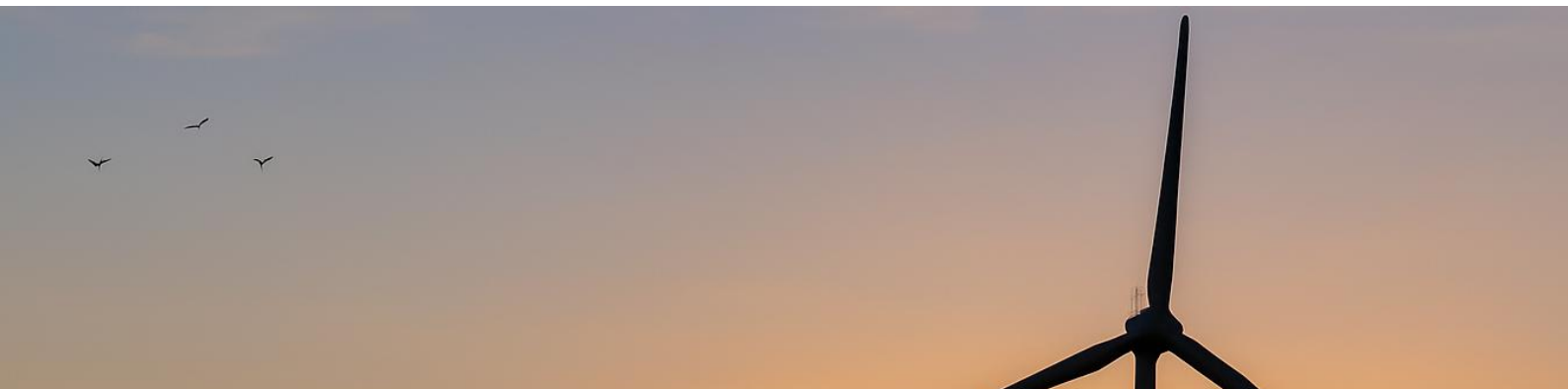
India's renewable energy sector is well-positioned to lead global **Energy Transition** efforts, but its success depends on how effectively policy, capital, infrastructure, and execution capabilities evolve in parallel. Scaling domestic manufacturing, closing infrastructure gaps, enforcing consistent regulation, and embedding ESG standards will be essential to converting policy ambition into durable growth and investment-grade outcomes.

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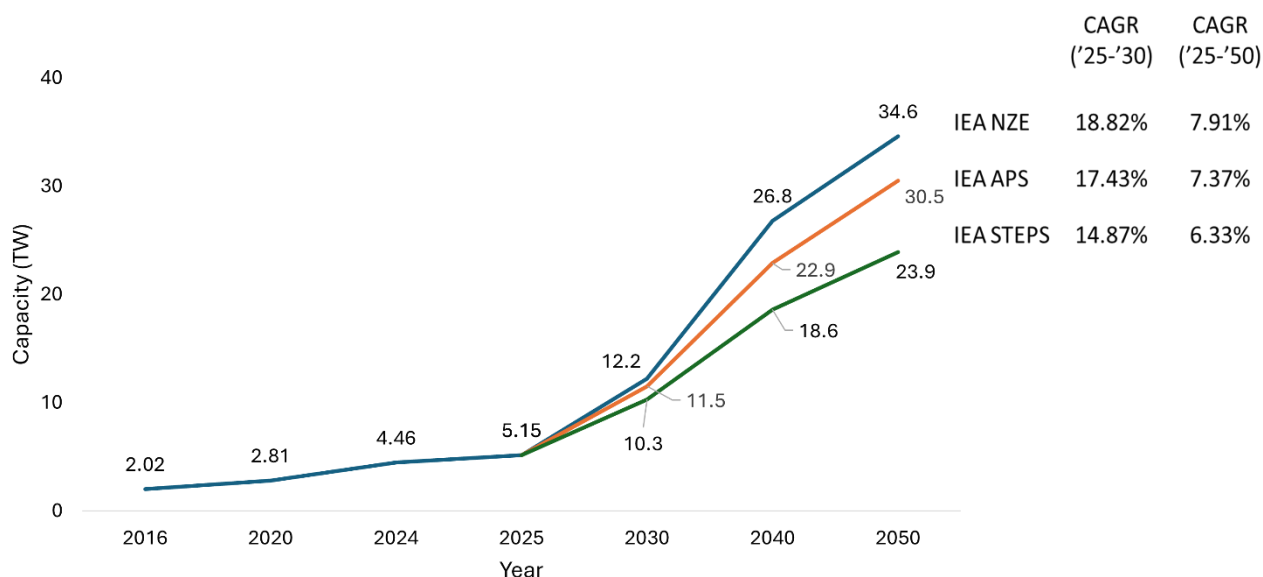
1 INTRODUCTION

India's renewable energy journey is undergoing a structural transformation anchored in a national ambition to achieve 500 GW of non-fossil fuel capacity by 2030. This transition is not only a response to global decarbonization imperatives but also a strategic move to enhance energy security, manage rising power demand, and reduce reliance on imported fossil fuels. The country's clean energy pathway is centered on three key technology segments: solar photovoltaic (PV), onshore wind, and pumped storage projects (PSPs). These segments are seen as the most commercially scalable and technically viable options to deliver large-scale, grid-connected renewable energy at a competitive cost.

Solar and wind power have emerged as the two dominant components of this strategy. Solar PV is expected to experience the most rapid growth, given the country's abundant solar irradiation, policy momentum, and maturing project execution capabilities. Onshore wind remains a critical part of the mix, particularly in states like Tamil Nadu, Gujarat, and Karnataka. PSPs are gaining importance as a long-duration energy storage solution capable of addressing intermittency and enhancing grid flexibility. While technologies such as biomass, hydro, solar thermal, and nuclear offer supplementary generation potential, they are expected to play more localized and specialized roles due to constraints around scalability, regulatory frameworks, and cost structures.

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Figure 1: Global clean energy installed capacity across scenarios (TW)



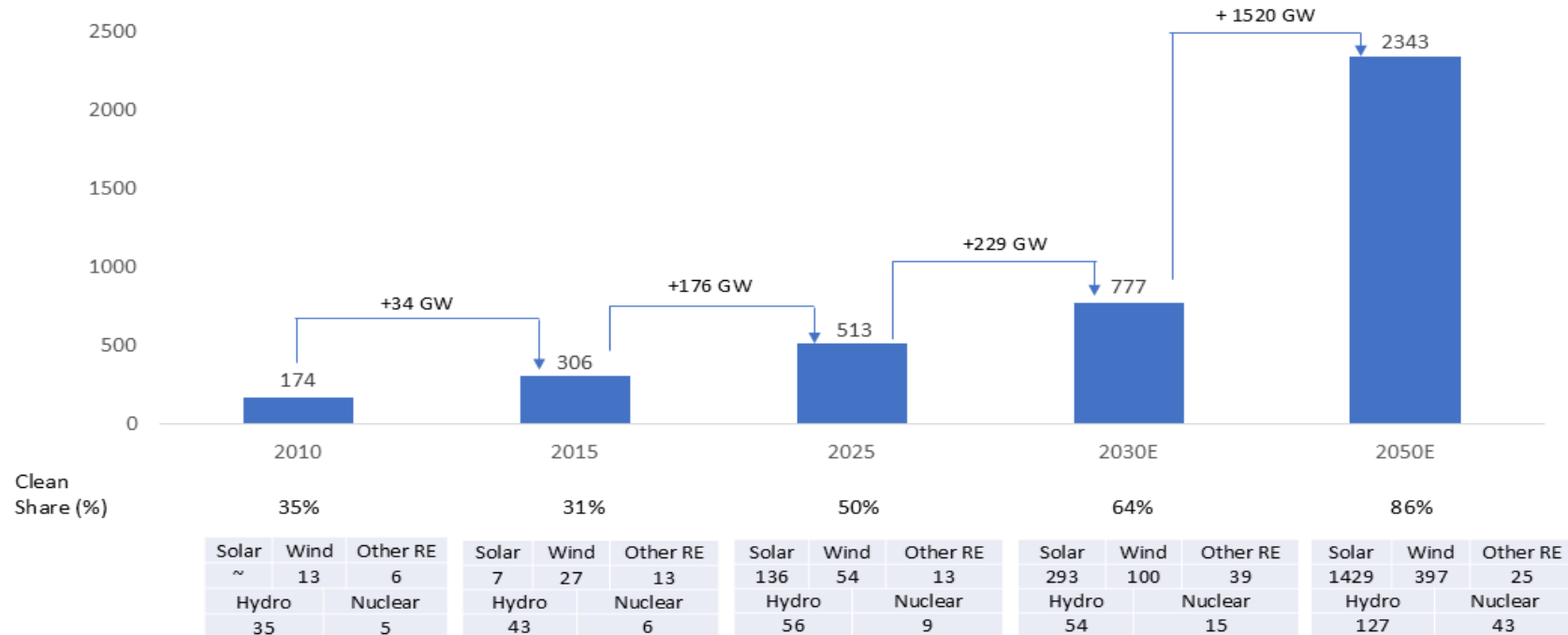
Source: IEA WEO, IRENA

In the broader international context, renewable energy deployment is accelerating. According to the International Renewable Energy Agency (IRENA), global renewable power capacity reached a record 5.15 terawatts (TW) by the end of 2025, up from 4.46 TW in 2024. This growth took the share of renewables in global electricity capacity to 49.4% in 2025. The expansion was primarily driven by a surge in solar power installations, which grew by 511 gigawatts (GW) to reach 2.39 TW globally, confirming Solar's position as the world's largest renewable source. Projections under the International Energy Agency's (IEA) three scenarios, Stated Policies (STEPS), Announced Pledges (APS), and Net Zero Emissions (NZE), indicate that solar will continue to contribute the majority of new capacity additions through 2050.

Under the STEPS scenario alone, solar is projected to comprise 69% of clean energy capacity, driven by declining module prices, enhanced deployment models, and technical improvements. The global trend is also shifting toward decentralized and hybrid energy systems, with countries like China and India spearheading regional buildouts.

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Figure 2: India installed capacity (GW)



Note: (1) Clean Share includes Renewable and other clean sources of energy such as Nuclear; (2) Other RE includes small hydro, pumped storage and bioenergy

Source: Niti Aayog, IEA-WEO STEPS scenario

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India has emerged as a key growth engine within the global renewable energy ecosystem. By 2030, clean energy is projected to comprise 64% of India's installed power capacity. Solar capacity is forecasted to rise from the current 150 GW in 2026 to approximately 293 GW by 2030, while wind capacity is expected to double from around 56 GW in March 2026 to 100 GW by 2030. These additions will be supported by modest expansions in small hydro, bioenergy, and nuclear. Independent assessments by institutions like TERI, IEA, and Niti Aayog consistently predict that solar and wind will constitute between 70% and 80% of India's total clean energy capacity by the end of the decade, underscoring their foundational role in the country's **Carbon Neutrality**.

