India Renewable Energy Market Report 2026

Analysis and forecast to 2030



International Energy Agency

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Foreword by IEA Executive Director, Dr Fatih Birol

At the time of heightened geopolitical tensions and volatile energy prices, countries are seeking to strengthen energy security while keeping household energy bills affordable. For India, where electricity demand is rising rapidly, this requires careful long-term planning and more power supply. India's renewable energy progress shows how sustained ambition and steady implementation can build a more secure, affordable and sustainable energy system.

Over the past decade, India's renewable capacity has quadrupled, to now exceed 300 gigawatts. Non-fossil sources account for 50% of installed power capacity, meeting a key national target five years ahead of schedule. India is also among the world's largest biofuels producers, with production increasing sixfold since 2020. In 2025, it became the world's second-largest market for renewable capacity growth, a position it is expected to maintain through 2030. These achievements reflect a long-term vision, ambitious targets and stable investment conditions.

India has achieved some of the world's lowest costs for renewable power generation, making renewables increasingly competitive with other sources. This progress has been supported by an evolving policy framework that has shifted from prioritising the deployment of variable renewables to integrating shares of them into the power system reliably and affordably. Innovative auction designs that combine wind, solar PV and storage to provide more flexible renewable power have attracted international attention and offer lessons for other countries. At the same time, India is rapidly expanding its domestic solar PV manufacturing capacity. This can reduce reliance on imported fuels and technologies, strengthen the country's energy security and help diversify global energy supply chains.

This first-of-its-kind report examines the policies and market developments behind India's progress, assesses remaining challenges and identifies opportunities for further growth. I hope it will support India as it builds on these achievements and offer valuable lessons for other emerging and developing economies.

I would like to warmly thank the Ministry of New and Renewable Energy for its close co-operation, as well as the many experts and institutions whose contributions have enriched this analysis. The IEA greatly values its partnership with India and looks forward to deepening it further.

Dr. Fatih Birol

Executive Director,

International Energy Agency

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Foreword by the Hon. Minister of New and Renewable Energy, Pralhad Joshi

India's renewable energy journey is powering the country's economic growth, strengthening energy security and creating new opportunities for investment and manufacturing. As one of the world's fastest-growing major economies, India's electricity demand is expected to continue rising. Our focus is on ensuring that this growth is supported by reliable, affordable and increasingly clean sources of energy.

The progress achieved in recent years reflects the scale of India's energy transition. In 2025, India reached the milestone of 50% non-fossil installed electricity capacity, five years ahead of its target. During the first seven months of 2026, non-fossil sources met around one-third of the country's electricity demand, highlighting their growing contribution to India's power supply.

India is also building the foundations for the next phase of this transition by strengthening domestic manufacturing, mobilising investment and expanding transmission infrastructure. The country attracted USD 72 billion in energy-transition investment in 2025, reflecting the scale of investment opportunities emerging in its energy sector. With plans to develop transmission capacity to connect 336 GW of renewable energy by 2032, India is preparing its power system to accommodate a larger share of clean energy while meeting its growing electricity needs.

Together, these developments illustrate how a rapidly growing economy can expand its energy infrastructure while steadily increasing the contribution of non-fossil sources. India has shown the world that economic progress and rising emissions need not go hand in hand, demonstrating that growth can be decoupled from emissions.

Sustaining this progress will require consistent policy direction, effective implementation and close collaboration among government, industry, financial institutions and research organisations. As India advances towards its long-term energy and climate objectives, affordability, reliability, energy security and a competitive domestic clean energy ecosystem will remain central to its approach.

I appreciate the International Energy Agency and its Executive Director, Dr Fatih Birol, for their continued engagement with India and their contribution to advancing global energy dialogue. I also commend the IEA for its *India Renewable Energy Market Report 2026 – Analysis and Forecast to 2030*, which will be launched at the Bharat Renewable Energy Summit in New Delhi in November 2026. The report will be a valuable contribution to understanding India's renewable energy progress, emerging opportunities and future trajectory. I look forward to continued collaboration with the IEA in advancing India's renewable energy ambitions and our shared pursuit of a secure, affordable and sustainable energy future.

H.E. Pralhad Joshi

Minister of New and Renewable Energy

Government of India

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Abstract

India has emerged as a leading renewable energy market, supported by sustained policy ambition, competitive procurement, infrastructure development and a growing domestic manufacturing base. This report examines the evolution and outlook of renewable energy across the power, transport and heating sectors, and considers its implications for affordability, reliability and energy security. It finds that renewable deployment is broadening across technologies and end uses, reducing exposure to fossil fuel imports and price volatility. Continued progress will depend on faster grid and storage development, streamlined project implementation, more effective integration of variable renewables and building efficient feedstock supply chains, underpinned by high sustainability standards. India's experience offers valuable lessons for emerging economies seeking to advance affordable, reliable and secure clean energy transitions.

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Executive summary

India has become world's second fastest-growing renewable energy market and the second-largest manufacturer of solar PV modules. Renewable power capacity has surpassed 300 GW[1] in Q4 2026, almost quadrupling over the past decade. India achieved its objective of sourcing 50% of installed power capacity from non-fossil technologies in 2025, five years ahead of schedule. It also became the fourth-largest liquid biofuel market, with production increasing sixfold since 2020. India's leadership reflects years of sustained ambition, consistent policy support, adaptation to changing conditions and long-term strategic planning**.**

A decade of policies facilitating renewable energy investment is paying dividends for India's energy security at a time of high fuel prices and market volatility. Without the solar PV, wind and bioenergy capacity added since 2010, coal imports in 2025 would have been around 110 million tonnes higher and the import dependence of electricity generation would have exceeded 30%, approximately twice the actual level. Renewable electricity reduced cumulative spending on coal and natural gas imports by more than USD 100 billion between 2011 and 2025, with savings set to more than double by 2030. In transport, domestic biofuels reduced crude oil import dependence by around 4 percentage points in 2025, while biogas provides an additional domestic substitute for imported natural gas. Without renewables growth, fossil fuel use for heating would have been 17% higher in 2025. These buffers become particularly valuable when supply disruptions and price spikes put fossil fuel markets under strain.

India's renewable capacity is set to reach around 530 GW by 2030, led overwhelmingly by solar PV. Solar PV accounts for more than 80% of this growth, with capacity exceeding 350 GW by 2030. Wind approaches 90 GW, while hydropower reaches 75 GW as large conventional plants are commissioned and pumped storage investment accelerates. As a result, India is expected to meet its target of 500 GW of non-fossil capacity by 2030 on time, an important milestone towards its ambition of achieving net zero greenhouse gas emissions by 2070.

Renewables are set to supply 35% of India's electricity by 2030, with generation almost doubling from today's levels. Renewable generation exceeded 500 TWh in 2025, accounting for one-quarter of India's total electricity supply, and is forecast to approach 950 TWh in 2030. Solar PV overtook hydropower as India's largest source of renewable electricity in 2025 and is expected to provide more than half of renewable generation by 2030. The share

[1] All capacity values presented in the Executive summary include solar PV capacity measured in alternating current terms.

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of variable renewables in total electricity supply rises from around 14% to approximately 26% nationally – and significantly higher in some states – increasing the need for investment in grids, energy storage and system flexibility.

India's competitive auctions have driven down costs, while policy measures have tackled non-cost barriers to deployment. Since 2010, India has awarded over 220 GW of utility-scale renewable capacity through competitive auctions. Transparent price discovery, standardised contracts and central agencies that aggregated demand and reduced counterparty risk have brought tariffs down rapidly. Today, utility-scale solar PV in India has the world's second-lowest levelised generation costs, at USD 30-35/MWh, while tariffs for solar PV projects commissioned in 2025 were around 40% below the average cost of coal-fired electricity. In parallel, the solar parks scheme reduced land and permitting risks, the Green Energy Corridors expanded transmission from resource-rich states, and interstate transmission charge waivers lowered delivery costs.

As solar PV and wind scaled up, policy shifted towards system integration, making India the world leader in hybrid renewable projects procurement. New tendering guidelines moved auctions from stand-alone solar PV and wind towards hybrid, storage-linked products. Such hybrid renewable systems are characterised by reduced output variability, better use of land and transmission infrastructure, and a generation profile more closely aligned with demand. In 2025, India auctioned 15 GW of hybrid projects, taking cumulative auctioned capacity to 64 GW, in both cases the largest volumes globally. Average tariffs achieved between 2023 and 2025 were around USD 45/MWh, approximately 20% below the average cost of electricity from coal-fired power plants in 2025.

The supply-side push through auctions is now being matched by households and businesses investing in solar PV for self-consumption and corporate open-access procurement. Distributed solar PV capacity for self-consumption is set to triple to more than 100 GW by 2030. The PM Surya Ghar Muft Bijli Yojana scheme is accelerating residential rooftop installations, while PM-KUSUM supports solarisation of agricultural feeders and irrigation pumps. Meanwhile corporate procurement becomes a major source of demand. Open-access reforms have simplified renewable procurement for commercial and industrial consumers, with corporate power purchase agreements expected to underpin around 20% of utility-scale solar PV and wind capacity additions by 2030.

India is becoming a leading clean energy manufacturing hub globally, helping to diversify international supply chains. Annual solar PV module manufacturing capacity reached around 225 GW in September 2026 and is projected to rise further by 2030, maintaining India's position as the world's second-largest manufacturer. Its wind manufacturing industry is also expanding, with India projected to become the world's second-largest manufacturer by 2030.

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India's industrial policies, including the Production Linked Incentive and domestic sourcing requirements, have mobilised investment in solar PV manufacturing. New policies are also targeting strategic upstream segments of the solar PV supply chain where global dependence on imports from China exceeds 95%.

India increased biofuel production sixfold between 2020 and 2025, driven by strong policy support. Liquid biofuel consumption reached around 11 billion litres in 2025 and is projected to rise to 16 billion litres by 2030. Sustainable aviation fuel blending targets for international flights, starting at 1% in 2027 and rising to 5% by 2030, are opening a new market. Electrification is advancing in parallel: electric vehicles accounted for more than 11% of new vehicle sales in 2026, while India leads global growth in electric three-wheelers.

Compressed biogas is emerging as a domestic alternative to imported natural gas. India's sustainable feedstock potential could support production of up to 75 billion cubic metres equivalent annually – close to current natural gas demand. As natural gas import dependence rises from 52% in 2024 to around 71% by 2030, scaling up biogas could strengthen energy security and reduce import needs. Over the longer term, the National Green Hydrogen Mission offers an additional important route to reduce fossil fuel use in industry.

India has made significant progress in expanding access to clean cooking, with the number of people without access more than halving since 2010. This progress is accelerating the shift away from traditional biomass, improving health outcomes for millions of Indians. By 2030, traditional biomass use falls by 20% and renewable heat consumption increases by 25%, led by modern bioenergy. Solar thermal heat generation is forecast to increase by more than 50%, lifting India from sixth to fourth place globally. In industry, the Carbon Credit Trading Scheme, biomass support programmes and a 2026-2031 roadmap for electrifying selected industrial heat uses are creating new opportunities for renewable heat.

The next phase of India's renewable energy growth will depend on aligning infrastructure and market reforms with the pace of deployment. Faster transmission expansion, improved forecasting and dispatch, more energy storage, stronger demand-side flexibility and greater flexibility from fossil fuel power plants will be needed to efficiently integrate growing shares of variable renewable energy into the power system. Improving DISCOM finances remains central to investor confidence, while facilitating land acquisition, streamlining permitting and reducing execution delays are crucial for wind and hydropower projects. Swiftly addressing these challenges could accelerate renewable power capacity deployment over 2026-2030 by more than 20%. More extensive and efficient feedstock supply chains, underpinned by high sustainability standards will also be needed to accelerate the use of biogas, biofuel and solid bioenergy.

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Introduction

India emerges as a leading renewable energy powerhouse

India has emerged as one of the world's most dynamic renewable energy markets. Over the past decade, the country has transformed its power sector through rapid deployment of solar PV, wind power and other renewable technologies. This transformation was accompanied by the development of domestic manufacturing capabilities, innovative procurement mechanisms and new approaches to renewable energy integration. Today, India ranks among the global leaders in renewable energy investment and deployment and is expected to be the second-largest market for renewable power expansion worldwide by 2030.

India renewable energy achievements and India's global ranking

Achievement	2025		2030	
	Value	Ranking	Value	Ranking
Auctioned hybrid renewable capacity	15 GW annual 64 GW cumulative	1st 1st	–	–
Auctioned total renewable capacity	20 GW annual 210 GW cumulative	2nd 1st	–	–
Average LCOE of utility-scale solar PV	35 USD/MWh[2]	1st	–	–
Annual net renewable capacity additions	49 GW (AC) 59 GW (DC)	2nd	58 GW (AC) 70 GW (DC)	2nd
Annual PV module manufacturing capacity	150 GW	2nd	250 GW	2nd
Annual onshore wind turbine nacelle manufacturing capacity	20 GW	3rd	29 GW	2nd
Total installed renewable capacity	262 GW (AC) 296 GW (DC)	3rd	530 GW (AC) 621 GW (DC)	3rd
Total renewable electricity generation	502 TWh	4th	950 TWh	3rd
Annual liquid biofuels consumption	11 billion litres	4th	16 billion litres	4th
Solar thermal heat generation	80 PJ	6th	123 PJ	4th

Notes: AC = alternating current, DC = direct current, LCOE = levelised cost of electricity. Capacity values that include solar PV are presented both in AC and DC.

Sources: IEA analysis based on data from India, Ministry of New and Renewable Energy; International Renewable Energy Agency; S&P; InfoLink Consulting; BNEF.

[2] Ranking among 15 largest utility-scale solar PV markets.

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This transformation has been driven by a combination of long-term policy vision, ambitious deployment targets and a willingness to continually adapt policies as market conditions evolve. India has progressively strengthened its renewable energy framework through competitive auctions, renewable purchase obligations (RPOs), transmission planning initiatives, distributed solar programmes and industrial policies supporting domestic manufacturing. As deployment accelerated, policies increasingly shifted from creating demand for renewable energy towards addressing system integration, supply chain development and market design challenges.

The results have been remarkable. Renewable power capacity has surpassed 300 GW in Q4 2026, quadrupling over the past decade. In 2025, India became the second-largest renewable capacity deployment market globally – a position it is expected to hold by 2030. In the same year, India had already achieved its target of sourcing 50% of installed electricity capacity from non-fossil technologies, 5 years ahead of schedule. Looking ahead, renewable capacity is expected to almost double by 2030, enabling the country to achieve its target of 500 GW of non-fossil fuel capacity by the end of the decade.[3]

The country has also been at the forefront of developing hybrid renewable projects combining solar PV, wind and energy storage, as well as procurement frameworks designed to deliver firm and dispatchable renewable electricity. These innovations are increasingly supporting system integration while maintaining cost competitiveness relative to conventional generation technologies.