This growth trajectory is being propelled by a combination of central and state-level policies, strong investor interest, and the rising competitiveness of clean energy technologies. Key enablers include Renewable Purchase Obligations (RPOs), policy-linked tenders, open access reforms, and financial incentives for domestic manufacturing. These measures have helped reduce project-level risks and increase the bankability of clean energy assets. States like Gujarat, Maharashtra, and Tamil Nadu have been early movers, offering dedicated land parcels, streamlined approvals, and attractive fiscal incentives to attract renewable energy investments.

From a technological perspective, India's renewable energy landscape is becoming increasingly diversified. Solar PV and onshore wind continue to dominate due to their rapid deployment potential and falling levelized cost of electricity (LCOE). At the same time, pumped storage is evolving as a vital piece of the energy puzzle, particularly as the share of renewables on the grid increases. PSPs can absorb surplus generation during periods of low demand and dispatch it during peak hours, thereby providing ancillary services such as load balancing and frequency regulation.

Taken together, India's clean energy transition is positioned at the intersection of policy ambition, technological evolution, and capital allocation. However, achieving the 2030 targets will depend heavily on parallel progress in transmission infrastructure, domestic manufacturing, project execution, and regulatory consistency. Infrastructure bottlenecks, tariff uncertainties, and land acquisition challenges remain persistent risks. Addressing these issues through cohesive planning, regulatory clarity, and cross-agency coordination will be critical to sustaining momentum.

The chapter concludes with a recognition of India's growing strategic relevance in the global decarbonization narrative. By expanding its renewable energy base, the country not only reduces its carbon footprint but also enhances energy sovereignty and becomes a credible export hub for clean energy technologies. The underlying message is clear: India has the ingredients for a successful clean energy transition, but translating potential into delivery will require disciplined execution, sustained policy support, and active stakeholder alignment

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2 SOLAR

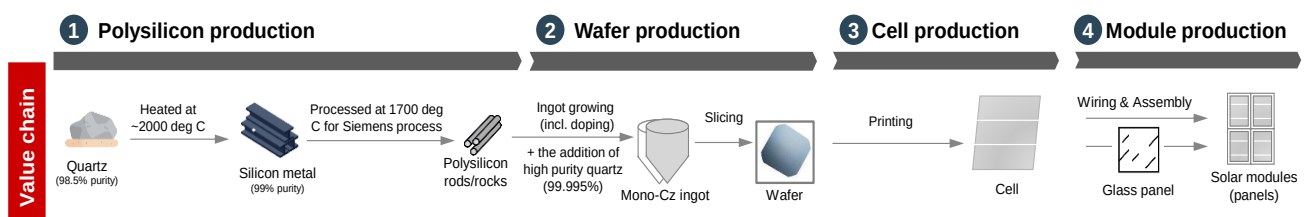
India's solar energy ecosystem is structured around a three-tiered value chain encompassing component manufacturing, system deployment, and long-term service provision. Each segment plays a critical role in shaping the scalability, efficiency, and durability of solar power assets across the country.

Figure 3: Solar PV Supply Chain



The solar PV manufacturing process is defined by a technically demanding and highly energy-intensive four-stage value chain: **polysilicon production**, **wafer manufacturing**, **cell fabrication**, and **module assembly**.

Figure 4: Solar PV manufacturing process



Each stage plays a distinct role in determining cost, efficiency, and energy output of solar PV systems. The value chain also includes balance-of-system components such as inverters, glass, and mounting

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structures. Of these, module manufacturing currently has the most mature domestic presence, while upstream segments such as polysilicon and wafer production remain underdeveloped.

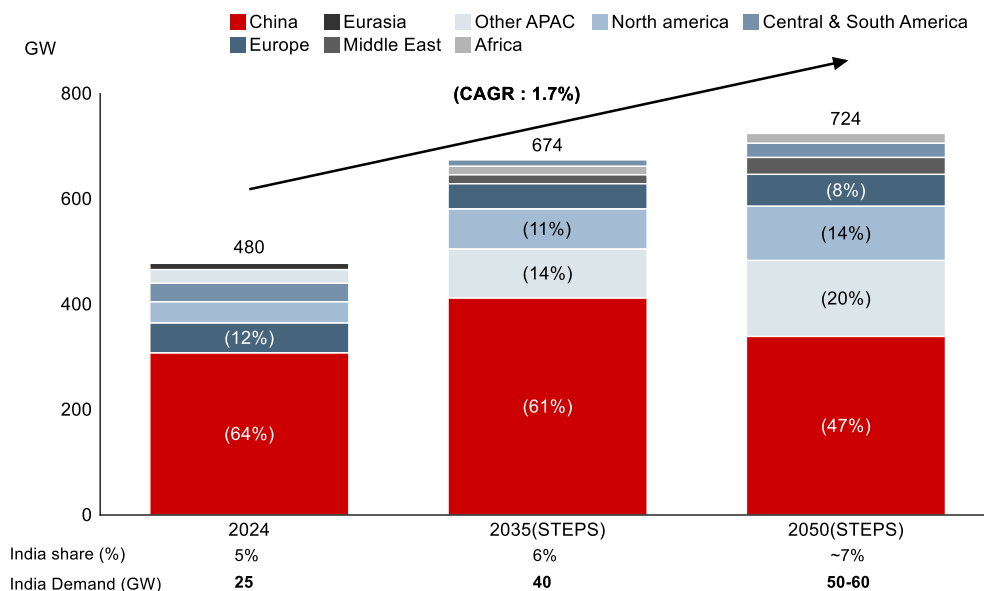
Solar PV manufacturing in India is expanding, driven by strong policy tailwinds and demand certainty. Major capacity is concentrated in module manufacturing, with progressively smaller footprints for cells, wafers and, at present, virtually no polysilicon production.

Module Manufacturing

Demand

Although China continues to dominate the segment, demand is gradually diversifying, with India and other Asian markets emerging as meaningful contributors. Global module demand is projected to grow at a compound annual rate of ~3% until 2035 and ~1.7% through 2050.

Figure 5: Global demand for solar PV modules by region (2024-2050)



Note: * Capacity for India reported as per actuals in FY 2024

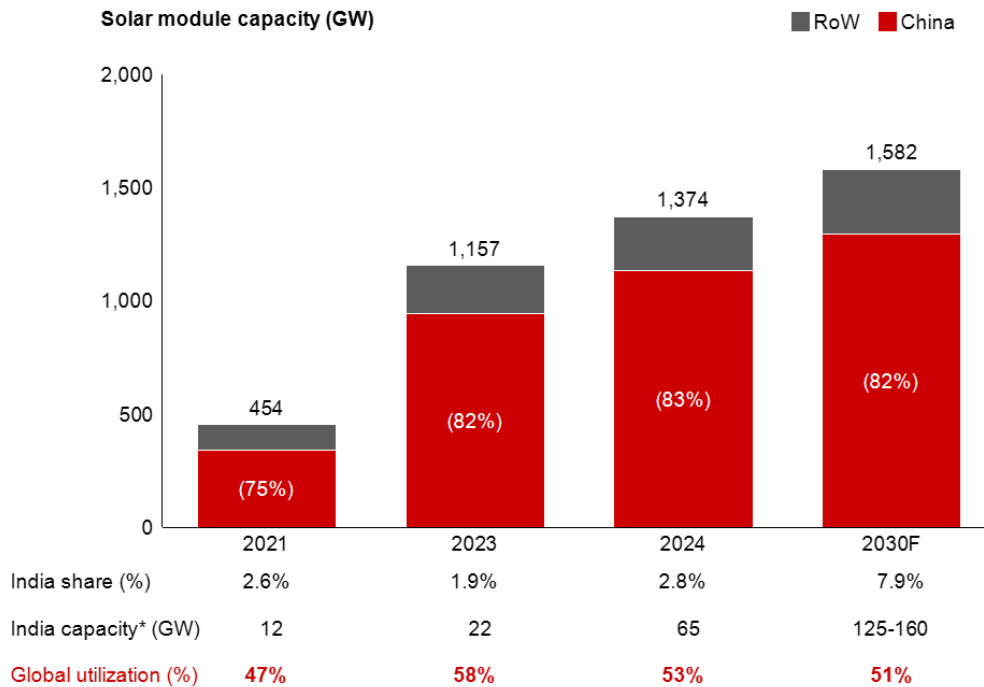
Source: International Energy Agency (IEA)

Supply

The global solar module supply chain remains heavily concentrated, with China accounting for the vast majority of installed capacity. Global solar module capacity has expanded dramatically, rising from 454 GW in 2021 to a projected 1,374 GW in 2024-marking a threefold increase in just three years. China continues to dominate this growth, contributing ~83% of global capacity in 2024, with its share expected to remain steady at ~82% through 2030.

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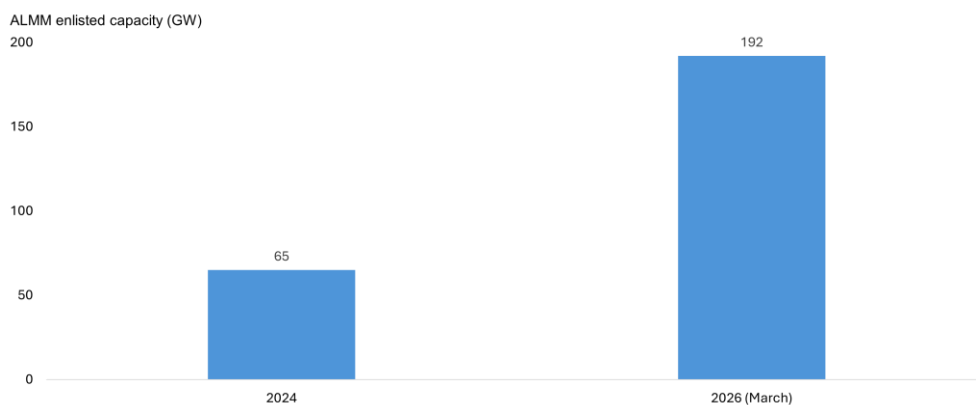
Figure 6: Global supply of solar PV modules by region (2021-2030F)



Note: * Capacity for India reported as per actuals in FY24
Source: International Energy Agency (IEA)

In India, the enlisted module manufacturing capacity stands at 192GW (as of May 2026).

Figure 7: Enlisted module capacity in India



Source: ALMM Enlisted manufactures list

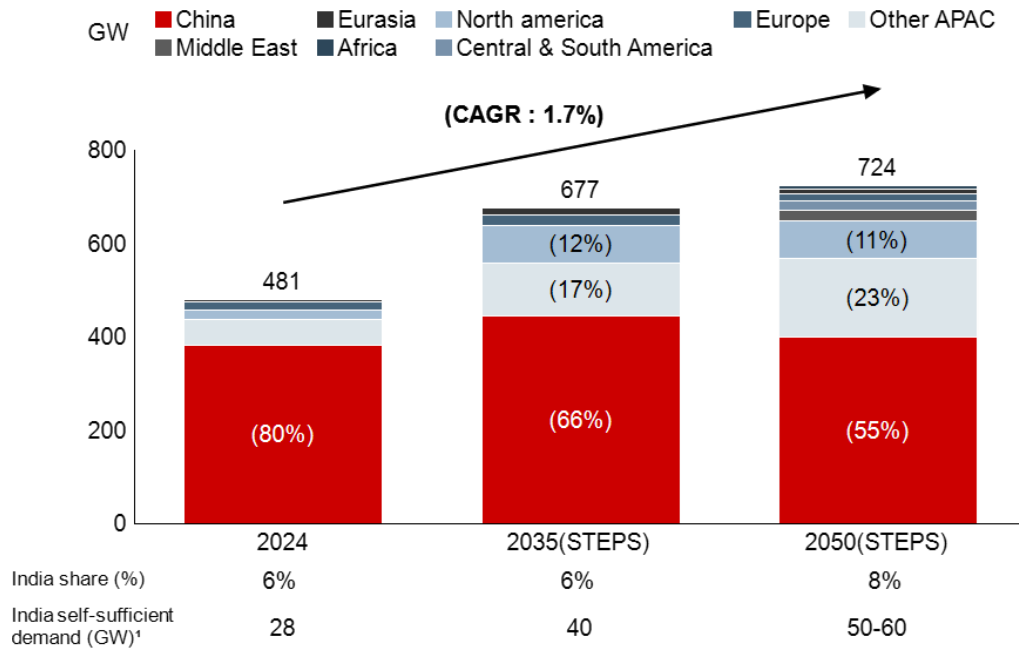
Cell Manufacturing

Demand

Global demand for solar cells is projected to grow at a modest CAGR of 1.7% through 2050. Asia is expected to remain the primary demand center, accounting for more than three-fourths of global volumes across the forecast period. China alone is set to maintain a dominant position, with its demand share exceeding 50% in all three reference years.

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Figure 8: Demand for solar cells by country/region (2024-2050)



Notes: 1) India cell demand is represented by the module production volume in India for 2024; for 2035 and 2050, cell demand forecasts based on self-reliant PV manufacturing value chain

Source: International Energy Agency (IEA)

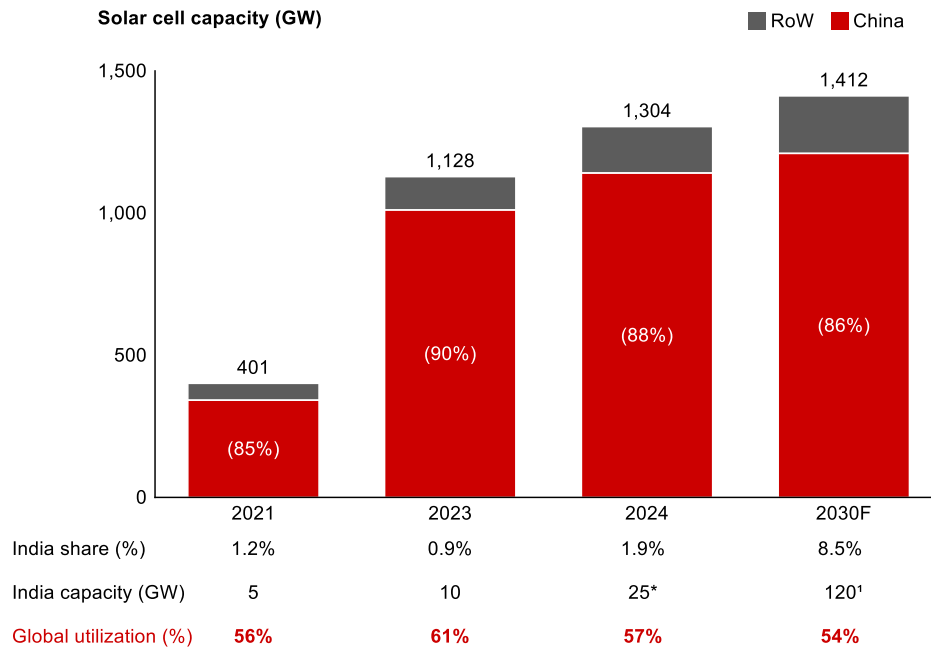
India's share in global cell demand stands at ~6% in 2024, translating to an estimated 28 GW of cell consumption-driven by module assembly for domestic deployment. This figure is expected to rise to 40 GW by 2035 and up to 60 GW by 2050, keeping pace with India's aggressive solar deployment targets and planned manufacturing expansions

Supply

Global solar cell capacity has expanded nearly threefold, from 401 GW in 2021 to a projected 1,304 GW by 2024. China continues to lead, accounting for over 1,100 GW in 2024-roughly 90% of total global capacity. Despite the growth in installed capacity, global utilization rates remain weak hovering between 54% and 61% during this period. The mismatch signals that supply will continue to outpace demand in the short to medium term, potentially driving down margins and discouraging new entrants without competitive cost structures or captive demand.

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Figure 9: Global solar cell supply by region (2021-2030F)

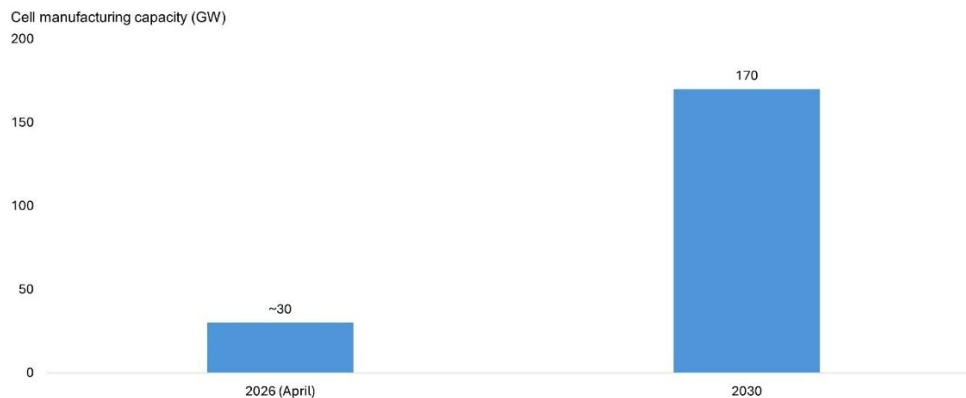


Note: Data extracted using online tools, hence are approximates; (*) Capacity for India reported actuals as of CY 2024 (1) Estimates as per the National Solar Energy Federation of India and actual capacity plans by players have not been made yet

Source: International Energy Agency (IEA)

In India, cell fabrication stands at around 30 GW as on 30th April 2026; projects under construction or at advanced planning stages would raise capacity to roughly 170 GW by the end of the decade. Cell manufacturing has grown but is still heavily dependent on older AI-BSF technology. The transition to higher-efficiency cell types like TOPCon and HJT is underway but will need significant investments and upgraded skill sets.

Figure 10: Current and forecasted cell manufacturing capacity in India



Source: MNRE – ALMM II, TERI – India's PV Manufacturing Report

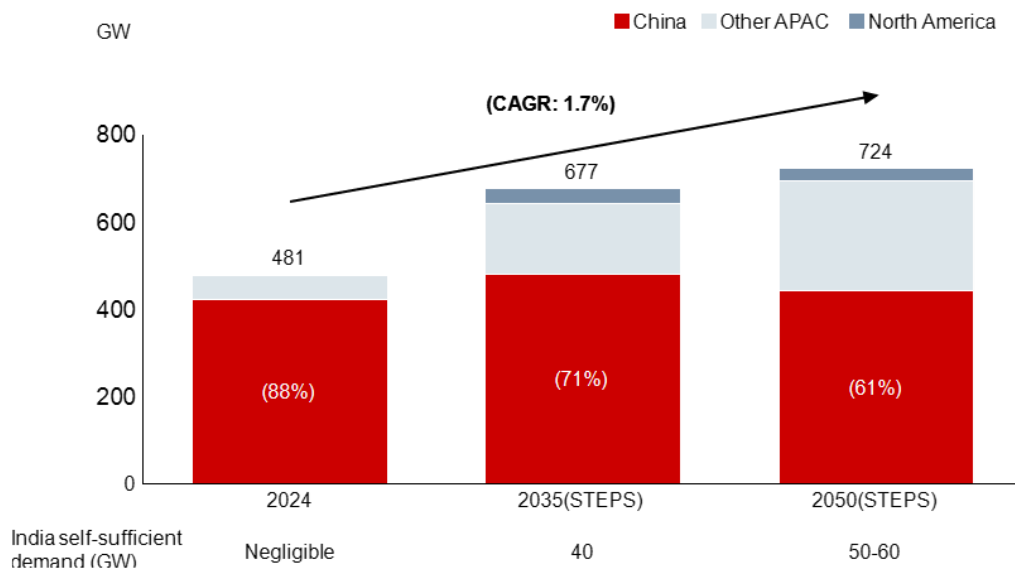
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Wafer Manufacturing

Demand

Global wafer demand is expected to grow steadily at a CAGR of ~1.7% through 2050. China, which accounts for ~88% of global wafer demand in 2024, will continue to lead the segment, although its share is projected to decline to ~61% by 2050. This change reflects a growing diversification.

Figure 11: Global demand for solar wafers by country/region (2024-2050)



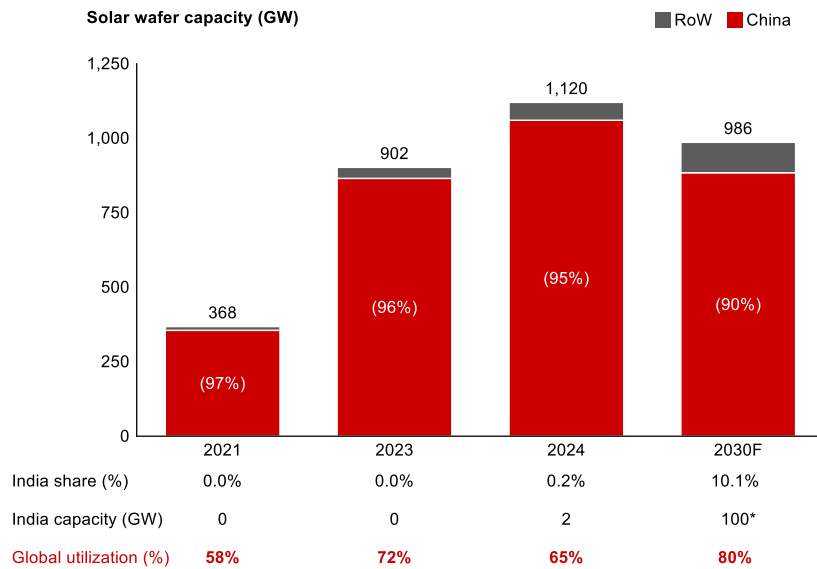
Note: Currently negligible wafer demand; for 2035 and 2050, wafer demand forecasts based on self-reliant PV manufacturing across the value chain. Source: International Energy Agency (IEA)

Supply

While wafer demand is gradually diversifying, global supply remains overwhelmingly concentrated in China. As of 2024, China continues to account for nearly all global wafer output, with India making only a marginal entry into production.