India has also emerged as one of the world's most important renewable energy manufacturing hubs. Supported by industrial policies such as the Production Linked Incentive scheme, import protection measures and domestic market growth, solar PV manufacturing capacity expanded rapidly, making India the second-largest producer in the world. Country also hosts one of the world's largest wind manufacturing industries, with domestic and international companies supplying both the national market and export destinations. These developments strengthen energy security, support economic development and contribute to global supply chain diversification.

Renewable energy deployment is also expanding beyond the power sector. India has increased its biofuel production almost sixfold in 2020-2025, becoming one of the world's largest markets, driven by strong policy support. The country is accelerating deployment of biogas and other renewable fuels to reduce fossil fuel consumption in transport, industry and agriculture. Together with renewable

[3] All capacity values presented in this paragraph include solar PV expressed in alternating current capacity.

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electricity, these technologies contribute to broader energy transition objectives while improving air quality and reducing dependence on imported fuels.

The expansion of renewable energy has delivered significant energy security benefits. Despite being one of the world's largest coal producers, India remains exposed to international fossil fuel markets through imports of coal and natural gas. Rapid growth of solar PV and wind generation has reduced fossil fuel demand, lowered exposure to international price volatility and limited growth in import dependence despite rapidly rising electricity consumption. By reducing fuel import requirements and supporting domestic manufacturing, renewable energy investments increasingly contribute to both economic resilience and electricity security.

India's experience demonstrates that large-scale renewable energy deployment is not solely a function of resource availability or technology costs. It also depends on policy stability, institutional capacity, transmission planning, market design and the ability to adapt regulatory frameworks as deployment scales up. The country's renewable energy transition therefore offers valuable lessons for other emerging economies seeking to accelerate clean energy deployment while maintaining affordability, reliability and energy security.

The objective of this report is to analyse the evolution of India's renewable energy sector, identify the key drivers behind its success and assess prospects through 2030. The report examines developments across renewable power technologies, distributed energy, manufacturing supply chains and renewable fuels, while also assessing their implications for electricity security and economic development. It also highlights the challenges that remain, including system integration, transmission expansion, financial health of distribution companies, renewable energy curtailment and preservation of manufacturing competitiveness in international markets.

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Chapter 1. Renewable electricity

Global trends

Global cumulative renewable electricity capacity almost tripled between 2015 and 2025, with solar PV and wind accounting for almost 95% of total expansion. Solar PV was the primary driver of this growth, supported by declining technology costs, supportive policy frameworks and increasing competitiveness relative to conventional generation technologies.

Solar PV capacity direct current and alternating current metrics

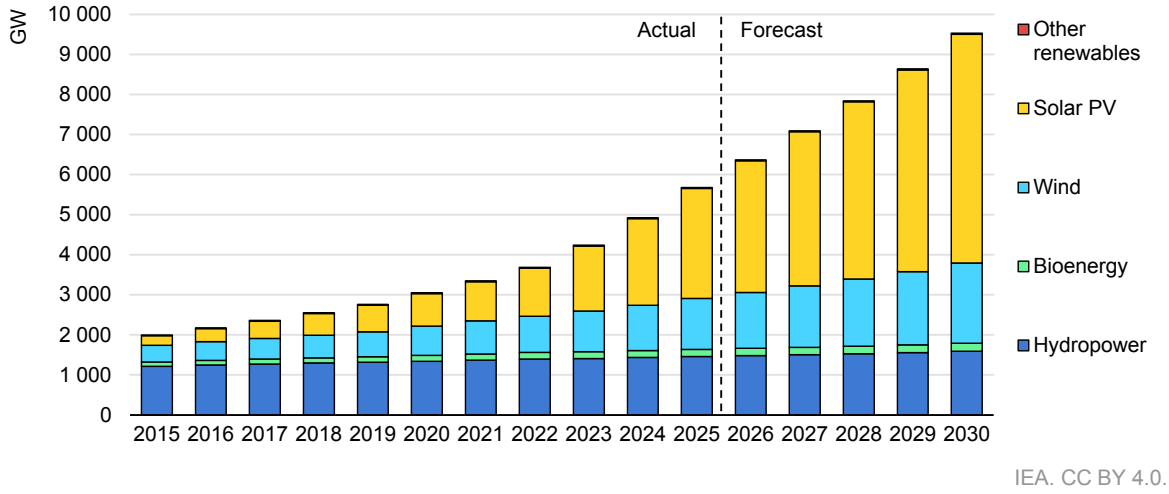
Solar PV systems generate direct current (DC) electricity, which is typically converted by an inverter into alternating current (AC) for use by electrical devices and power systems. Until around 2010, the DC capacity of PV modules and the AC capacity of inverters were generally similar. Since then, increasing use of higher DC-to-AC ratios – whereby the capacity of PV modules exceeds inverter capacity – has widened the difference between the two measures, particularly for utility-scale systems. Today, DC capacity can be up to 40% higher than AC capacity.

India's Ministry of New and Renewable Energy reports installed solar PV capacity in AC terms, while the IEA tracks solar PV capacity globally in DC terms to ensure consistency and comparability across markets. In this report, capacity figures that include solar PV are presented in AC unless specified otherwise.

The strong momentum achieved during this period is expected to continue through 2030, further accelerating the transformation of the global electricity sector. Global renewable electricity capacity is projected to increase by a further 70% by 2030, with additions exceeding 3 850 GW (DC). Renewable deployment is expected to accelerate compared to the past 5 years in more than 80 out of 104 tracked countries and regions, reflecting technology competitiveness and continued policy support.

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Global cumulative renewable electricity capacity by technology, 2015-2030



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Note: Solar PV expressed in DC capacity.
Source: IEA (2025), Renewables 2025.

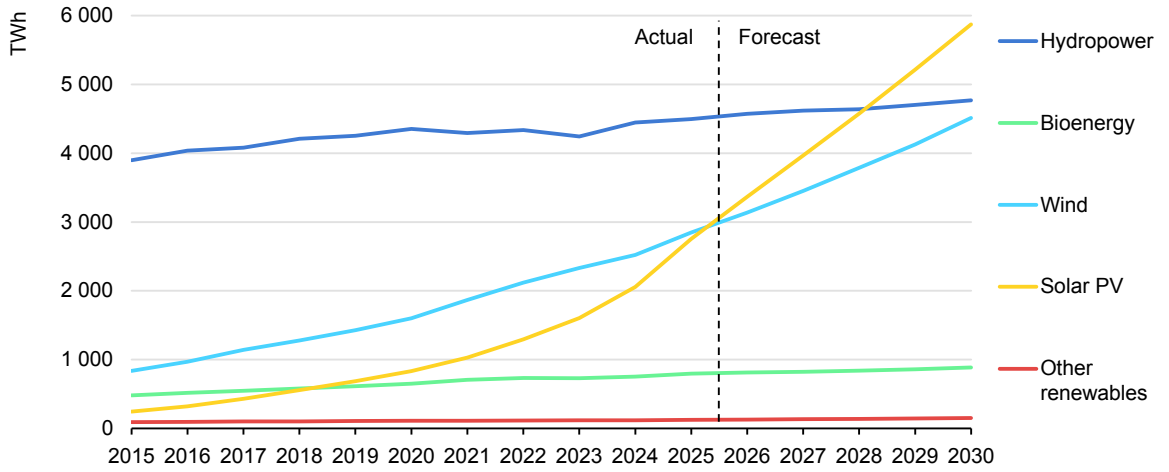
Solar PV is expected to remain the main driver of global renewable energy expansion through 2030. Capacity is projected to double over the forecast period, accounting for more than three-quarters of total renewables growth. Competitive costs, short development timelines and wide acceptance among governments, businesses and consumers support rapid deployment across both utility-scale and distributed applications.

Wind power is forecast to remain the second-largest source of new renewable capacity globally. Although the sector faces challenges related to permitting, costs and supply chain constraints, global wind capacity is still projected to increase by almost 60% by 2030 as major markets address development bottlenecks and accelerate installations.

Other renewable technologies will also contribute to power sector transformation, although at a much smaller scale. Hydropower expansion is increasingly supported by pumped storage projects that provide long-duration storage and system flexibility, while geothermal deployment is expected to accelerate, with annual additions reaching record levels by the end of the decade. However, despite their important role in enhancing system reliability and flexibility, dispatchable renewable technologies such as bioenergy, geothermal and concentrated solar power are expected to remain relatively niche markets. Lower cost-competitiveness, site-specific constraints and more limited policy support continue to restrict their wider deployment.

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Global renewable electricity generation by technology, 2015-2030



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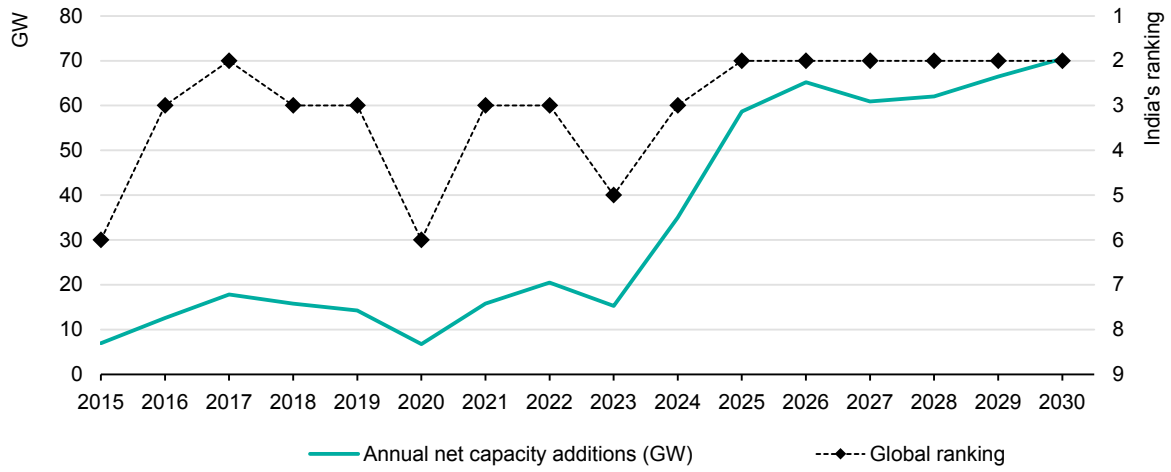
Source: IEA (2025), Renewables 2025.

The rapid expansion of renewables is underpinned by increasingly ambitious policy commitments. At COP 28 in Dubai, United Arab Emirates, in 2023, nearly 200 countries agreed to pursue the global objective of tripling renewable energy capacity by 2030 as part of broader efforts to limit global warming to 1.5°C. Under current policies and market trends, global renewable capacity is expected to reach approximately 9 530 GW (DC) by 2030, representing a 2.6-fold increase compared with 2022 levels. While this represents substantial progress, it remains below the level required to achieve the global tripling target, highlighting the need for further action to address implementation barriers and accelerate deployment.

The expansion of renewable capacity is expected to drive a fundamental shift in global electricity generation. Renewable electricity output is projected to increase by almost 50% between 2025 and 2030, rising from approximately 11 000 TWh to 16 200 TWh. As a result, renewables are expected to surpass coal as the largest source of global electricity generation in 2026 or shortly thereafter. Solar PV generation is forecast to exceed hydropower in 2028-29 and become the largest source of renewable electricity globally. The share of renewables in global electricity generation is project to increase from around 34% in 2025 to 43% in 2030, while the contribution of variable renewable technologies is project to rise from 17% to 27%.

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India renewable electricity capacity net additions and India's global net capacity additions ranking, 2015-2030



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Note: Includes solar PV expressed in DC capacity.
Source: IEA (2026), Renewables 2026 (forthcoming).

The People's Republic of China (hereafter, "China") has been the leading market for renewable energy deployment over the past decade, accounting for more than half of global capacity additions. The country is expected to maintain this position through 2030, driven by continued expansion of solar PV and wind power. Historically, the United States was the second-largest growth market for renewables; however, recent policy changes are expected to slow the deployment. India became the world's second-largest renewable growth market in 2025 and is projected to retain this position through the end of the decade, supported by strong policy frameworks, rising electricity demand and a robust project pipeline. The European Union will remain another major centre of renewable capacity expansion, however growth is forecast to stagnate in the forecast period.

India forecast

Overview

Renewable capacity in India has reached 299 GW in September 2026 and is expected to surpass 300 GW by the end of the year, close to quadrupling since 2015. By 2030, capacity is expected almost double again, positioning India as the second-largest renewable growth market globally.

Targets and growth trends

Policy ambition has been a key driver of this expansion. In 2015, the government significantly increased its renewable energy target to 175 GW by 2022, including

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100 GW of solar PV, 60 GW of wind power, 10 GW of bioenergy and 5 GW of small hydropower. Although this target was not fully met within the original timeline, it significantly accelerated deployment and reinforced India's position as one of the fastest-growing renewable energy markets. Building on this momentum, India adopted a broader clean energy goal in 2021, aiming for 500 GW of non-fossil electricity capacity by 2030 and for non-fossil sources to account for 50% of total installed capacity. The latter target has been achieved 5 years ahead of schedule, with about 260 GW installed as of 2025 and a 300 GW milestone has been passed in Q4 2026. Building on this success, in April 2026 India submitted an updated nationally determined contribution, aiming to achieve 60% non-fossil fuel share in installed power capacity by 2035.