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Figure 12: Global supply of wafers by region (2021-2030F)

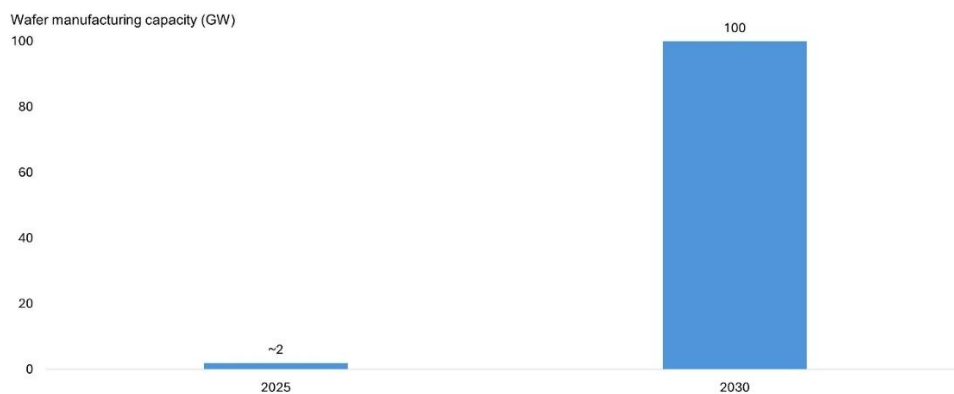


Note: Data has been extracted using online tools, hence are approximates; * Estimate from the National Solar Energy Federation of India (NSEFI)

Source: International Energy Agency (IEA)

In India, wafer slicing remains nascent at close to 2 GW, although investment commitments point to a potential scale-up toward 100 GW over the same horizon.

Figure 13: Current and forecasted wafer manufacturing capacity in India



Source: TERI – India's PV Manufacturing Report

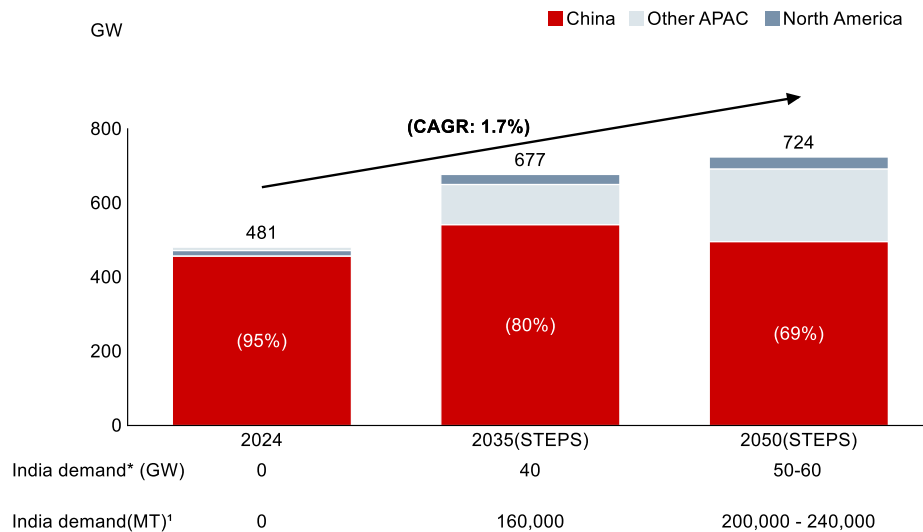
Polysilicon Manufacturing

Demand

Global polysilicon demand is expected to grow steadily at a CAGR of ~1.7% through 2050, driven by ongoing expansion in solar PV deployment worldwide. China continues to dominate consumption, but its share is projected to decline from 95% in 2024 to 69% by 2050, reflecting broader regional diversification.

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Figure 14: Global demand for solar PV polysilicon by country/region (2024-2050)

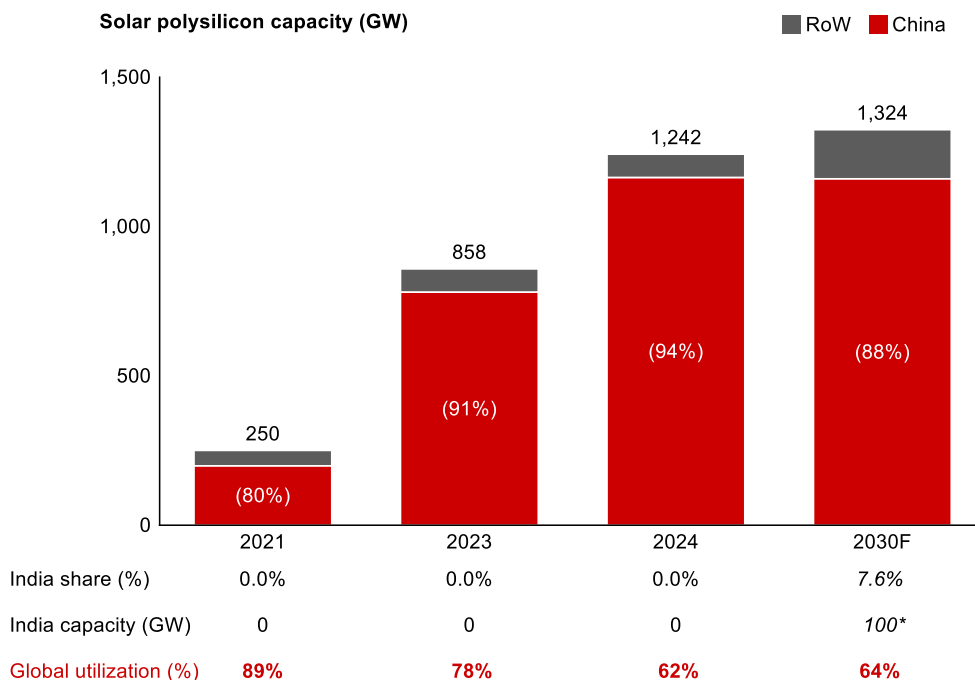


Notes: (1) The specific consumption of polysilicon is considered ~4,000 tons per (GW) of installed capacity for the production of PV cells; * for 2035 and 2050, polysilicon demand forecasts based on self-reliant PV manufacturing value chain (no imports of Polysilicon, Wafer, cell, or module). Source: International Energy Agency (IEA), Ministry of New and Renewable Energy of India (MNRE), International Renewable Energy Agency (IRENA)

Supply

The global polysilicon supply landscape is marked by extreme concentration and rapid capacity expansion-led almost entirely by China.

Figure 15: Global polysilicon manufacturing capacity (2021-2030F)



Note: Data has been extracted using online tools, hence are approximates; * Estimate from the National Solar Energy Federation of India (NSEFI). Source: International Energy Agency (IEA)

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In India, polysilicon production is still absent, but facilities totalling more than 40 GW-equivalent are slated to come online by 2027, with prospective additions that could bring capacity to about 100 GW by 2030.

Future manufacturing outlook in India

Presently, India's solar manufacturing landscape has rapidly matured with operational milestones replacing projected targets. According to official company disclosures, Tata Power's Tirunelveli facility successfully ramped up its operations, reaching a production mark of 2.8 GW of solar cells and 2.9 GW of modules as of December 2025. Meanwhile, Reliance Industries has advanced its fully integrated "sand-to-module" complex in Jamnagar, progressing from initial module production to successfully commissioning its cell manufacturing facility, with 1.24 GW of its high-efficiency heterojunction (HJT) solar cells officially entering the government's approved ALMM list in April 2026. Simultaneously, Adani Solar has operationalized 4 GW of cell and module capacity alongside 2 GW of ingot and wafer production at Mundra, while actively expanding to hit its 10 GW integrated milestone during FY 2027. Together, these production and expansion figures demonstrate that substantial domestic investments have successfully established robust, gigawatt-scale capabilities across the entire solar supply chain.

Cost Comparison

India's manufacturing sector faces stiff cost disadvantages versus global benchmarks. This gap stems from an entrenched import dependency, high input tariffs, and weak domestic integration across key upstream processes such as polysilicon and wafer manufacturing. The module supply chain is overwhelmingly controlled by Chinese producers, who command 83-95% of global capacity across critical inputs such as polysilicon, wafers, and cells. In contrast, India imports nearly all wafers and a significant share of cells.

India's solar modules remain roughly 12 percent costlier than landed Chinese panels for domestic buyers - about Rs. 16.2 / Wp versus Rs. 14.5 / Wp - because imported wafers and cells, higher bills of materials, and duties (20 percent BCD plus 7.5 percent AIDC) inflate the local cost stack.

Technology Overview across the value chain

Technological advancements are crucial for competitiveness. Polysilicon production is expected to shift toward upgraded metallurgical-grade and Siemens process variants. Wafer production is moving toward M10 and G12 formats that support higher efficiency and power density. Cell manufacturing is transitioning to more advanced technologies such as TOPCon, HJT, and IBC. These offer improved efficiency but also require significant capital investment and process optimization. Module design is evolving through the adoption of bifacial, half-cut, and multi-busbar configurations that enhance performance. Integrated modules with embedded electronics are also emerging, particularly for utility-scale applications.

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WIND

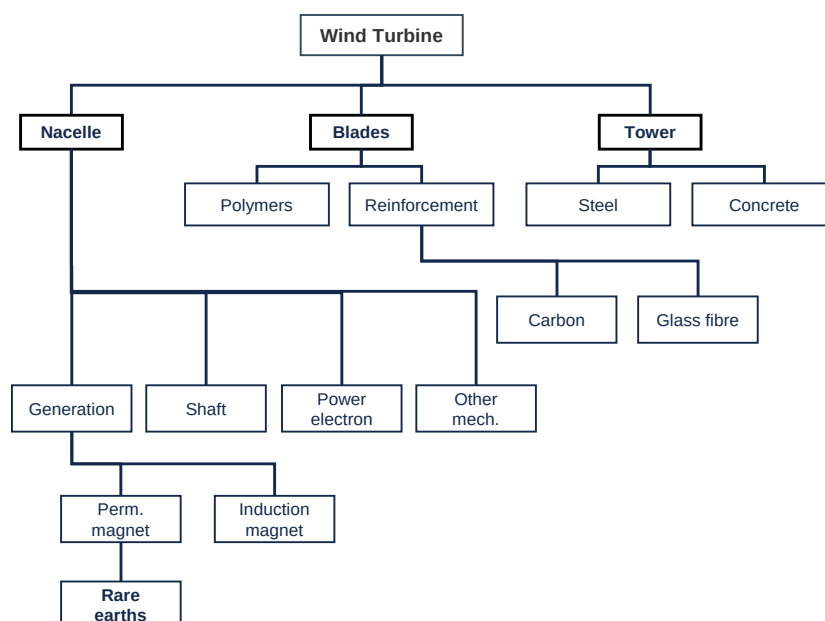
India's wind energy sector is predominantly onshore, with all operational capacity to date coming from onshore installations. While offshore wind has high theoretical potential, it remains commercially unviable in the short term due to high capex, long permitting timelines, and limited grid readiness. Offshore projects are still in early feasibility stages. To support the development of the offshore wind sector, the Government has approved Viability Gap Funding (VGF) of INR 7,453 crore. This includes an outlay of INR 6,853 crore for the installation and commissioning of 1 GW of offshore wind projects, comprising 500 MW each off the coasts of Gujarat and Tamil Nadu.

In addition, a grant of INR 600 crore has been approved for the upgradation of two ports to meet the logistics requirements of offshore wind projects. Other policy support measures, such as concessional transmission access, will also be important to accelerate project development. In contrast, onshore wind benefits from mature infrastructure, an established supply chain, and well-developed logistics corridors - positioning it as the primary focus for capacity expansion through 2030.

A modern wind turbine is a complex electromechanical system designed to harness kinetic wind energy and convert it into electrical power.

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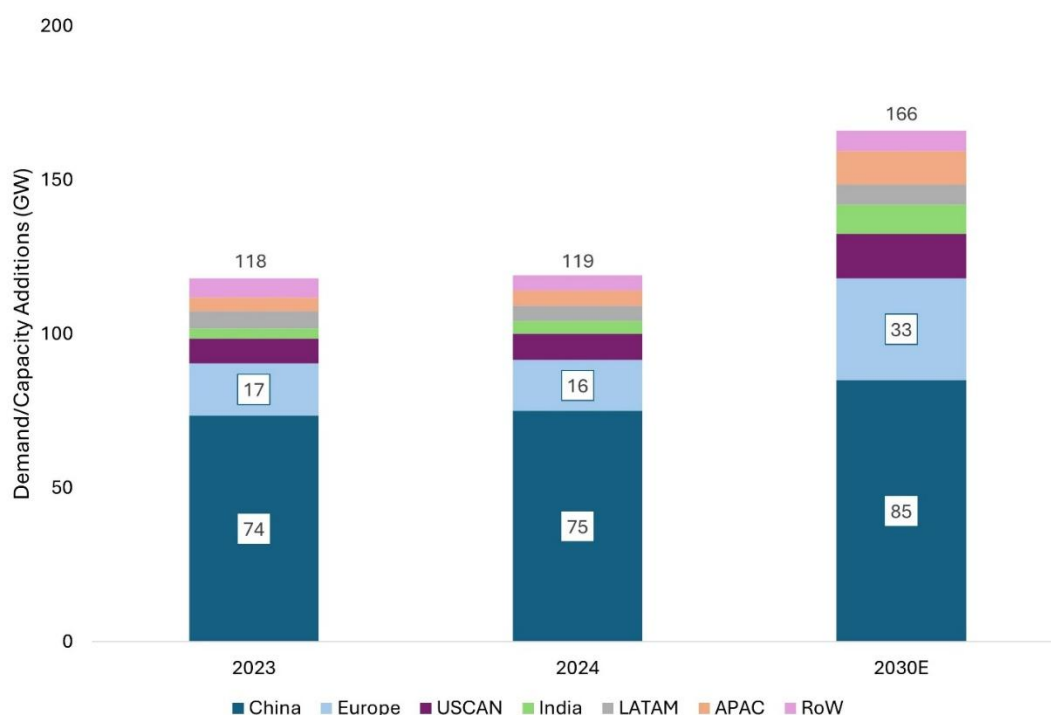
Figure 16: Key components of wind turbine



Source: Secondary research

At the heart of this system lie three primary components that define both the operational performance and capital intensity of the installation: the nacelle, the blades, and the tower. These elements collectively form the core of the turbine's value chain and are central to manufacturing, investment, and supply chain decisions.

Figure 17: Global annual demand for wind turbines split by region, 2023-2030E



Note: 1) Estimation based on Wind manufacturing capacity and gross installations stacked column chart from the IEA Renewables 2025, Report, 2) Demand data includes both offshore and onshore wind, 3) India's demand figures for 2023, 2024 are based on

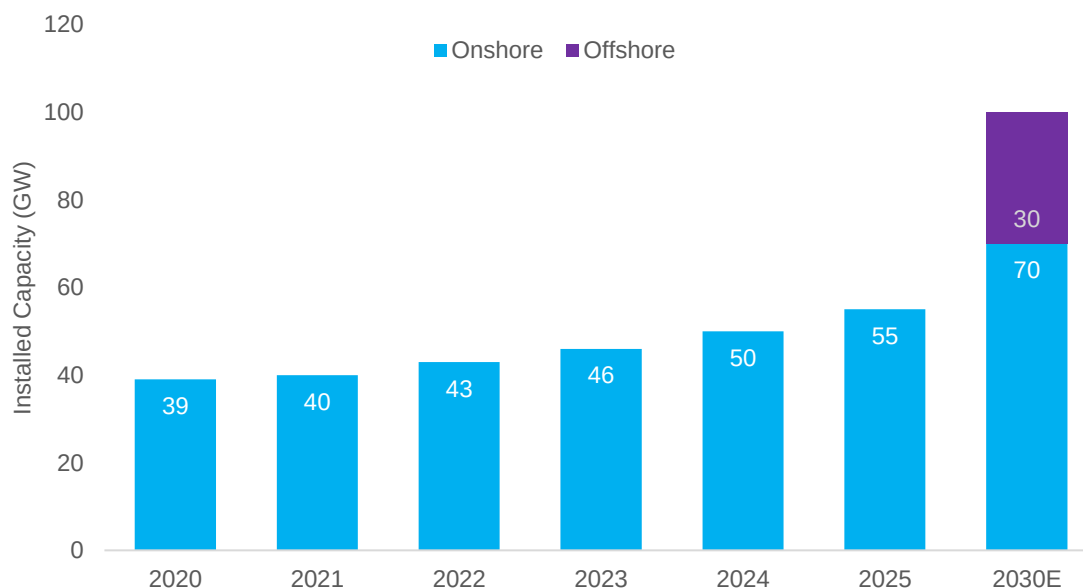
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capacity additions reported by IEA Renewables Report 2024 and 2025 while the projections for 2030 are derived from IEA Renewables 2025, Report, 4) USCAN = United States and Canada, LATAM = Latin America, APAC = Asia-Pacific (excludes India and China), RoW = Rest of the world

Source: International Energy Agency (IEA)

Global demand for wind turbines is expected to grow steadily, reaching approximately 166 GW of annual installations by 2030. While China currently dominates with over 60% of all global installations, its market share is expected to decrease as domestic growth stabilizes. This allows India to rapidly expand its footprint, with projections showing India will double its global market share from roughly 3% to 6% by the end of the decade. India's domestic growth is clearly accelerating, with new capacity additions jumping from 3.25 GW in FY24 to 4.15 GW in FY25 and reaching 6.06 GW in FY26. This brings India's total operating wind capacity to 56.09 GW as of March 2026. However, to achieve its ambitious national target of 100 GW by 2030, India must install 8 to 10 GW annually over the next five years. While India has become a strong exporter of turbine blades to countries like the US and Vietnam, meeting its own domestic goals will be a challenge. Progress is currently being slowed down by land acquisition delays, crowded power grids, and local factories struggling to produce enough of the larger, modern turbines the industry now requires.

Figure 18: Installed wind energy capacity in India (2020-2030F)



Source: MNRE, JMK Research, GWEC

India's entire installed wind capacity of ~56 GW as of March 2026 is derived exclusively from onshore projects. Offshore wind has an identified potential of over 70 GW off the coasts of Gujarat and Tamil Nadu. While progress was historically negligible due to high costs, the government took a major step in 2024 by approving a Rs. 7,453 Crores Viability Gap Funding (VGF) scheme to set up India's first 1 GW of offshore wind projects. The long-term target of the government is to auction 30 GW of offshore capacity by 2030.

Onshore wind manufacturing in India is spread unevenly across different parts of the supply chain.

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Suzlon leads the production of the main turbine units (nacelles) with an annual capacity of up to 4.5 GW, followed by major players like Siemens Gamesa and GE. For turbine blades, companies like Vestas, LM Wind Power, and Envision hold the most capacity, while tower manufacturing remains fragmented among EPC contractors and smaller fabricators. Utilization of existing capacity remains suboptimal, particularly for nacelles and towers, due to limited domestic demand and export friction caused by heavy logistics requirements and insufficient port-side infrastructure.

Building on India's wind manufacturing evolution, nacelle, blade, and tower technologies are rapidly advancing to support larger, more efficient turbines. Nacelles are moving toward modular, torque-dense designs like MSGD and SPMG to reduce weight and improve maintainability. Chinese OEMs are shortening development cycles through tighter integration, while global players focus on platform standardization and faster deployment. Blades are increasing in size, now crossing 100–150 meters, with offshore designs shifting to carbon fiber for strength and weight efficiency. Modular blade formats are emerging to address transport constraints, while recyclability and acoustic performance are gaining attention. Towers are scaling in height to tap low-wind sites, using spiral-welded steel and hybrid concrete designs to manage weight and cost. Innovations like the Nabrabase tripod cut material use and emissions. Localized production, including mobile factories, is becoming critical to meet transport and permitting challenges. Together, these trends are pushing the wind sector toward larger, more flexible, and cost-efficient infrastructure ready for next-generation deployment.

Capital expenditure estimates for setting up a 1.5 GW per annum wind manufacturing facility vary significantly by component. Nacelle assembly requires approximately INR 510-765 crore for a 5MW plant, driven by the need for specialized sub-systems such as gearboxes, generators, and control units. Blade manufacturing facilities involve a capex of INR 500 to 600 crore, depending on blade length and material mix, with costs rising for carbon fibre or segmented blade designs. Tower fabrication requires around INR 550 crore, influenced by the type of welding technology and availability of domestic flanges and heavy steel. Capex recovery timelines also differ across segments:

Margin profiles across these components vary, with tower manufacturing offering more stable margins due to standardized demand and localization, while nacelles and blades are more margin-sensitive, influenced by technology upgrades, material costs, and order visibility. Key performance indicators for wind manufacturing include maintaining utilization rates above 80%, product-level yields above 95%, and streamlined logistics operations to support the movement of large components across long distances efficiently.

Overall, India's wind manufacturing ecosystem is technically sound but constrained by demand variability, export friction, and infrastructure gaps. Addressing tower bottlenecks, expanding flange forging and heavy-steel fabrication, and enabling logistics solutions will be critical to support India's ambition of installing 100 GW of wind capacity by 2030 and establishing itself as a global manufacturing hub.