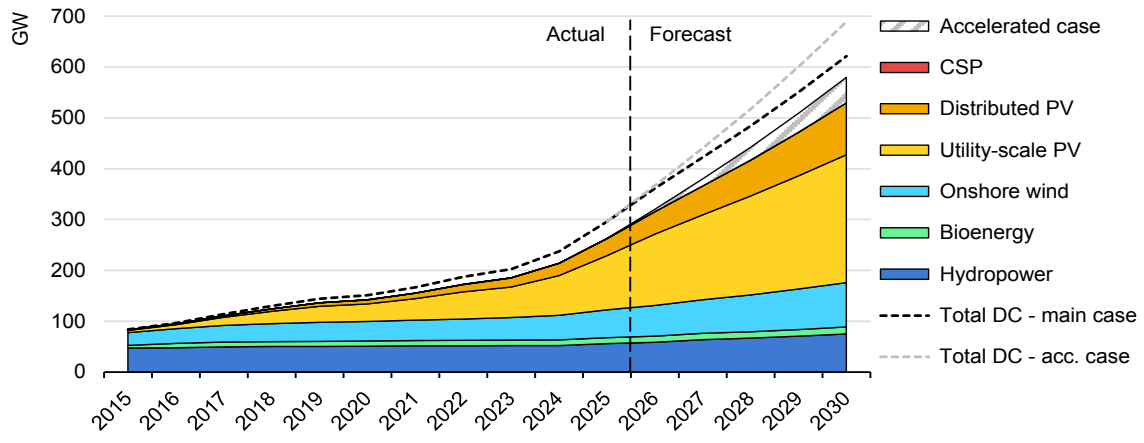
Looking ahead, India is on track to reach 530 GW (620 GW in DC) of renewable capacity by 2030[4]. Under the forecast accelerated case, assuming stronger policy support and timely resolution of existing challenges, India's renewable capacity could approach 580 GW (690 GW in DC) by 2030. Further into the future, the Long-Term Resource Adequacy Plan published by the Central Electricity Authority in March 2026 projects 770-860 GW of installed renewable capacity by 2035. India also has a commitment of net zero greenhouse gas emissions by 2070, with renewable electricity expected to play a leading role in achieving it, as envisaged in a Study Report on Scenarios Towards Viksit Bharat and Net Zero, published in 2026 by NITI Aayog.

Renewable annual capacity additions reached 49 GW (59 GW in DC) in 2025, more than triple the average recorded during the previous 5 years. Even stronger growth is expected in 2026, driven by record-high auction volumes in 2024 and developers accelerating the commissioning of solar PV projects ahead of the introduction of domestic solar cell sourcing requirements. Annual additions are expected to remain above 50 GW through 2030. In the accelerated case of the forecast, capacity additions continue to grow and reach 70 GW (almost 90 GW in DC) in 2030.

[4] Forecasted cumulative renewable capacity in 2030 is a result of IEA modelling. According to the Report on Optimal Generation Mix 2030 from Central Electricity Authority, in FY 2029-30 installed capacity is projected to reach 485 GW, including 293 GW of solar PV, 100 GW of wind, 59 GW of hydropower, 19 GW of pumped storage hydropower (PSH), and 15 GW of bioenergy. The differences between the IEA forecast and Central Electricity Authority projections result from different modelling assumptions.

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Cumulative installed renewable electricity capacity, main and accelerated cases, India, 2015-2030



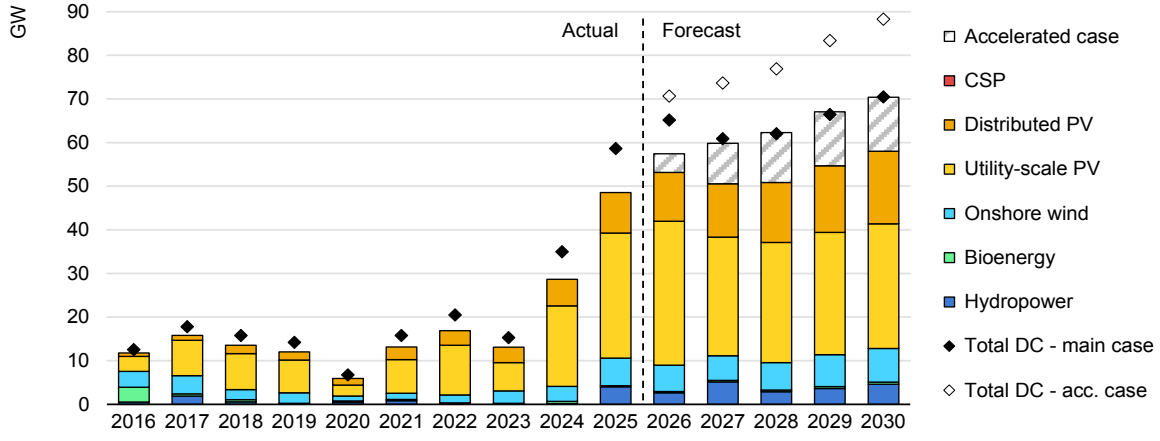
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Notes: acc. case = accelerated case; CSP = concentrated solar power; DC = direct current. Forecasted cumulative renewable capacity in 2030 is a result of IEA modelling. According to the Report on Optimal Generation Mix 2030 from Central Electricity Authority, in FY 2029-30 installed capacity is projected to reach 485 GW, including 293 GW of solar PV, 100 GW of wind, 59 GW of hydropower, 19 GW of pumped storage hydropower (PSH), and 15 GW of bioenergy. The differences between the IEA forecast and Central Electricity Authority projections result from different modelling assumptions.

Source: IEA (2026), Renewables 2026 (forthcoming).

Solar PV accounts for more than 80% of the deployment, led by utility-scale facilities. PV's dominance reflects India's strong solar resource potential, falling equipment costs, relatively short project development timelines and highly competitive generation costs.

Renewables net capacity additions, India, 2016-2030



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Notes: acc. case = accelerated case, CSP = concentrated solar power, DC = direct current. Utility-scale PV includes ground-mounted projects feeding electricity directly to the grid, without significant self-consumption on site.

Source: IEA (2026), Renewables 2026 (forthcoming).

Wind power played a central role in India's renewable energy development in the 2010s, before the sharp decline in solar PV costs. More recent capacity additions have been increasingly driven by hybrid auctions, where a wind component is used to meet generation firmness requirements.

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Conventional hydropower is expanding at a more moderate pace, reflecting the limited availability of suitable sites and long project development timelines. Pumped storage hydropower deployment is expected to accelerate in the coming years due to its role in facilitating the integration of increasing shares of variable renewable generation and a government target of 100 GW by 2035.

Main drivers

India's progress reflects continuous and evolving policy support. Over time, the government has actively adapted policy frameworks to address emerging challenges related to competitiveness, revenue uncertainty, land acquisition, transmission availability, utility company (DISCOM) procurement risks, and renewables integration. The ability of policy makers to adapt support mechanisms to evolving market conditions has been a key driver of renewable energy deployment. Policy measures such as competitive auctions, RPOs, inter-state transmission charge waivers and the Green Energy Open Access (GEOA) Rules have strengthened investment visibility and improved project economics. The rapid expansion of renewable energy has also been supported by parallel investments in power transmission infrastructure. Programmes such as Green Energy Corridors have enhanced connectivity between resource-rich regions and demand centres, easing grid constraints and enabling the integration of large-scale renewable capacity.

Competitive auctions have been the primary policy tool driving renewable capacity deployment in India. They enabled large-scale procurement of solar PV and wind power at rapidly declining purchase tariffs, significantly improving the competitiveness of renewable electricity relative to conventional generation technologies. Central agencies played an important role in standardising procurement frameworks, aggregating demand and reducing counterparty risks. Early tenders focused primarily on stand-alone solar PV and wind projects. However, more recent auctions have increasingly prioritised hybrid, storage-linked and dispatchable renewable energy projects as policy makers seek to improve renewable integration, increase the use of transmission infrastructure and enhance the reliability of renewable power supply.

Generation

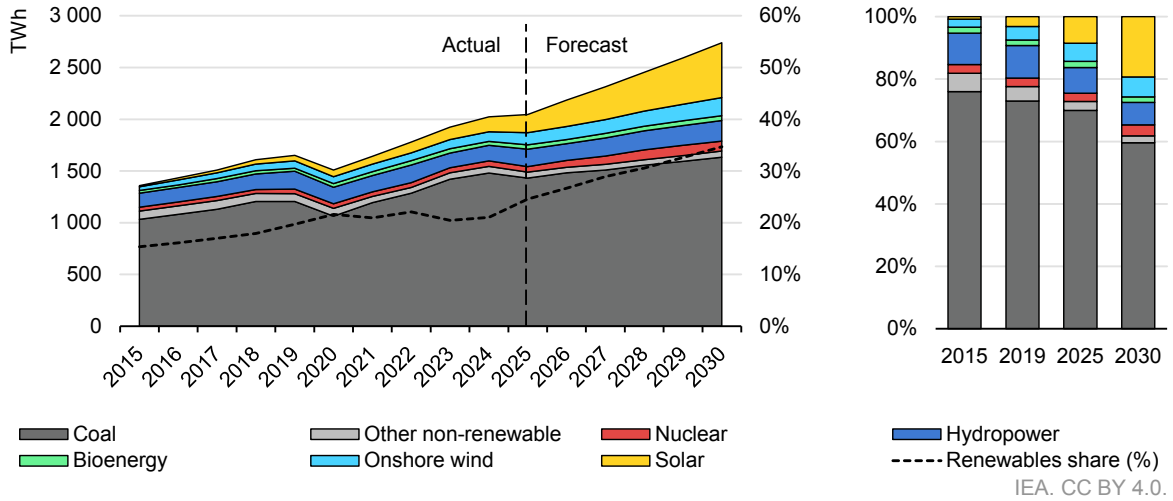
The rapid expansion of renewable capacity is translating into a fundamental shift in India's electricity generation mix. While coal remains the largest source of electricity, renewable generation has been increasing much faster than overall electricity demand, allowing renewables to steadily gain market share. In 2025, renewable generation reached almost 500 TWh, following growth of around 50% over the previous 5 years. As a result, the share of renewables in total electricity generation increased to almost one-quarter. By 2030, renewable electricity

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generation is projected to nearly double, reaching 950 TWh and raising its share of total generation to 35%[5]. According to the Central Electricity Authority's Long-Term Resource Adequacy Plan, renewables share in electricity generation in India could reach 44% by 2035.

Solar PV is expected to account for the largest increase in generation, with output tripling between 2025 and 2030. In 2025, solar PV overtook hydropower as India's largest source of renewable electricity and, by 2030, is projected to account for more than half of total renewable generation. Wind generation is expected to increase by around 50%, and generation from hydropower and bioenergy is expected to grow by around 20%.

Renewable electricity generation and share in total generation, India, 2015-2030



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Notes: Forecasted electricity generation by 2030 is a result of IEA modelling with utilisation of IEA data. According to the Report on Optimal Generation Mix 2030 from Central Electricity Authority, in FY 2029-30 share of renewable generation, including hydropower, is expected to reach 40% by 2030. The differences between the IEA forecast and Central Electricity Authority projections result from different modelling assumptions regarding the pace of technologies deployment and effective capacity utilisation factors. IEA analysis assumes following average capacity utilisation factors in 2030: solar PV = 18% (AC), onshore wind = 24%, hydropower = 38%, bioenergy = 41%.

Source: IEA (2026), Renewables 2026 (forthcoming).

As a result, the share of variable renewable energy (VRE) sources – solar PV and wind – is expected to increase from around 14% of electricity generation in 2025 to approximately 26% by 2030. The next phase of India's power sector transition will increasingly depend on integrating these technologies efficiently into the electricity system through continued investment in transmission infrastructure,

[5] Forecasted electricity generation by 2030 is a result of IEA modelling with utilization of data from IEA Energy Data Centre. According to the Report on Optimal Generation Mix 2030 from Central Electricity Authority, in FY 2029-30 share of renewable generation, including hydropower, is expected to reach 40% by 2030. The differences between the IEA forecast and Central Electricity Authority projections result from different modelling assumptions regarding the pace of technologies deployment and effective capacity utilization factors. IEA analysis assumes following average capacity utilization factors in 2030: solar PV = 18% (AC), onshore wind = 24%, hydropower = 38%, bioenergy = 41%.

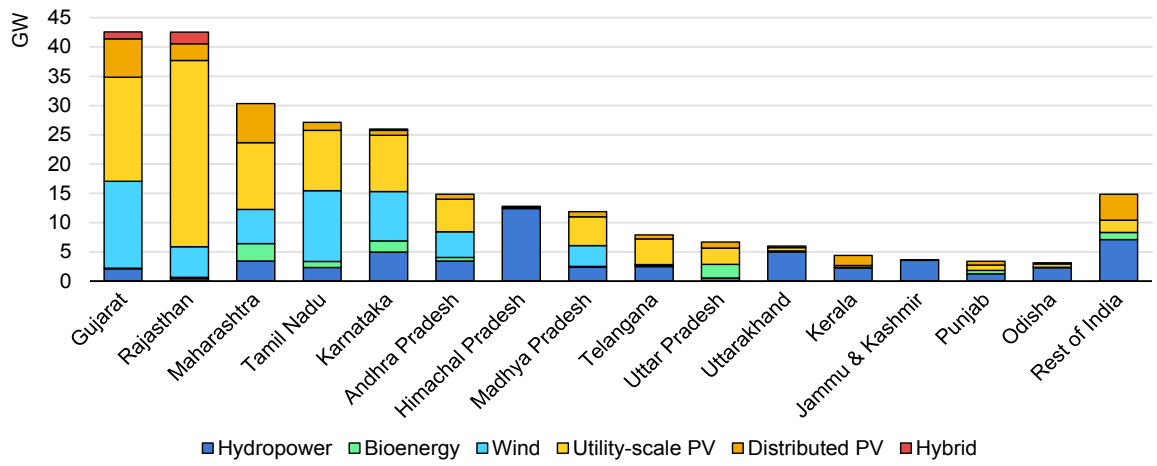
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energy storage, system flexibility and demand-side management, while maintaining electricity supply affordability, power system reliability and an attractive investment environment.

State-level deployment

Solar PV and wind deployment have been concentrated in Gujarat, Rajasthan, Maharashtra, Tamil Nadu and Karnataka, owing to a combination of favourable resource availability, supportive state policies, strong industrial demand and relatively well-developed transmission infrastructure. Rajasthan and Gujarat possess some of the country's highest solar irradiation levels and large areas of low-cost land suitable for utility-scale solar projects, making them the preferred locations for large solar parks and gigawatt-scale developments.

Cumulative installed renewable electricity capacity by state, India, 2025



IEA. CC BY 4.0.

Source: IEA analysis based on data from India, Ministry of New and Renewable Energy.

Gujarat, Tamil Nadu, Karnataka and Maharashtra also benefit from strong wind resources, particularly along coastal and elevated inland regions, and were among the first states to implement supportive policies for wind power deployment. Proactive state-level regulatory frameworks and greater institutional experience in renewable project development have further reduced implementation risks and facilitated large-scale deployment in these states.

As a result, these five states account for around 65% of India's installed renewable power capacity and are expected to remain the principal centres of renewable energy expansion through 2030. Such a concentration of generation capacity amplifies system integration challenges and increases the need for continued investment in transmission infrastructure and system flexibility resources.