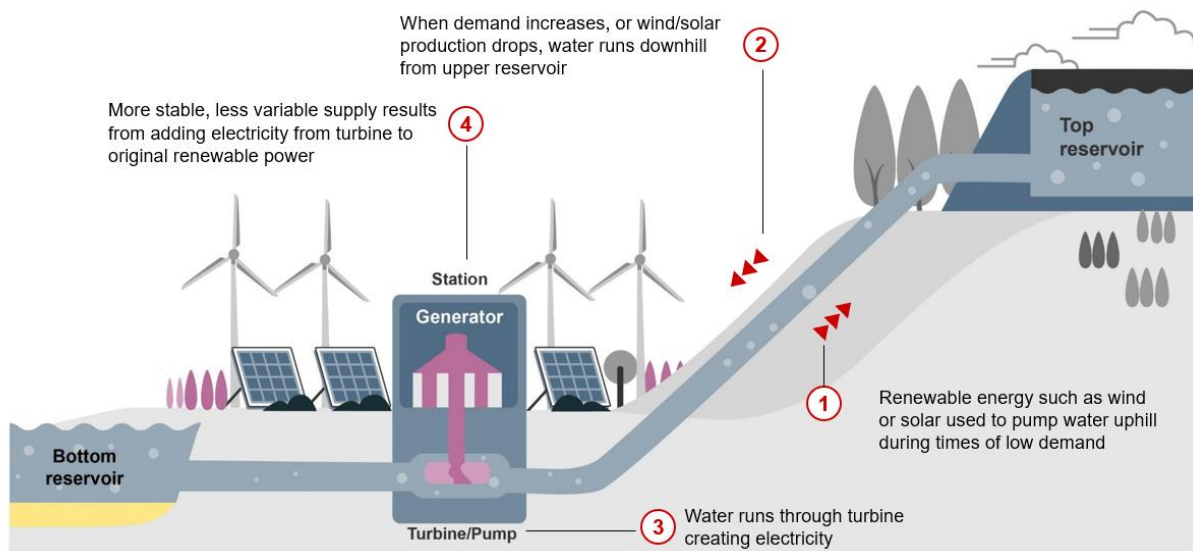
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4

PSP

A PSP consists of two water reservoirs at different elevations. During off-peak hours, electricity—often from renewable sources—is used to pump water to the upper reservoir. When demand spikes, the stored water is released, flowing through turbines to generate electricity. This closed-loop system ensures high round-trip efficiency (~70-80%) with long operational lifespans of over 40 years.

Figure 19: The operational cycle of PSP across its various stages



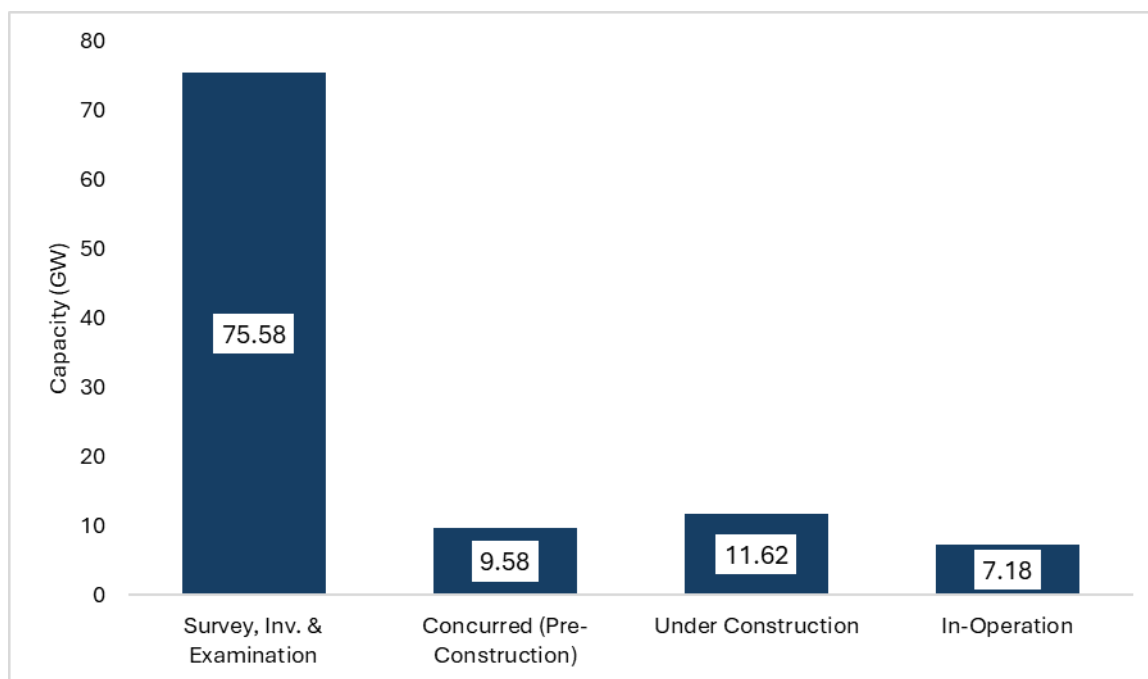
Source: Secondary research

Pumped hydro storage operates by shifting water between two reservoirs to store and release energy based on grid demand. During periods of low electricity consumption, typically at night or when renewable sources generate surplus power, electricity powers pumps that move water from a lower to an upper reservoir, storing energy as gravitational potential. The water remains in the upper reservoir until needed, capable of holding energy for hours or days with minimal loss. When demand spikes or renewable output dips, water is released to flow downhill through tunnels, spinning turbines connected to generators that convert kinetic energy into electricity for the grid. After discharge, water collects in the lower reservoir, ready for another cycle. This system offers rapid, dispatchable power

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and is highly effective for balancing renewable energy variability, thanks to its long-duration storage, reusability, and grid-stabilizing properties.

Figure 20: PSP projects in India by capacity (in GW)



Source: Central Electricity Authority (CEA)

According to the Central Electricity Authority's (CEA) roadmap report published in January 2026, India has an estimated technical potential of about 267 GW, out of which ~96 GW of capacity is in various stages of planning and development. The demand for PSPs is growing due to increasing renewable energy penetration, which creates grid management challenges and the need for firm capacity. PSPs are well positioned to meet India's peak demand growth, which is expected to reach approximately 230 GW by 2030. The flexibility of PSPs makes them more suitable than lithium-ion batteries for daily and weekly storage cycles, especially in regions with significant hydrological resources and grid congestion. Several large-scale projects are being driven by state utilities and private developers, with demand expected to rise in tandem with the rollout of hybrid solar and wind power plants.

Technology advancements are improving the functionality and viability of PSPs. Variable-speed units allow partial load operation and provide better frequency regulation, while closed-loop and underground configurations reduce ecological footprint and land dependency. Ternary machines enable faster switching between pump and generation modes, supporting greater flexibility for ancillary services. The introduction of digital twins and AI-enabled performance monitoring is also enabling predictive maintenance and lifecycle cost optimization. As demand for long-duration storage grows, these trends are expected to play a critical role in making PSPs more scalable and grid-integrated.

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5

REGULATORY & POLICY LANDSCAPE

India's renewable energy sector is underpinned by a comprehensive regulatory framework driven by central and state governments, designed to accelerate project deployment, lower financing costs, enhance grid readiness, and attract long-term capital. The policy ecosystem spans generation, transmission, procurement, storage, and sustainability, reflecting a whole-of-system approach aimed at reaching the 500 GW non-fossil capacity target by 2030.

At the central level, the Ministry of Power (MoP) and the Ministry of New and Renewable Energy (MNRE) are the principal agencies driving renewable energy policy. Several critical regulations have been notified to create demand certainty and enable infrastructure development:

- **Renewable Purchase Obligations (RPOs):** The MoP has mandated a trajectory for RPOs extending through FY30, with specific carve-outs for solar, wind, hydro, and other clean energy sources. States are required to progressively scale up renewable procurement, creating long-term demand visibility.
- **Tariff-based competitive bidding (TBCB):** The competitive bidding framework for solar, wind, hybrid, and RTC (round-the-clock) power procurement continues to be central to pricing discovery and investor participation. Guidelines are issued and updated by the MNRE to standardize risk allocation, power sale terms, and offtake arrangements.
- **Green Open Access Rules, 2022:** These rules simplify procedures for commercial and industrial (C&I) consumers to procure renewable power. Key provisions include reduced approval timelines, elimination of minimum load requirements (now set at 100 kW), and transparent cross-subsidy surcharge methodologies. This enables C&I users to transition to renewables through open access and group captive models.
- **Inter-state transmission system (ISTS) charge waivers:** To promote scalability, the government has extended waiver of ISTS charges for renewable energy projects commissioned by June 2025. This is applicable to both solar and wind, and also covers green hydrogen and green ammonia projects when tied to renewable sources.
- **Green Energy Corridor (GEC):** This scheme, in its second phase, provides viability gap funding and strategic transmission planning to evacuate power from renewable-rich states. A

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total outlay of INR 12,000 crore has been allocated to create over 10,000 circuit kilometers of transmission lines and 27 GW of integration capacity.

- **Regulatory Relaxation for Off-Stream PSPs:** In a notification dated August 1, 2025, the Government of India updated the approval rules for new hydropower projects. Now, standard hydro generating stations only require approval from the Central Electricity Authority (CEA) if their capital cost exceeds ₹3,000 Crores. Further, the government has completely exempted all off-stream, closed-loop pumped storage projects from needing CEA approval, regardless of how much they cost to build.

India's state governments play a pivotal role in translating national renewable energy goals into actionable capacity on the ground. Several states have developed independent renewable energy policies that complement central schemes by providing location-specific benefits. These include capital subsidies, land allocation in renewable energy parks, stamp duty waivers, electricity duty exemptions, and fast-track clearances. Gujarat and Rajasthan have leveraged their high solar irradiance to attract major solar park investments, while Tamil Nadu and Karnataka have focused on wind and hybrid projects due to favorable climatic and grid conditions. States like Maharashtra and Andhra Pradesh have expanded their support frameworks to include pumped storage projects and integrated grid infrastructure planning, reinforcing their position as renewable corridors.

Globally, renewable energy policy is evolving toward greater market alignment, integration, and resilience. The European Union continues to drive regulatory innovation through instruments like the Renewable Energy Directive III, which mandates aggressive renewable capacity targets, streamlines permitting, and prioritizes clean energy dispatch across member states. Germany's updated EEG framework offers premium-based support mechanisms, replacing fixed tariffs to improve price discovery and enhance grid readiness. In the United States, the Inflation Reduction Act provides performance-linked tax credits for renewable generation and storage, fostering long-term capital investment while encouraging domestic manufacturing and grid upgrades. Federal agencies are concurrently promoting reforms in transmission planning and resource adequacy. China's regulatory framework is characterized by state-directed targets under its 14th Five-Year Plan, provincial capacity quotas, and eligibility norms tied to local content and grid balancing requirements. Green certificate trading and hybrid procurement are key levers in China's policy toolkit. Other emerging economies, including Brazil, Vietnam, and the Philippines, continue to rely on reverse auctions and long-term power purchase agreements to de-risk investments. A unifying theme across these jurisdictions is the rising emphasis on storage integration, real-time market reforms, and carbon pricing frameworks that enable dispatchable and low-emission energy systems. India's regulatory trajectory is increasingly aligned with these global trends, with recent initiatives around hybrid tenders, energy storage viability gap funding, and carbon market pilots laying the groundwork for deeper international competitiveness and capital mobilization.

Looking ahead, regulatory priorities will focus on enabling firm and flexible power supply from renewable sources. Hybrid projects, PSPs, and battery storage will require customized frameworks for revenue stacking, multi-part tariffs, and risk mitigation. Emerging sectors such as green hydrogen and offshore wind will also be guided by new enabling regulations expected in the next two years.

A continued emphasis on power market reforms, transmission planning, and digital infrastructure is

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expected to facilitate deeper renewable integration and enhance investor confidence across the value chain. The evolving regulatory architecture signals a maturing energy ecosystem where renewables are no longer treated as niche but as core assets in India's energy future.