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Solar PV and wind

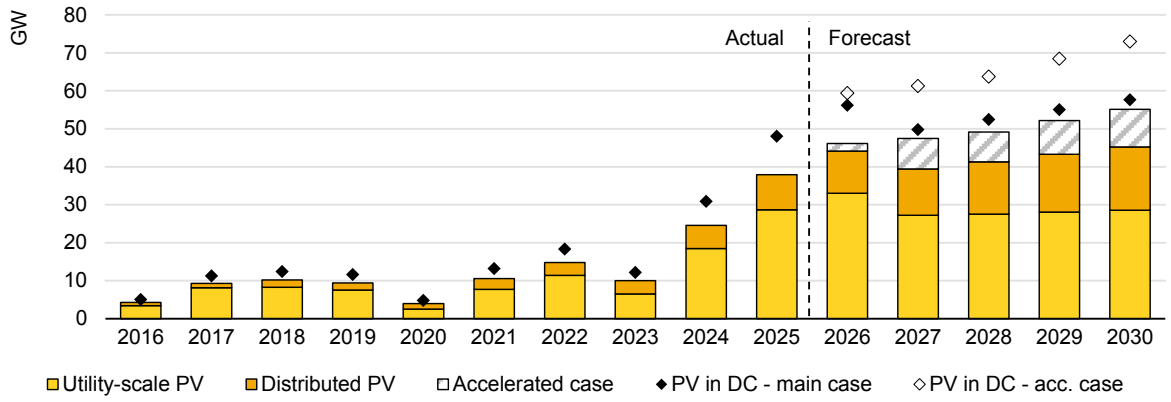
Growth trends

Solar PV and wind power have accounted for more than 90% of renewable capacity additions in India over the past decade and are expected to remain the main drivers of growth through 2030.

Solar PV installed capacity tripled between 2020 and 2025 to about 140 GW (174 GW DC), with annual additions reaching a record 38 GW in 2025 (48 GW DC). Between January and August 2026, India installed a further 32 GW (about 40 GW DC), supported by record auction volumes in 2024 and developers rushing to commission projects ahead of new domestic sourcing requirements for solar PV cells coming fully into effect. Annual deployment is therefore expected to reach a new record in 2026, followed by a short-term slowdown due to lower auction volumes in 2025 and 2026.

By 2030, India's solar PV capacity is expected to increase by a factor of 2.5, exceeding 350 GW (almost 450 GW in DC). This expansion is supported by strong cost competitiveness, sustained auction activity, growing demand through open-access mechanisms and accelerating deployment of rooftop solar. Utility-scale projects have accounted for around 75% of solar PV capacity additions over the past 5 years. Their share is expected to gradually decline to around 70% by 2030 as policy support, improving economics and simplified administrative procedures accelerate growth in the distributed segment.

Solar PV net capacity additions, India, 2016-2030



IEA. CC BY 4.0.

Notes: acc. case = accelerated case. Utility-scale PV includes ground-mounted projects feeding electricity directly to the grid, without significant self-consumption on site. Distributed PV includes projects mostly used for self-consumption.
Source: IEA (2026), Renewables 2026 (forthcoming).

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Competitive auctions have been a key enabling mechanism for utility-scale projects, supporting transparent price discovery, lowering procurement costs and facilitating large-scale capacity deployment. Since 2010, India has awarded around 220 GW of utility-scale renewable capacity through this mechanism, with a record 60 GW allocated in 2024. In 2025, average auction tariffs for newly commissioned solar PV projects were around 40% lower than the average cost of the coal-fired electricity supply. In recent years, auction design has evolved from technology-specific tenders towards more sophisticated formats requiring hybrid projects that combine solar PV, wind power and energy storage to deliver firmer and more dispatchable electricity supply. The solar park model has further accelerated deployment by reducing risks associated with land acquisition, permitting and grid connection, while the Green Energy Corridor programme has expanded transmission infrastructure to facilitate the evacuation of renewable electricity from resource-rich regions.

Open-access procurement – direct power contracting between consumers and generators – has also become an increasingly important source of demand for utility-scale renewable energy, particularly among commercial and industrial consumers seeking to reduce electricity costs and meet corporate sustainability targets. Open-access renewable projects have become an important complement to government-led procurement programmes, particularly in states with high industrial electricity demand such as Gujarat, Maharashtra, Karnataka, Tamil Nadu and Rajasthan. About 7 GW of solar PV and wind capacity was contracted through open access in 2025.

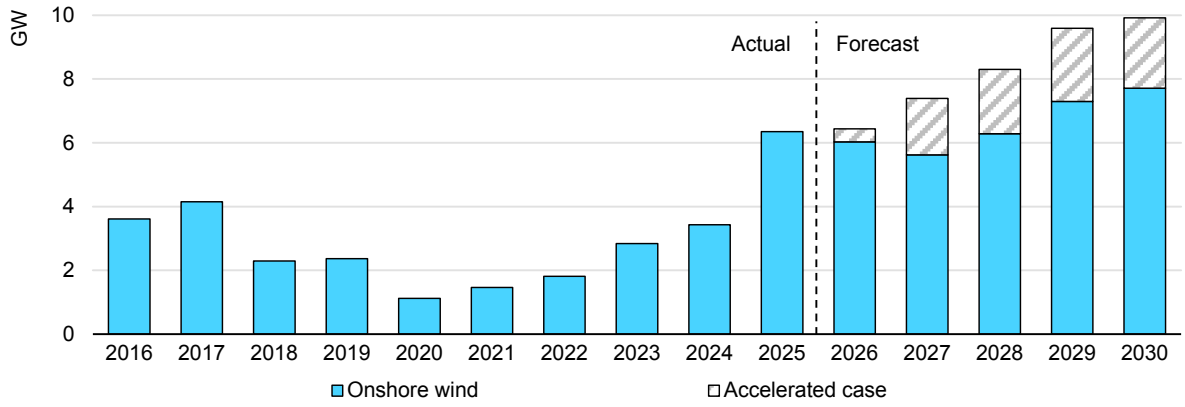
Distributed solar PV has accelerated in recent years, supported by investment subsidy schemes and state-level net-metering or net-billing policy frameworks. The scheme PM Surya Ghar Muft Bijli Yojana, launched in 2024, provides capital support for residential rooftop systems and aims to accelerate household adoption. Rooftop solar deployment is also driven by increasing demand from commercial and industrial consumers seeking to lower their electricity bills among rising retail electricity tariffs. Expansion accelerates in off-grid applications, driven by the PM-KUSUM scheme supporting solarisation of the agricultural sector. PM-KUSUM is expected to support about 1.7-2.0 GW of annual installations in the forecast period, reducing required agriculture sector electricity subsidies and increasing reliability of supply. However, growth remains uneven across states owing to differences in DISCOM procedures, metering approvals, consumer awareness and the level of financial support available to households and businesses.

India’s PV demand-side policies are increasingly complemented by supply-side measures, with solar PV deployment closely linked to the country’s industrial and supply chain strategy. Policy instruments such as the Approved List of Models and Manufacturers (ALMM), basic customs duties on imported cells and modules, and

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the Production Linked Incentive (PLI) scheme for high-efficiency solar PV modules and cells aim to strengthen domestic manufacturing capacity and reduce import dependence. These measures can improve supply security, support industrial development and encourage investment across the solar value chain. They may also increase procurement costs in the short term if domestic manufacturing capacity does not expand sufficiently or remains concentrated in selected production segments.

Wind net capacity additions, India, 2016-2030



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Source: IEA (2026), Renewables 2026 (forthcoming).

Wind power has expanded more slowly than solar PV over the past decade but remains a key component of India's renewable energy mix. Installed capacity increased by around 40% between 2020 and 2025, reaching approximately 55 GW and is expected to grow to almost 90 GW by 2030. A record 6 GW was added in 2025, more than double the average of the previous three years, supported by a strong pipeline of auctioned projects and the commissioning of projects delayed from previous years. However, annual deployment is expected to moderate in the short term, reflecting lower auction activity. Land acquisition challenges, permitting complexity and grid connection constraints in several of the country's highest-quality wind resource areas are expected to limit potential growth acceleration through 2030. Nevertheless, wind remains important to the power system as its generation profile complements solar PV, particularly during the monsoon season and outside peak solar generation hours.

Growth is likely to be driven less by stand-alone wind tenders and increasingly by hybrid projects and open-access or corporate power purchase agreements (PPAs). Repowering of older wind projects with larger and more efficient turbines is also expected to contribute increasingly to capacity growth, particularly in states where the availability of high-quality wind sites is limited.

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India has set ambitious targets for offshore wind development. The country has identified significant offshore wind potential along the coasts of Gujarat and Tamil Nadu and has announced offshore wind targets of 5 GW by 2022 and 30 GW by 2030. However, progress has been slower than anticipated because the market remains at an early stage of development, project costs remain high, port and grid infrastructure require further investment, and policy support has so far been insufficient to close the competitiveness gap with solar PV and onshore wind. Given these challenges and the typically long project lead times, offshore wind is unlikely to make a significant contribution to renewable capacity growth by 2030.

Challenges

Despite strong growth prospects, several challenges remain that could impact the pace of solar PV and wind deployment. Land acquisition is becoming increasingly challenging for large utility-scale projects, particularly in regions with high resource potential where competing land uses and environmental or social concerns are growing. Grid connection delays and transmission bottlenecks are also becoming more important as project pipelines expand. DISCOM financial health remains a structural challenge because delayed payment risks, slow finalisation of PPAs, and procurement uncertainty can weaken investor confidence. System integration challenges are also increasing as the share of solar PV rises, requiring greater deployment of energy storage, improved forecasting, fossil fuel generators and demand-side flexibility, market reforms and dispatchable capacity. Curtailment risks may also increase in renewable-rich regions unless transmission expansion, storage deployment and system flexibility keep pace with rapid capacity growth.

Accelerated case

In the accelerated case of the forecast, solar PV deployment during 2026-30 could be more than 15% higher than in the main case, while wind deployment could increase by around 25%. Achieving this outcome would require faster investment in transmission and distribution infrastructure, further improvements in the financial health of DISCOMs, streamlined permitting and procurement procedures, and stronger enforcement of RPOs. Additional priorities include expanding rooftop solar awareness programmes, facilitating open-access procurement, accelerating land acquisition and grid connection in wind-rich regions, incentivising the repowering of older wind farms, and maintaining an appropriate balance between domestic manufacturing support and affordable PV module availability. Accelerating the implementation of power system integration measures including energy storage, demand management and an expanding ancillary services market would also be necessary.

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Floating solar PV

Floating solar PV, which installs PV modules on structures anchored or moored to reservoirs and other water bodies, remains a small part of India's solar market but offers significant potential for further deployment. Unlike ground-mounted projects, floating PV requires little additional land and can make use of reservoirs associated with hydropower plants, irrigation systems and thermal power stations. The cooling effect of water can also increase PV output, while partial coverage of reservoirs can reduce evaporation. Co-location with hydropower is particularly attractive, as projects can share existing grid infrastructure and reservoir flexibility can complement variable solar generation. These advantages come with higher costs and greater technical complexity. Floating structures and anchoring and mooring systems increase capital requirements, while high humidity and continuous exposure to water also increase requirements for equipment durability and maintenance. About 10 GW of floating PV capacity is installed globally, with China, Korea, Israel, Thailand, Japan and India as leading markets.

In June 2026, the National Institute of Solar Energy, under the Ministry of New and Renewable Energy, published the first comprehensive national assessment of India's floating solar potential, estimating around 102 GW across suitable reservoirs and other inland water bodies. Deployment, however, remains limited, with around 700 MW commissioned by early 2026.

Until recently, floating PV development relied primarily on individual public sector projects and existing solar programmes rather than a dedicated national support framework. In 2022-2023 almost 1 GW was awarded through auctions, with an average tariff of about INR 3 610/MWh (USD 45/MWh), about 30% higher than the average ground-mounted PV tariff in that period.

In 2026, following the publication of the national potential assessment, the government approved the Pradhan Mantri Surya Sarovar Yojana, a capital subsidy scheme that targets 5 GW of floating PV combined with at least 10 GWh of co-located energy storage, supported by INR 50.7 billion (Indian rupees*; around USD 530 million) of central funding. Several states, including Madhya Pradesh, Odisha, Kerala and Andhra Pradesh, have also introduced measures to facilitate floating PV development.

Despite this progress, floating PV is expected to remain more expensive than ground-mounted solar in the near term due to the additional cost of floating structures, anchoring and mooring systems, and more complex construction and maintenance. However, avoiding land acquisition, sharing existing grid infrastructure and potentially generating higher electricity yields can partly offset these costs at suitable sites. Further deployment will therefore depend increasingly on systematic identification of suitable water bodies, clearer procedures for their allocation, environmental standards and continued reductions in equipment and project development costs.

* Exchange rate: 1 Indian rupee (INR) = USD 0.01048 (average exchange rate in August 2026).

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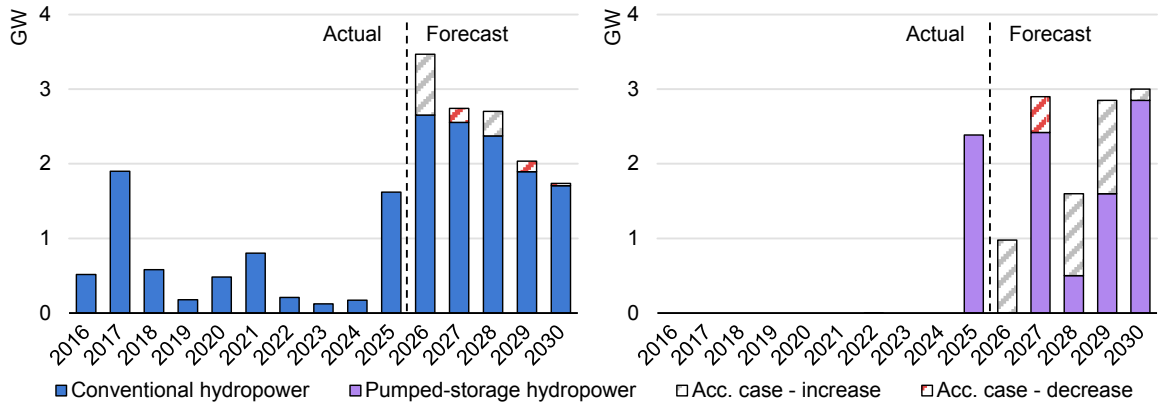
Hydropower and bioenergy-for-power

Hydropower and bioenergy continue to play important roles in India's renewable electricity system, providing dispatchable generation that complements the rapid expansion of solar PV and wind power. While their contribution to renewable capacity growth has been significantly smaller than that of variable renewable technologies, both are expected to become increasingly important for power system flexibility, reliability and resource diversification as renewable penetration rises.

Hydropower

Hydropower development has progressed relatively slowly over the past decade. Annual capacity additions ranged between 0.1 GW and 2 GW, reflecting the long development timelines and complexity of large-scale projects. Conventional hydropower cumulative capacity reached almost 49 GW in 2025, with additions of approximately 1.6 GW, the highest level since 2017. Despite India's substantial hydropower resource potential, particularly in the Himalayan and north-eastern regions, project development has frequently been affected by construction delays, difficult geographical conditions, limited site accessibility, financing challenges and lengthy administrative procedures. Environmental permitting challenges, land acquisition requirements and resettlement obligations have also contributed to extended development timelines in several projects.

Hydropower net capacity additions, India, 2016-2030



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Note: Acc. case = accelerated case.
Source: IEA (2026), Renewables 2026 (forthcoming).

Recognising the strategic role of hydropower in supporting power system flexibility, the government introduced a set of policy measures in 2019 to revive investment in the sector. Large hydropower projects were formally classified as renewable energy, the Hydropower Purchase Obligation was established, and

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financial support was extended to associated infrastructure such as roads and bridges associated with new projects. These measures have improved project economics and strengthened incentives for project development after a prolonged period of limited growth.

Hydropower capacity growth is set to accelerate in the second half of the decade as several long-delayed projects near commissioning. Major plants are expected, by 2030, include the 1 250 MW Lower Subansiri, 1 000 MW Pakal Dul, 960 MW Polavaram and 850 MW Ratle projects. Together with smaller projects currently under construction, India's total conventional hydropower capacity is forecast to reach around 60 GW by 2030.

In addition to electricity generation, many hydropower facilities provide broader economic and social benefits through irrigation, flood control and water resource management, supporting agricultural productivity and regional development. The operational value of hydropower is also increasing as solar PV and wind account for a growing share of electricity generation. Reservoir hydropower plants can provide flexible generation, reserve capacity and ancillary services that help balance short-term fluctuations in renewable output. As renewable penetration rises, these system services become increasingly important for maintaining reliable and cost-effective power system operation. Realising the full value of hydropower flexibility, however, will require continued expansion of transmission infrastructure, as the country's largest hydropower resources are concentrated in the northern mountainous regions, far from the main centres of solar PV and wind generation.

Pumped storage hydropower (PSH) is emerging as a strategic priority for India's energy transition. The first new PSH facility since 2008 was commissioned in 2025, bringing total installed capacity to more than 7 GW. The rapid expansion of solar PV is a key driver behind growing interest in PSH, as such facilities can absorb surplus daytime generation and supply electricity during evening peak demand periods. Recognising this need, the government announced a plan in 2026 to develop 100 GW of PSH capacity by 2035. To facilitate project development, authorities have introduced measures to simplify site allocation and approval procedures, streamline environmental and administrative clearances, and improve co-ordination among central and state agencies.

The project pipeline for PSH has expanded rapidly. Around 16 GW of capacity is currently under construction, with about 7 GW expected to become operational by 2030, doubling total installed capacity to almost 15 GW. Additional projects are progressing through various stages of survey, permitting and investment approval. The increasing procurement of storage-linked, round-the-clock and firm renewable energy projects is also expected to strengthen the commercial case for pumped storage investments. Nevertheless, project economics continue to depend on

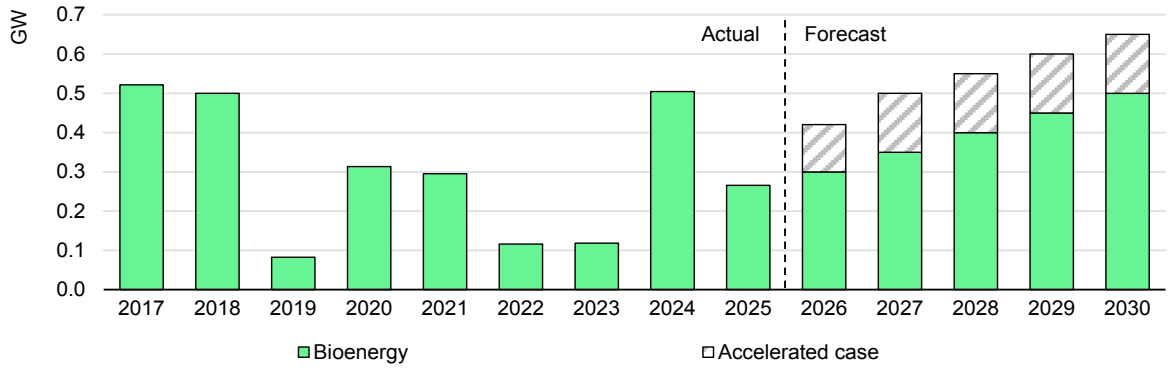
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future electricity market structures and storage remuneration mechanisms, while construction schedules remain exposed to geological risks, land acquisition challenges and transmission infrastructure availability. Ensuring timely project execution will therefore be critical for achieving India's longer-term system flexibility plans.

Bioenergy-for-power

Bioenergy represents another important source of dispatchable renewable electricity. India possesses one of the world's largest bioenergy resource bases, supported by extensive agricultural production, large volumes of crop residues, animal waste, municipal solid waste and agro-industrial by-products. The country's large sugar industry has also enabled substantial deployment of bagasse-based cogeneration plants, while biomass power projects contribute to electricity supply in several agricultural states. In addition to supporting renewable electricity generation, bioenergy can help address air pollution associated with agricultural residue burning, particularly in northern states, while creating additional income streams for rural communities.

Bioenergy-for-power net capacity additions, India, 2017-2030



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Source: IEA (2026), Renewables 2026 (forthcoming).

Despite this significant resource potential, bioenergy deployment has expanded relatively slowly. India has typically added between 100 MW and 500 MW of new bioenergy power capacity annually over the past decade, and this pace is expected to continue through 2030 under current policy settings. The principal barriers include local feedstock availability, collection logistics and project economics. Biomass resources are often geographically dispersed and seasonal, increasing transportation and handling costs. Project developers frequently face difficulties in securing long-term and reliable feedstock supplies at predictable

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prices, while competition from alternative uses – including animal feed, industrial applications, domestic fuel consumption and biofuel production – can further constrain availability and increase costs.

Accelerated case

In the accelerated case, India could add around 20% more hydropower capacity by 2030 if delays in project construction and commissioning are minimised and administrative bottlenecks are addressed more rapidly. Bioenergy deployment could be approximately 35% higher if barriers related to feedstock availability, collection logistics and project economics are mitigated through stronger biomass supply chains, improved market incentives and targeted policy support. Under such a scenario, both technologies could make a larger contribution to system flexibility and renewable energy integration while supporting broader environmental and rural development objectives.

Geothermal, concentrated solar power, and ocean energy technologies

Geothermal, concentrated solar power (CSP) and ocean energy technologies currently play a negligible role in India's renewable electricity sector and are not expected to contribute significantly to capacity growth before 2030. Nevertheless, these technologies continue to attract interest because of their potential to provide dispatchable renewable generation and support long-term power system flexibility as the share of VRE increases.

Geothermal

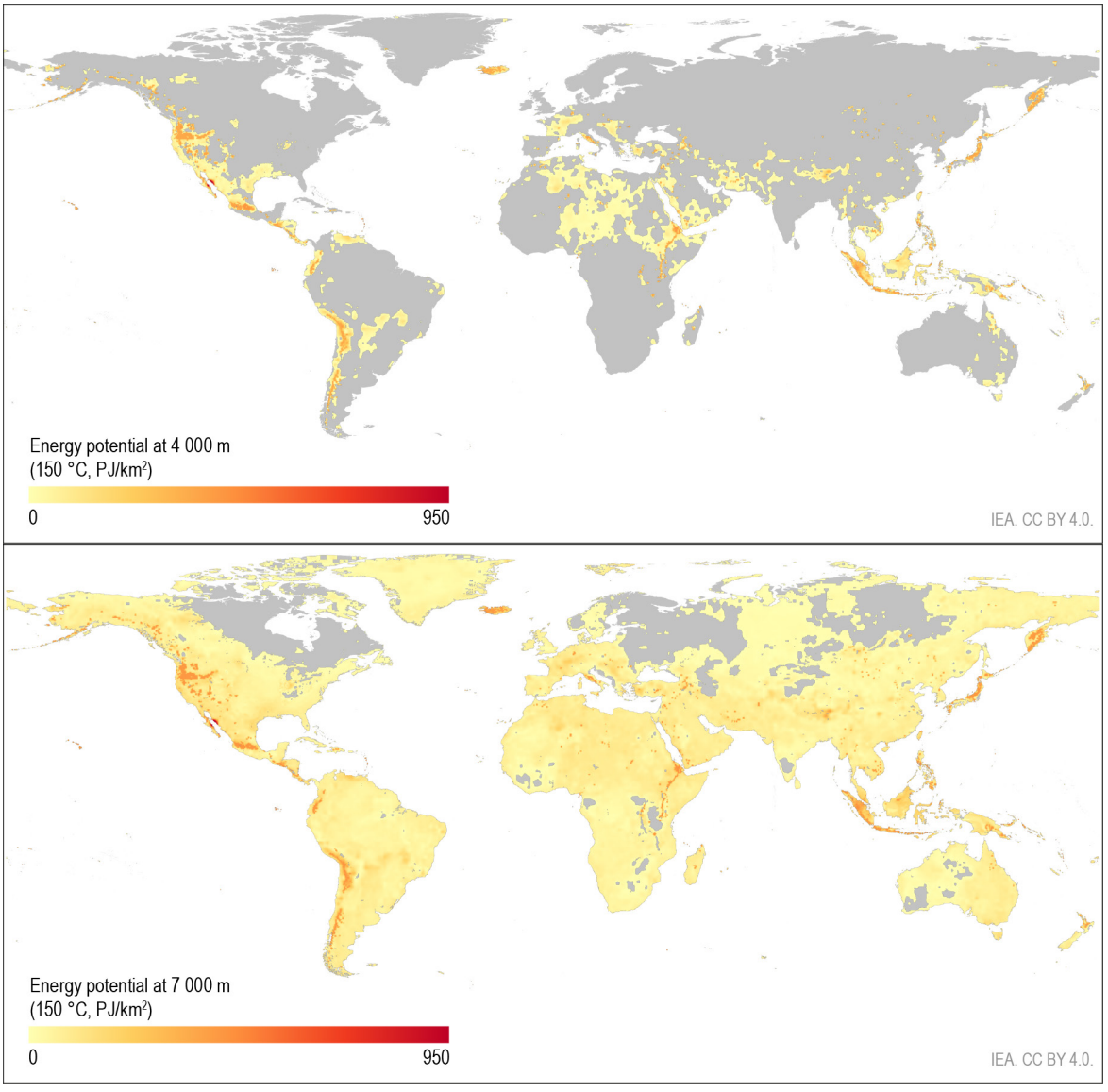
India possesses geothermal resources in several regions, including in Ladakh, Gujarat, and parts of the Himalayan geothermal belt. However, the overall resource base is relatively limited compared with leading geothermal markets, and most identified sites are located in remote areas with challenging terrain and limited infrastructure. High exploration risks and the absence of a proven commercial-scale project have constrained investment to date. As a result, geothermal power deployment remains at the demonstration and resource assessment stage, with no significant capacity additions expected during the current forecast period.

Over the longer term, Enhanced Geothermal Systems (EGS) could significantly expand the technically recoverable geothermal resource base by enabling the use of heat from deep geological formations that are not suitable for conventional geothermal development. At depths of up to approximately 7 km, subsurface temperatures in most parts of the world are sufficiently high to support electricity generation. EGS technologies could therefore provide dispatchable low-emission

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electricity while also contributing to power system flexibility. However, the technology remains at an early stage of commercialisation globally, with only the first large-scale projects currently under development. Due to significant uncertainty regarding resource productivity, drilling costs and overall project economics deployment of EGS projects in India during the forecast period is unlikely.

Global geothermal technical potential at 4 000 and 7 000 m for electricity generation using enhanced geothermal systems



Source: IEA (2024), The Future of Geothermal Energy.

Concentrated solar power

CSP attracted interest during the early phases of India's solar development under the Jawaharlal Nehru National Solar Mission. Several projects, with a total capacity of about 200 MW, were commissioned in the early 2010s; however,

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deployment subsequently stalled as rapidly declining costs for solar PV and battery storage widened the cost gap with CSP for dispatchable renewable generation. Compared with solar PV, CSP projects generally require higher upfront investment, more complex operation and maintenance procedures, and greater water availability, reducing their attractiveness in most regions of India. As a result, CSP deployment is expected to remain limited through 2030 under current market conditions. Nevertheless, CSP with thermal energy storage retains a potential long-term advantage, offering up to 12 hours of storage compared with typically 2-4 hours for solar PV coupled with battery storage.

Ocean energy technologies

Ocean energy technologies, including tidal and wave energy conversion systems, remain at a relatively early stage of development, with about 500 MW installed globally. India possesses a long coastline and significant technical ocean energy potential. However, technology costs remain high, commercial experience is limited and resource assessments are still evolving. As a result, ocean energy is unlikely to contribute materially to India's renewable electricity supply by 2030.

Outlook

Although geothermal, CSP and ocean energy technologies are expected to remain niche sources of electricity through 2030, they could play a larger role over the longer term if technological improvements reduce costs and improve commercial viability. Their ability to provide dispatchable renewable generation, long-duration energy storage or predictable output profiles could become increasingly valuable in a power system dominated by solar PV and wind.

Policy drivers and challenges

Policy evolution overview

India's renewable energy policy framework has evolved significantly over the past two decades, supporting the country's emergence as one of the world's largest solar PV and wind markets, while continually adapting to address evolving challenges. Early policy development focused on establishing the legal and regulatory foundations for renewable electricity deployment, while more recent measures have aimed to accelerate capacity additions, strengthen grid integration, expand distributed generation and develop domestic manufacturing supply chains. Today, renewable energy deployment is driven by a combination of long-term capacity targets, competitive procurement mechanisms and targeted incentives.

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India's renewable energy expansion was enabled by the Electricity Act 2003, which empowered state regulators to promote renewable generation and introduce RPOs. Subsequent policies, including the 2006 National Tariff Policy and the 2008 National Action Plan on Climate Change, strengthened renewable procurement and established preferential tariffs. Over time, the RPO system evolved into a structured national mechanism with increasingly ambitious targets.

Momentum accelerated after the launch of the Jawaharlal Nehru National Solar Mission in 2010, which set national solar goals and introduced financial incentives and competitive procurement. During this period, India also created a renewable energy certificate market and introduced auction-based contracting, helping drive steep cost declines for solar PV and wind.