6

ESG CONSIDERATIONS

Environmental performance is becoming a key determinant of project viability in India's renewable energy sector. Technologies such as solar and wind demonstrate strong energy payback times, with utility-scale PV offsetting embedded energy within a year and wind turbines doing so within a few months. As the sector scales, land use is becoming a growing concern, particularly for solar installations which require roughly three acres per megawatt. To address this, developers are turning to innovations such as agrivoltaics and floating solar which enable dual land use and reduce spatial conflict. Meanwhile, wind installations retain a land-use advantage by supporting agricultural activity within project footprints.

Material circularity is gaining attention as the installed base of renewable assets ages and decommissioning volumes grow. Solar panel recycling remains underdeveloped in India, with most activity concentrated in informal channels lacking adequate safeguards. Wind turbine recycling is more advanced for towers and nacelles, but blade disposal remains a challenge due to composite materials that are difficult to process. This has led to investments in R&D for blade recyclability and industrial partnerships that explore cement co-processing and new material design.

Environmental risks also extend to biodiversity and water conservation. Renewable projects intersect with ecologically sensitive areas, especially in Rajasthan and Gujarat, threatening habitats like those of the endangered Great Indian Bustard. In response, measures such as underground transmission lines and bird diverters are being mandated. Water usage, especially for solar panel cleaning in arid zones, is another critical issue. This has led to greater adoption of robotic dry-cleaning systems and surface coatings that reduce dust accumulation and lower cleaning frequency.

Social outcomes are becoming equally important, with employment generation and local community engagement at the forefront. The sector has created over 400,000 jobs as of 2023, with rooftop and off-grid solar installations proving particularly labor-intensive. Developers are also channeling Corporate Social Responsibility funds into rural infrastructure, education, and livelihood support in areas where land acquisition or displacement occurs. These efforts not only mitigate community

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resistance but also enhance the long-term sustainability of project operations.

Governance standards are evolving in response to both domestic regulation and global investor expectations. Traceability is now a central concern, particularly in solar supply chains where imports from high-risk regions have drawn scrutiny under international human rights laws. Compliance with global equipment standards and type certification is now mandatory across solar and wind segments, strengthening project quality. As digitalization spreads across energy infrastructure, cybersecurity has become a regulatory priority, with guidelines requiring data protection, network perimeter control, and emergency response plans. ESG reporting frameworks are maturing with SEBI's BRSR Core mandate, which requires listed firms to disclose and assure sustainability metrics. Together, these measures are raising the bar for transparency, accountability, and ethical performance across the renewable value chain.

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7

OPPORTUNITIES & CHALLENGES

Opportunities

India is positioned for a large-scale expansion in renewable energy, driven by a mix of regulatory reform, private sector innovation, and shifting consumer preferences. Multiple structural and technology-led shifts are enabling new business models beyond utility-scale procurement, with rising demand from commercial and industrial (C&I) consumers, expanding hybrid portfolios, and improving rooftop adoption. The following are the key opportunities emerging across the sector:

- **Rising corporate demand for renewables:** As per Business Standard article dated 4th Dec. 2025, India's Commercial and Industrial (C&I) segment is experiencing rapid uptake of renewables through open access and group captive models. Falling tariffs, net-zero mandates, and enabling policies are reinforcing this momentum. According to recent market projections, installed renewable energy capacity in the C&I segment is expected to reach 60 to 80 GW by 2030, with the sector having added over 6 GW of new capacity in 2025 alone.
- **Increased traction for hybrid renewable energy models:** Hybrid configurations combining solar, wind, and storage are gaining prominence as utilities and developers seek dispatchable, round-the-clock solutions. Central agencies have started issuing hybrid tenders and are offering viability gap funding to support these firm assets. This model is well suited to meet industrial baseload requirements and mitigate intermittency risks.
- **Positive outlook for rooftop solar adoption:** Rooftop solar, though historically underpenetrated, is now seeing renewed traction due to initiatives like the PM Surya Ghar scheme, revised net metering rules, and new financing models. These shifts are expanding participation from households and small commercial users. Rooftop solar is also viewed as a key enabler of job creation and demand-side resilience.

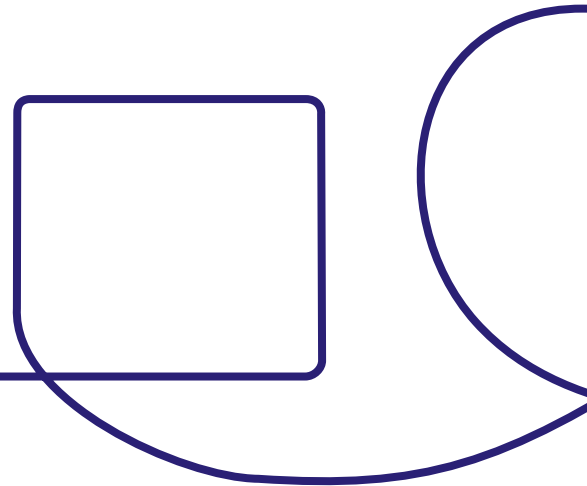
Challenges

Despite growing momentum, structural barriers remain that could impede the pace and quality of scale-up. The following are the most critical challenges identified in the report:

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- **Grid infrastructure limitations and intermittency risks:** Transmission congestion, land acquisition delays, and slow permitting continue to stall projects. By late 2025, the backlog of unsigned Power Sale Agreements (PSAs) for awarded renewable projects swelled to 42 GW, prompting the government to allow the formal cancellation of Letters of Award (LoAs) for unviable projects to clear the pipeline. Beyond contracting delays, the physical grid is struggling to keep pace with capacity additions. According to a March 2026 assessment by CRISIL Ratings, over 35 GW of renewable energy capacity faces severe grid curtailment risks in FY 2027. This is largely because the slow rollout of Inter-State Transmission System (ISTS) infrastructure is forcing many newly commissioned projects to rely on Temporary General Network Access (TGNA), leaving them vulnerable to power evacuation bottlenecks. Furthermore, hybrid and standalone storage tenders continue to face execution complexities, often driven by a mismatch between discovered tariffs and actual project costs.
- **Manufacturing capacity constraints and import dependence:** India's renewable supply chain is heavily reliant on imports for modules, wafers, turbines, and critical components. Domestic manufacturing remains underdeveloped, especially in upstream segments like polysilicon and forging. This exposure to foreign supply risks undermines cost stability and long-term competitiveness.
- **Structural fragmentation and technology lock-in in rooftop solar:** The residential rooftop segment suffers from disaggregated demand, limited economies of scale, and a fragmented supply chain. Financing gaps, inconsistent subsidies, and low consumer awareness further constrain uptake. Many installations are also technologically locked into suboptimal configurations, limiting future scalability and integration potential.

APPENDIX



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Appendix A: Glossary of Key Terms

Term	Description
Renewable Energy	Energy derived from naturally replenishing resources that are virtually inexhaustible in duration but limited in the rate of supply. Renewable energy sources include sunlight (solar), wind, water (hydro, including wave/tidal), geothermal heat, and biomass.
Decarbonization	The process of reducing and ultimately eliminating carbon dioxide and other greenhouse gas emissions from economic activities. In energy contexts, it involves transitioning from fossil fuels to renewable and low-carbon sources to lower the carbon intensity of power generation.
Energy Transition	The global shift from a fossil fuel-based energy system to one dominated by renewable and low-carbon energy sources. This transition involves moving towards wind, solar, hydro, biomass, etc., and away from coal, oil, and gas in order to reduce greenhouse emissions.
Carbon Neutrality	A state in which an entity or process has net-zero carbon dioxide emissions. This is achieved by balancing the amount of CO ₂ released with an equivalent amount sequestered or offset (for example, by carbon credits or reforestation). Often used interchangeably with “net zero carbon.”
Net Zero	A target or state where the total greenhouse gas emissions emitted is equal to the amount removed from the atmosphere, bringing net emissions to zero. Achieving net zero typically requires drastic emission reductions and offsetting any remaining emissions through removal or credits.
Baseload Power	The continuous minimum load (demand) on an electrical grid over a period, or the power plants (often coal, nuclear, etc.) that are operated at a constant output to meet this base level of demand. Baseload generation units run 24 hours a day to supply the base demand.
Peak Load	The maximum electrical power demand observed over a specified timeframe (e.g. daily or seasonally). It represents the highest point of electricity consumption on the grid in that period. Power systems must have sufficient capacity (or backup) to meet peak load requirements.
Dispatchable Generation	Generation sources that can be turned on, off, or adjusted on demand by grid operators to match the load. These resources (e.g. natural gas turbines, hydropower with reservoir) can be dispatched as needed to ensure grid

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stability.

Intermittent / Non-Dispatchable	Energy sources that are not continuously available because they depend on naturally variable inputs and cannot be controlled by operators. For example, solar and wind are intermittent resources - their output varies with sunlight and wind speed, so they cannot be turned on at will.
Distributed Generation (DG)	Decentralized, small-scale power generation located close to the point of consumption. Examples include rooftop solar panels or small wind turbines that supply a home or business. Distributed generation reduces transmission losses and can operate in conjunction with or independent from the main grid.
Off-Grid System	An electricity supply system not connected to the public utility grid. Off-grid systems (e.g. solar panels with batteries in a remote cabin) operate independently and are self-sufficient, often using local renewable generation and energy storage.
On-Grid (Grid-Tied)	An energy system that is connected to the main electric grid. A grid-tied renewable system (such as a rooftop solar PV with net metering) can feed excess power to the utility and draw power when local generation is insufficient. (Contrast with off-grid , which has no grid connection.)
Grid Parity	The point at which electricity from an alternative or renewable energy source is equal to or cheaper than power from the traditional grid (usually fossil-fuel based) on a levelized cost basis. Reaching grid parity means the renewable source can compete without subsidies.
Solar Terms:	
Term	Description
Photovoltaic (PV)	Relating to the direct conversion of light into electricity. A <i>photovoltaic cell</i> (solar cell) is a semiconductor device that generates DC electric current when exposed to sunlight (the photovoltaic effect). Multiple cells connected and packaged together form a solar module or solar panel.
Solar Cell	A single photovoltaic cell - a semiconductor diode structure that converts incoming solar radiation directly into electricity. Solar cells are the basic building blocks of solar panels and are usually made of silicon or other semiconductors.
Solar Panel (Module)	An assembly of interconnected solar photovoltaic cells packaged into a single unit, usually protected by glass and an aluminum frame. A solar panel generates a specified voltage and current from sunlight and modules can be combined into arrays for higher power output.

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Inverter A power electronic device that converts direct current (DC) electricity into alternating current (AC). In renewable systems, inverters are critical for converting DC from solar panels or batteries into AC that can be used by standard appliances or fed into the grid. Grid-tied inverters also manage safety and synchronization with utility power.

Net Metering A billing mechanism that credits owners of distributed renewable generation for the excess electricity they feed into the grid. When a home solar PV system produces more power than used, the surplus is sent to the grid and the producer's meter runs backward or earns credits at retail rate, which can offset electricity drawn from the grid at other times.