A major policy shift occurred in 2015, when the government announced a target of achieving 175 GW of renewable power capacity by 2022, including 100 GW of solar PV and 60 GW of wind power. To support this objective, India expanded the use of centralised competitive auctions, launched the Solar Park Scheme and accelerated transmission development through the Green Energy Corridor programme to connect renewable resource-rich regions with major demand centres. The same year, the government also introduced the National Offshore Wind Energy Policy, establishing the regulatory framework for offshore wind development and initiating resource assessment activities along the coasts of Gujarat and Tamil Nadu. India's first nationally determined contribution under the Paris Agreement further reinforced these ambitions by targeting 40% of installed electricity capacity to come from non-fossil fuel sources by 2030.

Since 2018, policy development has increasingly focused on renewable energy integration, distributed generation and system flexibility. The National Wind-Solar Hybrid Policy, introduced in 2018, aimed to improve the use of land and transmission infrastructure while reducing generation variability. Inter-State Transmission System charge waivers reduced delivered renewable electricity costs for projects located far from demand centres and supported deployment in resource-rich states. During the same period, the PM-KUSUM programme was launched to promote solarisation of the agricultural sector through solar irrigation pumps, decentralised solar power plants and grid-connected agricultural feeders, creating an additional market segment for distributed solar PV deployment.

India progressively expanded market-based procurement of renewable electricity with the introduction of the Green Term-Ahead Market in 2020 and the Green Day-Ahead Market in 2021. These dedicated power exchange segments enable generators to sell physical renewable electricity on short-term markets and allow DISCOMs and other consumers to procure renewable electricity competitively, with purchases counting towards RPOs compliance.

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More recently, policy measures have increasingly targeted consumer participation and corporate renewable procurement. The GEOA Rules introduced in 2022 expanded renewable procurement opportunities for commercial and industrial consumers by lowering the minimum eligibility threshold to 100 kW and simplifying approval procedures. In 2024, the PM Surya Ghar Muft Bijli Yojana introduced enhanced financial support for residential rooftop solar systems, accelerating adoption among households and reinforcing the government's objective of expanding distributed solar generation.

India further strengthened its renewable energy ambitions in 2021, announcing during COP 26 a target of 500 GW of non-fossil fuel capacity and aiming for around 50% of installed power capacity to come from non-fossil fuel sources by 2030. Having achieved the 50% target already in 2025, in April 2026 India submitted an updated nationally determined contribution, aiming to achieve a 60% non-fossil fuels share in installed power capacity by 2035.

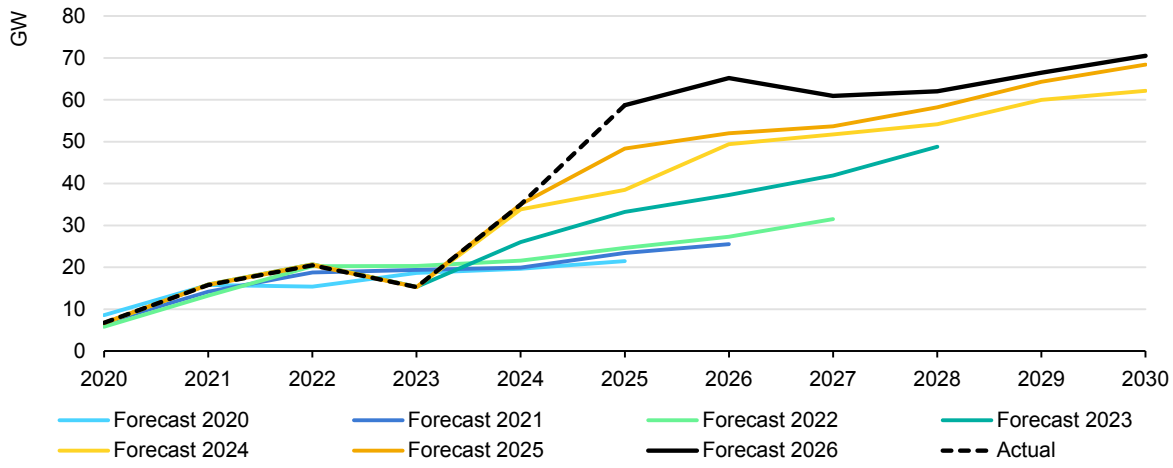
To provide greater investment certainty, the government subsequently announced an annual renewable energy bidding trajectory of 50 GW through fiscal year (FY) 2028, including dedicated auction volumes for wind power. Procurement frameworks have also evolved beyond technology-specific auctions towards hybrid, storage-linked, round-the-clock and firm renewable energy tenders designed to improve system integration and better align renewable generation with demand patterns.

Industrial policy has become an increasingly important and complementary component of India's renewable energy strategy. PLI schemes, the ALMM and customs duties on imported solar modules and cells aim to strengthen domestic manufacturing capabilities, improve supply chain resilience and reduce import dependence. In addition, continued investment in transmission infrastructure, including successive phases of the Green Energy Corridor programme, seeks to facilitate the integration of rapidly growing renewable generation capacity.

The evolution of India's renewable energy policy framework reflects a gradual shift from creating market conditions for renewable deployment towards enabling large-scale integration and domestic value creation. Continual adaptation of policy instruments has been a key factor enabling India to sustain rapid renewable energy deployment despite the increasing scale and complexity of its power sector transformation. The Draft National Electricity Policy, published in 2026, is the latest evidence of this approach, setting a long-term vision for the power sector and providing important guidance for future central and state-level regulation.

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Comparison of IEA forecasts of renewable electricity net capacity additions, 2020-2030



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Sources: IEA (2020), Renewables 2020; IEA (2021), Renewables 2021; IEA (2022), Renewables 2022; IEA (2023), Renewables 2023; IEA (2024), Renewables 2024; IEA (2025), Renewables 2025 and IEA (2026), Renewables 2026 (forthcoming).

The effectiveness of these measures is reflected in the pace of market growth, which has repeatedly exceeded earlier deployment expectations as policy reforms, declining technology costs and improved implementation frameworks have accelerated renewable energy adoption across the country. Over successive editions of the IEA Renewables report, India's projected deployment levels have been revised almost exclusively upwards due to policy improvements addressing deployment bottlenecks, stronger project pipelines and faster-than-expected market development.

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Key policy developments and their impact on renewable power capacity growth

Policy	Date adopted	Description	Impact
Electricity Act	2003	Established legal basis for power sector reform; mandated promotion of renewables and enabled RPOs via state regulators.	Foundational framework enabling subsequent renewable energy policies.
National Electricity Policy	2005	Established an early policy framework for renewable power development, through preferential tariffs, competitive procurement mechanisms.	Policy framework for subsequent renewables support schemes.
Electricity Rules	2005	Provided implementing provisions under the Electricity Act, clarifying aspects of generation, distribution, captive power plants and open access.	Enabled faster deployment of renewables in C&I segment.
National Tariff Policy	2006	Directed regulators to promote renewables through preferential tariffs and procurement obligations for DISCOMs.	Created early demand for renewable electricity.
National Action Plan on Climate Change	2008	Introduced renewable procurement objectives at the national level and embedded renewables within climate policy.	Anchored long-term demand-side policy support.
Generation-Based Incentive (GBI) for Wind	2008	Introduced performance-linked incentives for wind power generation.	Boosted early wind deployment and private investment.
Jawaharlal Nehru National Solar Mission	2010	Flagship programme for large-scale solar deployment through targets, incentives and procurement mechanisms.	Catalysed India's solar market.
Competitive bidding / reverse auctions (solar)	2010	Introduced auction-based procurement for utility-scale solar projects.	Drove rapid cost reductions and deployment scale-up.
Renewable Energy Certificates	2010	Market-based mechanism supporting RPO compliance through tradable certificates.	Improved compliance flexibility, though enforcement was limited.
Operationalisation of state-level RPOs	2011	State regulators established renewable procurement obligations for obligated entities.	Core demand-side driver of renewable deployment.
Establishment of Solar Energy Corporation of India	2011	Created central implementing agency for renewable auctions, PPAs and risk mitigation.	Critical institutional backbone for deployment scale-up.
Solar Park Scheme	2014	Government-supported development of plug-and-play solar parks with land and grid infrastructure.	Reduced project risks and accelerated utility-scale solar deployment.
175 GW renewable energy target (2022)	2015	National target comprising 100 GW solar, 60 GW wind, 10 GW biomass and 5 GW small hydro.	Provided a clear deployment signal and investor certainty.
Green Energy Corridor programme (Phase I)	2015	Dedicated transmission investments connecting renewable resource zones with demand centres.	Major enabler of large-scale renewable integration.
National Offshore Wind Energy Policy	2015	Established regulatory framework for offshore wind development in India's exclusive economic zone.	Enabled resource assessment and project preparation.
Paris Agreement NDC	2015	40% installed power capacity from non-fossil sources target by 2030.	Anchored long-term policy direction.
Competitive bidding / reverse auctions (wind)	2016	Transition from feed-in tariffs to auction-based wind procurement.	Increased procurement efficiency and reduced tariffs.
Revised Tariff Policy	2016	Introduced a national solar procurement target, reinforced RPOs, promoted competitive procurement, grid access and integration of renewables.	Strengthened regulatory framework for renewables deployment.
National Wind-Solar Hybrid Policy	2018	Promoted co-located hybrid projects and shared infrastructure.	Improved land and transmission utilisation.
PM-KUSUM	2019	Promoted solarisation of agriculture through solar pumps and decentralised solar generation.	Expanded distributed solar deployment.

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Policy	Date adopted	Description	Impact
Large hydro classified as renewable	2019	Included large hydropower in renewable energy category.	Improved project economics and broadened renewable portfolio.
Hydropower Purchase Obligation	2019	Introduced dedicated procurement obligation for hydropower.	Strengthened demand visibility for new hydropower projects.
Inter-State Transmission System charge waiver	2019/ 2023	Waiver of inter-state transmission charges for eligible renewable and storage projects.	Reduced delivered costs, especially for remote projects.
Green Term- and Day-Ahead Markets	2020/ 2021	Creation of a renewable-specific segments of the existing Term-and Day-Ahead markets on the Indian Energy Exchange.	Creation of an additional route to market for renewable projects.
Revised NDC / Panchamrit targets	2021	Announced targets of 500 GW non-fossil capacity and approximately 50% installed capacity from non-fossil sources by 2030.	Strong long-term deployment signal.
PLI scheme for solar PV manufacturing	2021	Financial incentives supporting domestic manufacturing of high-efficiency PV modules.	Strengthened domestic supply chains and manufacturing investment.
Approved List of Models and Manufacturers	2021/ 2022/ 2026	Restricted selected projects to approved manufacturers. Applies to solar PV modules (2021), cells (2022), wafers and ingots (2026).	Supported domestic manufacturing and localisation.
Green Energy Corridor programme (Phase II)	2022	Additional transmission infrastructure for integrating growing renewable capacity.	Addressed grid integration bottlenecks.
Basic customs duty on solar modules and cells	2022	Import duties designed to encourage domestic manufacturing.	Improved localisation incentives while increasing short-term project costs.
Green Energy Open Access Rules	2022	Simplified renewable open access and lowered eligibility threshold to 100 kW.	Boosted commercial and industrial segments demand for renewables.
Green tariffs	2022	Introduction of green tariffs allowing consumers to request renewable electricity directly from its DISCOM.	Boosted consumers' demand for renewable electricity.
Renewable purchase and consumption trajectory to 2029-30	2022	Established long-term renewable and non-fossil consumption obligations.	Improved demand visibility and compliance structure.
Strategy for Establishment of Offshore Wind Energy Projects	2023	Outlined seabed leasing, tendering and support mechanisms for offshore wind.	Established implementation framework for future deployment.
Annual renewable bidding trajectory (50 GW/year)	2023	Established minimum annual auction volumes through FY2028, including dedicated wind allocations.	Improved investment certainty and project visibility.
Firm and dispatchable renewable energy tendering guidelines	2023	Enabled auctioning and procurement of renewable electricity combined with storage according to predefined demand profiles.	Boosted hybrid projects development.
National Green Hydrogen Mission	2023	Support framework for domestic green hydrogen production.	Expected to increase long-term renewable electricity demand.
PM Surya Ghar Muft Bijli Yojana	2024	Enhanced subsidies and support for residential rooftop solar.	Substantially accelerated rooftop solar PV adoption.
Draft National Electricity Policy	2026	Statutory policy update providing overarching strategic direction for the power sector.	Direction for future regulations and schemes across the power market.

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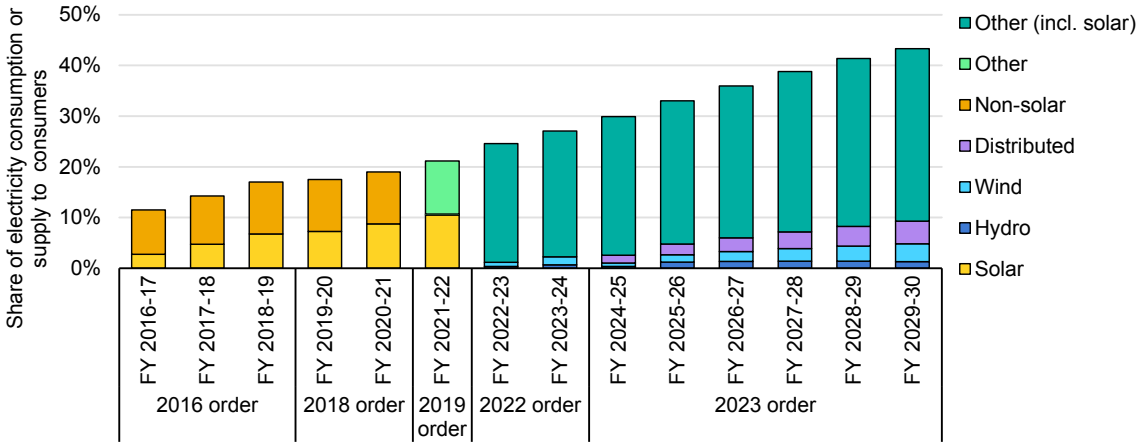
Renewable consumption obligation

India's RPO and renewable consumption obligation (RCO) frameworks have been some of the central policy instruments supporting renewable electricity deployment over the past two decades.

Policy schemes

Established under the Electricity Act 2003 and reinforced through successive policy and regulatory reforms, the mechanism obliges DISCOMs, open-access consumers and captive power producers to source a minimum share of their electricity consumption from renewable technologies. State electricity regulatory commissions set state-level targets and oversee compliance, and the Ministry of Power defines the overarching policy framework and publishes long-term RPO/RCO trajectories. The framework was designed to generate a stable demand signal for renewable electricity and enhance investment visibility for project developers.

National RPO/RCO trajectories, India, 2016-2030



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Source: IEA analysis based on data from India, Ministry of Power.

State-level RPO targets began to emerge in the late 2000s, following the National Action Plan on Climate Change in 2008, which recommended increasing the share of renewable electricity consumption to 15% by 2020. Early implementation differed significantly across states because targets, technologies covered and enforcement mechanisms varied among regulators. Compliance levels remained relatively low during the initial years owing to limited renewable energy availability, weak enforcement mechanisms and the poor financial condition of many DISCOMs. Nonetheless, the framework played a foundational role in establishing

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an early market for renewable electricity procurement and Renewable Energy Certificates, enabling obligated entities with limited renewable resource availability to meet targets through tradable certificates.

Over time, the RPO framework evolved into a more structured mechanism with more ambitious targets. The Ministry of Power periodically announced long-term RPO trajectories to provide greater investment certainty and align renewable deployment with national energy and climate objectives. Under the current trajectory, announced in 2022 and amended in 2023, overall renewable energy consumption obligation rises from almost 30% in FY 2024-25 to over 43% by FY 2029-30. In addition, since FY 2024-25, the RPO framework has been accompanied by the RCO. Separate subtargets for wind power, hydropower and distributed renewable energy were introduced to support the deployment of these technologies, reflecting their generally higher development costs or more complex project implementation compared with utility-scale solar PV. In the case of hydropower, these subtargets also recognise its important contribution to power system flexibility.

Challenges

Despite an improving policy environment, challenges in RPO/RCO implementation remain. Compliance and enforcement continue to vary across states, reflecting differences in renewable resource availability, regulatory approaches and the financial condition of DISCOMs. The inflexibility of long-term PPAs with fossil fuel generators also plays an important role, limiting DISCOMs' ability to procure renewable power. Many DISCOMs have historically delayed procurement or have failed to meet targets without facing significant penalties. As compliance enforcement falls under the responsibility of state electricity regulatory commissions, enforcement practices and penalty mechanisms differ substantially across states. Monitoring compliance among open-access consumers and captive power producers also remains challenging because of limited data transparency and inconsistent reporting practices. In some states, RPO/RCO compliance reports are published with substantial delays or are not regularly disclosed publicly. According to Ministry of Power data for FY 2022-23, only 16 of 36 states and union territories met the overall RPO/RCO requirement.

Outlook

Overall, the RPO/RCO framework has played an important role in supporting India's renewable electricity expansion. Obligations create predictable demand for renewable electricity procurement by utilities and large consumers. Procurement associated with RPO/RCO targets is expected to continue to contribute to the deployment of solar PV and wind projects through competitive auctions and open-access contracting.

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Competitive auctions

Competitive auctions have become the central mechanism supporting utility-scale renewable deployment in India since their introduction in 2010 under the Jawaharlal Nehru National Solar Mission.

Awarded auction volumes

The first auction, conducted by NTPC Vidyut Vyapar Nigam, allocated 150 MW of solar PV and 470 MW of CSP, establishing a centrally co-ordinated auction framework that has since expanded into the world's second-largest renewable auction market, after China. India's auction scheme has evolved through three broad phases: an initial scale-up period focused on solar deployment and cost reductions (2010-16); a second phase characterised by diversification across technologies (2017-23); and, since 2024, a transition towards power system-friendly procurement centred on firm capacity obligations with utilisation of energy storage systems.

Since the first auction in 2010 and by June 2026, India has awarded around 220 GW of utility-scale renewable capacity through competitive auctions. Solar PV accounts for over 57% of total awarded volumes, reflecting early scalability and rapid cost declines; onshore wind, introduced in 2017, represents around 10%. The remaining 32% has been awarded in firm capacity auctions[6], which were introduced in 2018 and aim to address system integration challenges.

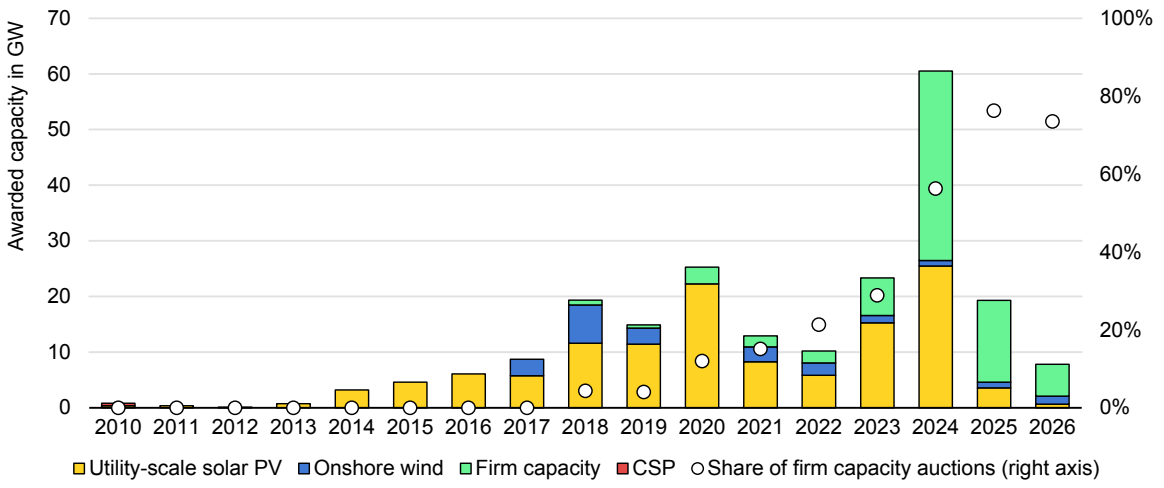
Auction volumes have accelerated strongly since the late 2010s, reaching record levels in 2024, with more than 60 GW awarded – exceeding the government's annual auction target by 20%. However, volumes declined sharply thereafter, falling back to around 20 GW in 2025 and reaching just 8 GW in the first half of 2026.

This decline increasingly reflects growing challenges in the contracting of successful projects: DISCOMs have become more selective in signing new power sale agreements and procuring new capacity, reflecting financial constraints, administrative delays, changing demand expectations and a growing preference for firm capacity. Consequently, the gap between auction awards and project execution has widened across the central portfolios of the renewable energy implementing agencies (REIAs), which are the main procuring entities in India. Delays in concluding power sale agreements have slowed PPA signing with successful bidders.

[6] These include auctions for (1) hybrid projects combining two renewable electricity generation technologies, in India typically solar PV and onshore wind; and (2) renewable energy projects coupled with storage, most commonly solar PV or hybrid projects paired with battery storage.

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Awarded utility-scale renewable capacity in competitive auctions in India, by technology, 2010-2026



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Note: 2026 includes only auctions that had concluded by H1 2026.
Source: IEA analysis based on IEA renewable power auctions global database.

Procuring entities

REIAs have been introduced by the Indian government to support large-scale deployment of renewables in a fragmented electricity market. Acting as intermediary procurers, REIAs conduct renewable auctions and sign PPAs with successful bidders and back-to-back power sale agreements with distribution companies. Over time, REIAs evolved from auction administrators into procurement and risk management platforms, taking a growing role in contract standardisation, market aggregation and project bankability. REIAs were able to procure projects at the national level, which together with waivers on Inter-State Transmission System charges for renewable technologies, supported their success in contracting large volumes of renewable capacity.

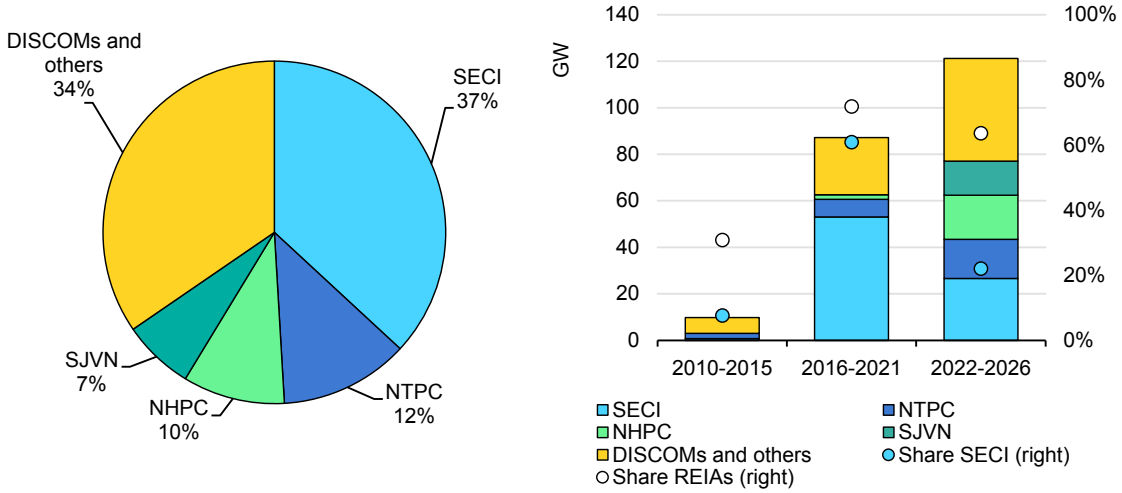
The four REIAs – Solar Energy Corporation of India (SECI), NTPC, NHPC and SJVN – have together awarded more than 140 GW of capacity since 2010, representing around two-thirds of total auctioned capacity in India. SECI, established in 2011 under the Ministry of New and Renewable Energy, became the principal intermediary as procurement expanded beyond solar into wind, hybrid and firm capacity products. SECI's role expanded significantly over time, peaking in 2020 when it accounted for around three-quarters of the annual awarded volume, declining to 15% in 2025 as procurement became more distributed across REIAs. For instance, SJVN only began conducting auctions as a REIA in 2023.

This decentralisation of REIAs was subsequently reversed in 2026, when the Ministry of New and Renewable Energy announced that SECI would become the

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sole REIA for future auctions. The remaining agencies continue managing their existing portfolios. The objective is to simplify procurement and strengthen the alignment between auctions and DISCOM demand.

Awarded renewable capacity by procuring entity, cumulative (left) and annual split (right), India, 2010-2026



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Notes: 2026 includes only auctions that had concluded by H1 2026. *DISCOMs and others* = MSAPL, KREDL, IREDA, REMCL, TSSPDCL, RUMS, RUVNL, UPNEDA, UPPCL, RECPDCL, Tata Power-D, TANGEDCO, CESC, PSPCL, PEDA, ASPDCL, MPPMCL, RUMSL, Tamil, Torrent Power, APDCL, MAHAGENCO, HPPC, BREDA, KSEB, UREDA, RRECL, MSPGCL, CSPDCL, MPJN, BSPCL, MCGM, GRIDCO, APGCL, DVC, OREDA, BMC.

Source: IEA analysis based on IEA renewable power auctions global database.

Outside the REIA framework, around one-third of awarded capacity has been procured directly by DISCOMs and other entities, such as the Railway Energy Management Company Limited, primarily to meet RPO requirements.

Firm capacity auctions

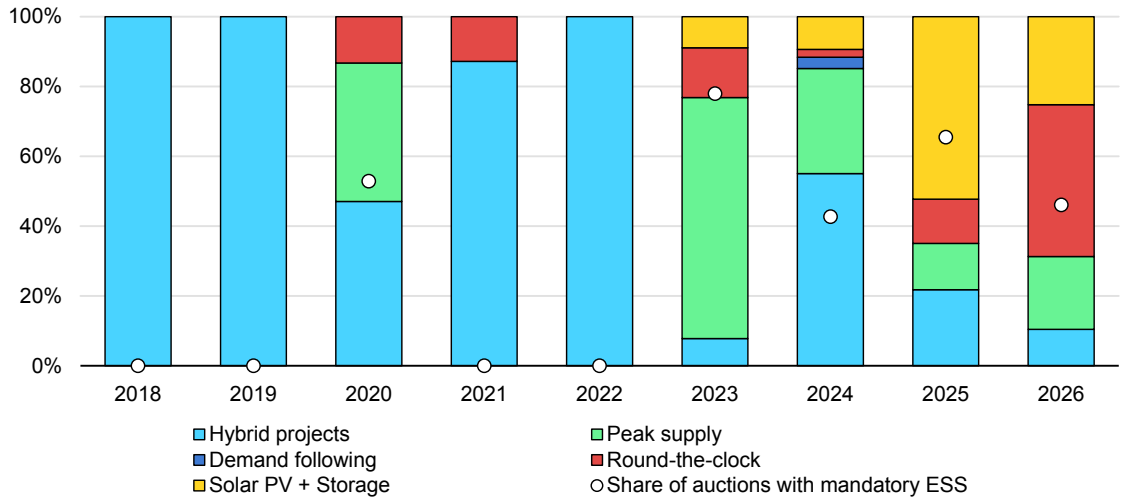
As renewable penetration increased and power system requirements evolved, auction products became progressively more sophisticated. Early auctions focused on minimising generation costs through procurement and large-scale deployment of stand-alone solar PV and, to a certain degree, onshore wind. Auctions for hybrid projects, combining solar PV and onshore wind components, later emerged to improve system integration without requiring storage and became the dominant firm capacity type until 2022. Declining battery storage costs have accelerated a transition towards auction designs that increasingly require dispatchability and time-based delivery, making storage a requirement in every second gigawatt awarded since 2023.

Firm capacity auctions can be grouped into five categories: hybrid projects, peak supply, demand-following, round-the-clock, and solar PV paired with storage.

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Peak supply auctions have expanded particularly rapidly since 2023 and now account for almost one-third of firm capacity awards, largely through “assured peak” designs requiring delivery during defined peak hours together with minimum annual utilisation requirements. Solar PV paired with storage has also grown quickly and now represents around one-fifth of firm awards. By contrast, RTC and demand-following auctions remain relatively limited and have faced cases of undersubscription or cancellation, reflecting their higher operational complexity and investment needs.

Shares of awarded volumes in firm capacity auctions, by firmness type, 2018-2026



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Notes: ESS = energy storage system. 2026 includes only auctions that had concluded by H1 2026.
Source: IEA analysis based on IEA renewable power auctions global database.