Gross Metering An arrangement where all the energy generated by a consumer's renewable system is fed into the grid at a predefined tariff, and all electricity consumption is metered and billed separately at the usual rate. In a gross metering scheme, the producer sells 100% of their solar generation to the utility (often at a feed-in tariff rate) and buys back all energy needed for load.

Rooftop Solar PV Solar power systems installed on the rooftops of residential, commercial, or industrial buildings. Rooftop solar is a form of distributed generation where PV panels generate electricity on-site. These systems can be grid-tied (often with net metering) or paired with batteries for backup/off-grid use, helping consumers reduce grid consumption and energy bills.

Wind terms:

Term	Description
Wind Turbine	A device that converts the kinetic energy of moving air (wind) into electrical energy. Modern wind turbines typically consist of rotor blades (which capture wind energy), a hub and nacelle (housing the gearbox, generator, and controls atop a tower), and associated control systems. Horizontal-axis wind turbines (with a propeller-like rotor facing the wind) are the most common design.
Wind Farm	A group of wind turbines in the same location, collectively used to produce electricity. Tilt Angle s can range from a few turbines to hundreds spread over a large area. They may be onshore (land-based) or offshore (located in bodies of water on fixed platforms or floating structures). Power from all turbines is pooled and fed into the grid.
Nacelle	The housing that sits atop a wind turbine tower, immediately behind the rotor hub. The nacelle contains the turbine's critical mechanical and electrical components - typically the gearbox, generator, drive train, and brake - and it may also include control systems. The nacelle is mounted on a yaw system so it can rotate to face the wind.
Onshore	Wind farms or turbines located on land. Onshore wind power is one of the cheapest

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Wind sources of new electricity in many regions. These installations can be in open plains, hilltops, or other windy land areas. They are more accessible for construction and maintenance than offshore turbines.

Offshore Wind Wind turbines installed in bodies of water (usually in the ocean on continental shelves). Offshore wind farms are built on the sea (fixed to the seabed in shallow water, or floating in deeper water) and take advantage of strong, steady ocean winds. Offshore projects can achieve very large scale but have higher installation and maintenance costs.

Hybrid systems:

Term	Description
Hydropower (Hydroelectricity)	Electricity generated by harnessing the energy of moving water. In conventional hydropower, a turbine and generator convert the kinetic and potential energy of flowing or falling water (e.g., from a river or dammed reservoir) into electricity. It is a well-established renewable source; water flow can be regulated for dispatchable power in reservoir-based plants.
Dam	A barrier constructed across a river or stream to hold back water for purposes such as water supply, flood control, or power generation. In a hydropower context, dams create elevated water reservoirs. Water released from the reservoir drives turbines in a hydroelectric plant. Dams enable impoundment hydropower, providing the stored energy head and flow control.
Reservoir	A stored body of water (often created by a dam) used in hydropower to provide a stable supply of water for electricity generation or other uses. The head (height difference between the reservoir surface and the turbine outlet) in a reservoir provides potential energy. Reservoirs allow power output to be controlled and scheduled, unlike run-of-river systems that lack large storage.
Run-of-River	A type of hydroelectric generation that operates on the natural flow and elevation drop of a river with minimal or no reservoir storage. Run-of-river plants divert a portion of a river's flow through turbines and typically have smaller environmental footprints (no large dams). They produce power in proportion to the river's flow and are subject to seasonal flow variability (less dispatchable).
Pumped Hydro Storage	A large-scale energy storage method that uses two water reservoirs at different elevations. During low-demand or surplus generation times, electricity pumps water from the lower reservoir to the higher reservoir (charging the storage by storing potential energy). During peak demand, the stored water is released back down through turbines to generate electricity. Pumped-storage hydro acts like a "water battery" for the grid.

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Policy terms:

Term	Description
Power Purchase Agreement (PPA)	A long-term contract between an electricity generator and a buyer (off-taker) to purchase electricity at agreed terms (price per kWh, duration, etc.). PPAs are common in renewable energy projects: for example, a solar farm developer signs a 20-year PPA with a utility or corporate buyer to sell all the generated power at a fixed rate.
Renewable Portfolio Standard (RPS)	A regulatory policy (often at the state/provincial or national level) that requires load-serving entities (utilities or retail electric providers) to supply a certain minimum percentage of their electricity sales from renewable sources by a target date. For instance, an RPS might mandate 30% renewables by 2030. Utilities typically comply by building renewable capacity or buying Renewable Energy Certificates from others.
Renewable Purchase Obligation (RPO)	A policy mechanism in India analogous to an RPS. It mandates that specified entities (e.g. distribution companies, large consumers with open access or captive power) must source a certain percentage of their electricity from renewable resources.
Net Metering Policy	Regulations that govern how distributed generators (like rooftop solar owners) are credited for excess electricity they export to the grid.
Open Access (Electricity)	A regulatory provision that allows large electricity consumers to buy power from generators of their choice (instead of being tied to the local utility's supply), using the existing transmission and distribution network for delivery.
Green Open Access (India)	A specific set of regulations (Green Open Access Rules 2022 in India) that streamline and encourage open access procurement of renewable energy. It lowers the eligibility threshold (from 1 MW to 100 kW) so smaller consumers can directly buy green energy, mandates simplified and time-bound approval processes, caps certain charges, and facilitates easier trading of green energy. The goal is to expand access to renewables for more consumers and promote renewable energy markets across state boundaries.
Cross-Subsidy Surcharge (CSS)	A fee that open access consumers must often pay to the local distribution company when they procure power from a source other than the utility. It is meant to compensate the utility for loss of revenue that would have helped subsidize other consumer categories.
Viability Gap Funding (VGF)	A form of capital grant or subsidy given, usually upfront, to cover the "viability gap" between a project's full cost and the level that would be affordable or bankable for investors at a tariff deemed reasonable. VGF schemes are used to make infrastructure projects (including renewables like solar parks or battery

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storage) financially feasible when the market-alone returns are insufficient.

MNRE	Ministry of New and Renewable Energy - the Government of India's ministry responsible for formulating and implementing policies, programs, and incentives for the development of renewable energy (solar, wind, biomass, small hydro, etc.) and overall promotion of new energy technologies.
SECI	Solar Energy Corporation of India - a public sector enterprise under MNRE, originally established to implement the National Solar Mission. SECI is the nodal agency for conducting centralized renewable energy auctions in India (for solar, wind, hybrid projects, and energy storage) and for development of solar parks. Through competitive bidding on behalf of distribution companies or the government, SECI has helped drive down costs and increase deployment.
Carbon Credit	A transferable instrument certified by governments or independent bodies representing a unit of carbon dioxide (1 tonne typically) prevented or removed from the atmosphere.

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Appendix C: References and data sources

- **International Energy Agency (IEA)** – Renewables 2025 Report (Analysis and forecasts to 2030)
- **International Energy Agency (IEA)** – Renewables 2024 Report (Analysis and forecasts to 2030)
- **International Energy Agency (IEA)** – World Energy Outlook (STEPS and APS scenarios, 2022/2023)
- **Central Electricity Authority (CEA)** – Roadmap to 100 GW of Hydro Pumped Storage Projects (PSPs) by 2035-36 (2026)
- **International Renewable Energy Agency (IRENA)** – Renewable capacity statistics 2026
- **International Renewable Energy Agency (IRENA)** – Renewable capacity statistics and global RE data (2023–2024)
- **NITI Aayog (Gov. of India)** – National energy scenario and renewables roadmap reports (2022)
- **Enerdata (EnerBase)** – Global energy database and forecasts (accessed 2023)
- **CRISIL Research** – India renewable energy sector analysis and reports (2023)
- **The Energy and Resources Institute (TERI)** – India's PV Manufacturing & Its Strategic Inflection Points (2026)
- **The Energy and Resources Institute (TERI)** – Research publications on renewables and climate (2023)
- **Ministry of Power (India)** – *Electricity (Promoting Renewable Energy Through Green Open Access) Rules* (June 2022)
- **Ministry of New & Renewable Energy (MNRE)** – *National Repowering & Life Extension Policy for Wind Power Projects* (2023)
- **Government of India** – Union Budget 2025 proposals on solar equipment duties (Feb 2025)
- **Ministry of New & Renewable Energy (MNRE)** – Production Linked Incentive (PLI) scheme guidelines for solar PV manufacturing (2021–2022)
- **Ministry of New & Renewable Energy (MNRE)** – Approved List of Models and Manufacturers (ALMM) for solar modules
- **Government of India** – Official renewable energy capacity targets
- **U.S. Dept. of Energy (DOE)** – Office of Energy Efficiency & Renewable Energy (EERE) data on renewable capacity (2023)
- **Rystad Energy** – Wind energy market analysis and forecasts (2023)
- **Global Wind Energy Council (GWEC)** – *Global Wind Report* and Market Intelligence (2020–2023)
- **National Institute of Wind Energy (NIWE)** – *India's Wind Potential Atlas* (120m hub-height assessment, 2020)

Renewable Energy Sector in India

- **Bridge To India** – India solar & renewables market reports and *India RE Navigator* database (2023–2024)
- **Business Standard** – C&I RE capacity may rise to 60-80 GW by 2030 (Dec. 2025)
- **Mercom India** – Solar industry news and market reports (2023–2024)
- **PV Magazine** – Global solar industry news articles (2023)
- **JMK Research & Analytics** – Indian renewable energy market updates (2023–2024)
- **CareEdge Ratings** – Solar PV manufacturing sector report and ratings analysis (2023)
- **Institute for Energy Economics & Financial Analysis (IEEFA)** – Energy finance research on India's renewables (2024)
- **PV Infolink** – Solar PV supply chain price and stock data (2024)
- **Oakland Capital** – Investment research on solar manufacturing (e.g. Waaree financial analysis, 2023)
- **CSTEP (Center for Study of Science, Tech. & Policy)** – *Solar Manufacturing in India* report (2018)
- **Company websites and press releases** – Official disclosures by major firms (e.g. Reliance 10 GW solar fab commissioning, First Solar 3.3 GW plant approval) (2023–2025)
- **AESC (Automotive Energy Supply Corp.)** – Company website and press releases (May 2025)
- **Reliance Industries** – Corporate press releases on new solar manufacturing facilities (April 2025)
- **First Solar, Inc.** – Company announcements on India thin-film factory plans (2024)
- **Adani Green Energy** – Company reports and press releases on renewable projects (2023)
- **ReNew Power** – Company press releases on RTC and C&I renewable projects (2022–2023)
- **Tata Power Renewable Energy** – Company press releases on project wins (2023)
- **Vestas, Siemens Gamesa, GE** – Sustainability reports and ESG disclosures (2022–2023)
- **Major OEM policies** – Human Rights and anti-forced-labor statements from wind OEMs (e.g. modern slavery statements, 2021–2022)
- **Central Electricity Authority (CEA)** – *Cybersecurity Guidelines for Power Sector* (India, 2021)
- **Worldwide Fund for Nature–India (WWF-India)** – Interview insight on corporate RE adoption (Varun Aggarwal quote, 2022)