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Design of stand-alone and firm capacity auctions

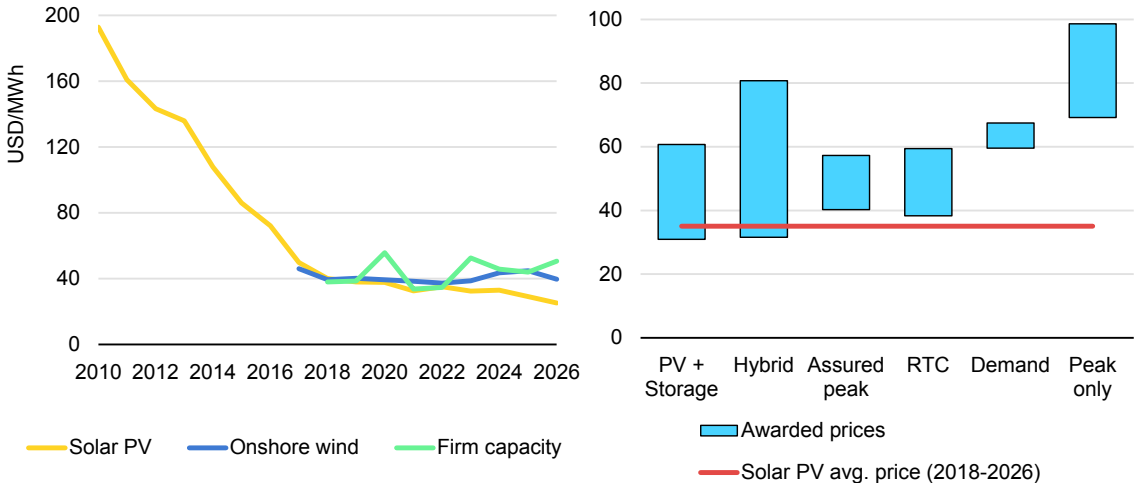
Design element	Stand-alone	Hybrid projects	Assured peak	Peak only	Round the clock	Demand-following	Solar PV + storage
Technology	Solar PV, onshore wind, offshore wind	Solar PV and onshore wind combined, typically ≥ 33% wind, ≥ 33% solar PV	Solar PV, wind, other renewable, or a combination	Solar PV, wind, other renewable, or a combination	Solar PV, wind, other renewable, or a combination (in older auctions, renewable energy combined with thermal power)	Solar PV, wind, other renewable, or a combination	Solar PV
Storage required	No	No	Yes	Yes	Yes[7]	Yes	Yes
Storage specification	n/a	n/a	0.25 MWh of storage for 1 MW of project capacity	No specifications	No specifications	No specifications	0.5 MW and 1-3 MWh of storage for 1 MW of project capacity
Delivery obligation (shape)	n/a	n/a	Peak hours: 2-6 hours Non-peak hours: specific capacity utilisation factor (CUF) requirements	Peak hours: 4 hours Non-peak hours: no requirements	Peak hours: 4 hours or specific CUF Non-peak hours: CUF requirements	Depending on demand schedule	Peak hours: 2-6 hours Non-peak hours: specific CUF requirements
Electricity supply requirements	No requirement	CUF: ≥ 30% or 35% (annual)	CUF: 40% (annual)	Only peak-hour fulfilment	CUF: 75% or 80% (annual) + 70% or 75% (monthly) + 90% (peak hours)	Demand fulfilment ratio: 75%/90% (monthly)	CFR: 19%/25%
Co-location of components required	n/a	No	No	Yes	No	No	Yes
Firmness penalty design	n/a				1.5-2 times the awarded tariff for each kilowatt hour of delivery obligation missed		
Contract duration	25 years						

[7] Round the clock auctions allowing oversizing of renewable capacity without storage, using market electricity procurement or combining renewables with thermal power were also tried.

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Utility-scale solar PV prices declined sharply over the past decade, from around USD 200/MWh in the first auctions to approximately USD 25-30/MWh in 2026, reinforcing solar PV's position as the lowest-cost benchmark technology in Indian auctions. Falling global module prices, improvements in module efficiency, economies of scale associated with rapid deployment, and strong competition among developers drove this decline. Onshore wind remained structurally higher at around USD 40-45/MWh, reflecting higher capital costs and lower cost reductions compared with solar PV. More recently, equipment cost inflation, supply chain constraints and less favourable financing conditions have contributed to higher wind auction prices, in line with trends observed across many global auction schemes.

Average awarded prices in renewable auctions by technology (left) and firm capacity design (right), India, 2010-2026



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Notes: RTC = round the clock. 2026 includes only auctions that had concluded by H1 2026.
Source: IEA analysis based on IEA renewable power auctions global database.

Firm capacity auctions averaged slightly above USD 45/MWh, remaining broadly competitive despite increasingly stringent delivery obligations. However, price volatility across firm capacity auctions widened considerably. Solar PV-plus-storage auctions and hybrid projects achieved the lowest average awarded prices among firm products, while RTC, assured peak and peak-only auctions recorded higher premiums associated with firmness and delivery obligations. Nevertheless, the average firm capacity tariffs achieved were about 20% lower than average coal power supply cost in 2025.

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Overall, India's auction framework is entering a new phase in which procurement scale alone is no longer the main challenge. Institutional co-ordination, contract execution and system integration requirements are becoming increasingly important. Auction design is evolving accordingly, shifting from procuring the lowest-cost renewable electricity towards procuring renewable generation that better aligns with power system needs.

Distributed solar PV

Consisting primarily of rooftop installations on residential, commercial and industrial buildings, as well as off-grid and decentralised systems serving agricultural consumers, distributed solar capacity increased from less than 1 GW in 2015 to around 35 GW by the end of 2025. Growth accelerated markedly in recent years, with almost half of total installed capacity added during 2024 and 2025 alone. Annual additions reached a record high of almost 10 GW in 2025, reflecting improving project economics, stronger policy support and increasing consumer awareness; deployment is expected to continue to accelerate through 2030.

Policy schemes

Distributed solar deployment in India and has undergone several distinct phases of development. Initial growth was relatively slow despite abundant solar resources and declining technology costs. Before 2020, market expansion was constrained by high upfront investment requirements, limited financing availability, administrative complexity and uncertainty regarding compensation mechanisms for exported electricity.

To accelerate the deployment, India introduced following policies:

2014 – Grid Connected Rooftop Solar Programme

The government launched in 2014 the Grid Connected Rooftop Solar Programme, providing central financial assistance to selected consumer categories and establishing the first nationwide framework for rooftop deployment. Although the programme helped initiate market development, deployment remained below expectations because implementation depended heavily on state-level execution, DISCOM participation and consumer awareness.

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2019 – Phase II of the Rooftop Solar Programme and 2022 targets

In 2019, policy support was strengthened significantly through Phase II of the Rooftop Solar Programme. The revised framework introduced higher capital subsidies for residential consumers, established state-specific deployment targets and reinforced the national objective of reaching 40 GW of rooftop solar capacity by 2022. The programme also increased the role of distribution companies in implementation and consumer outreach. While deployment accelerated gradually after these reforms, installation rates remained below target owing to persistent administrative barriers, lengthy approval processes and uneven policy implementation across states.

2020 – The Electricity (Rights of Consumers) Rules

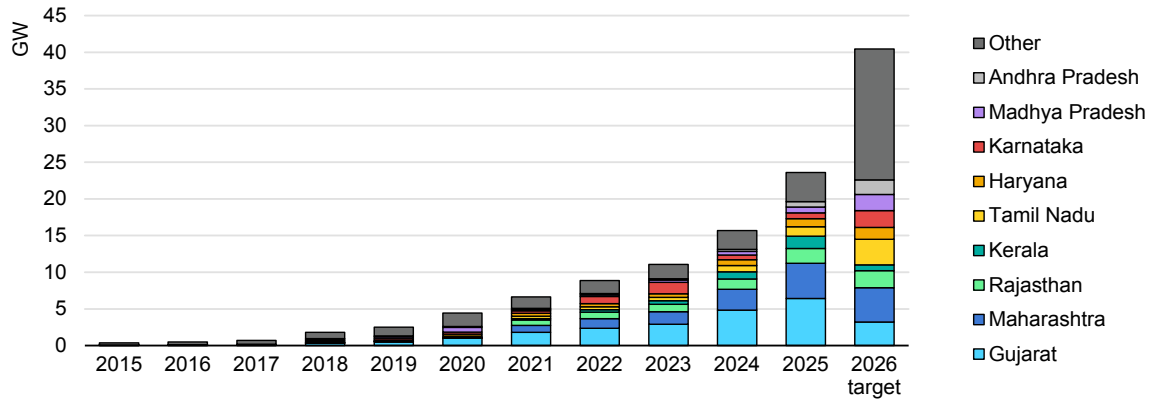
In 2020, the Electricity (Rights of Consumers) Rules were introduced, which established a national framework governing rooftop solar connections and compensation mechanisms. Subsequent amendments clarified the application of net-metering, gross-metering and net-billing arrangements while providing greater regulatory certainty for consumers and project developers. Further amendments in 2024 introduced mandatory timelines for rooftop solar approvals and commissioning procedures, requiring feasibility assessments and approvals to be completed within specified deadlines. Systems below 10 kW were exempted from certain technical approval requirements, reducing administrative complexity for residential consumers. These measures significantly shortened project development timelines and reduced one of the most frequently cited barriers to deployment.

2022 – National Portal for Rooftop Solar and target extension

In 2022, the launch of the National Portal for Rooftop Solar was another important step towards market simplification. The portal introduced a unified digital platform for subsidy applications, installation approvals and consumer registration, reducing the need for multiple interactions with utilities and government agencies. Although rooftop deployment continued to lag behind official targets, the portal improved transparency and standardised implementation procedures across states. Same year, the 2022 target was extended to 2026 to support continued market development.

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Rooftop solar PV capacity and 2026 target by state, India, 2015-2026



IEA. CC BY 4.0.

Note: Solar PV is presented in AC.
Source: IEA analysis based on data from Ministry of New and Renewable Energy.

2023 – Distributed subcategory in RPO

In 2023, a further policy milestone occurred when distributed renewable generation was incorporated into India's RPO framework. The introduction of dedicated distributed renewable energy obligations increased the policy importance of rooftop solar deployment and strengthened incentives for state-level implementation.

2024 - PM Surya Ghar Muft Bijli Yojana subsidy

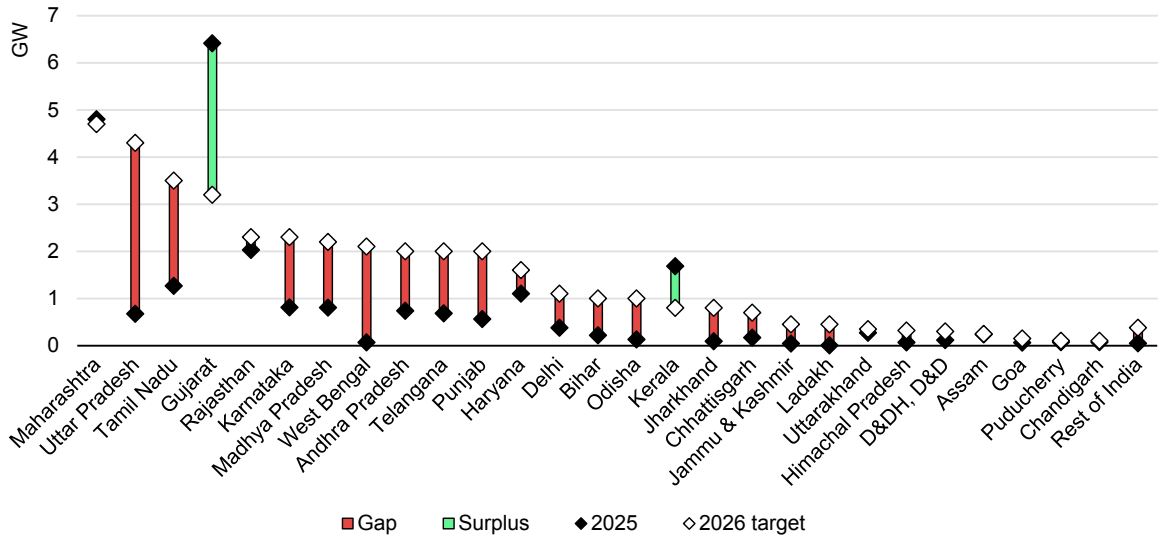
In 2024 came the most significant policy intervention, with the launch of PM Surya Ghar Muft Bijli Yojana. The programme introduced substantial capital subsidies for residential rooftop installations, simplified administrative procedures and established an ambitious target of installing rooftop systems on 10 million households by March 2027. Under the scheme, residential consumers receive subsidies of INR 30 000 (USD 324) per kilowatt for systems up to 2 kW (approximately 40-60% of typical capital expenditure) and an additional INR 18 000 (USD 194) per kilowatt for systems between 2 kW and 3 kW, with a total programme budget exceeding INR 750 billion (USD 8.1 billion). Together with simplified approvals and growing public awareness, these measures triggered an unprecedented acceleration in residential rooftop solar deployment during 2024 and 2025.

Deployment concentration

Deployment of rooftop PV remains highly concentrated, with almost 60% of installed capacity located in Gujarat, Maharashtra and Rajasthan. Compared to the 2026 target, among the states with a target of at least 0.8 GW, only these three states, plus Kerala and Haryana achieved significant progress.

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Cumulative rooftop PV capacity in 2025 and allocation of grid-connected rooftop solar PV target for 2026, by state



IEA. CC BY 4.0.

Note: Solar PV is presented in AC
Source: IEA analysis based on data from Ministry of New and Renewable Energy.

Gujarat accounts for more than one-quarter of India's installed rooftop solar PV capacity. The state has doubled its target and emerged as the national leader in deployment through a combination of state-level subsidies, attractive net-metering arrangements, proactive utility engagement and sustained consumer outreach.

Maharashtra benefits from high electricity demand, a large commercial and industrial consumer base, strong economic incentives for self-consumption, and high (5 MW) capacity limit for rooftop systems. It reached the target in 2025.

Rajasthan combines excellent solar resources with supportive state policies and growing consumer adoption. The state is expected to reach its target in 2026.

Kerala has experienced rapid growth driven by state-level subsidies, high retail electricity tariffs and strong household participation, allowing it to surpasss its target by over 100%.

Haryana achieved 70% of its target thanks to relatively high household incomes, proactive implementation of central support schemes, and favourable state policies promoting residential and institutional rooftop installations.

State-level policy examples demonstrate that successful rooftop solar deployment highly depends on effective implementation. Although the broad policy framework governing rooftop solar is relatively consistent across successful and unsuccessful states, deployment outcomes vary considerably. Differences in utility engagement, administrative efficiency, approval timelines, consumer awareness and implementation of support schemes appear to be important factors explaining variations in rooftop solar adoption and target achievement.

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State-level rooftop PV policy – states with at least a 1 GW target, as of September 2026

State	2025 capacity (GW)	2026 target (GW)	Target fulfilment	Max. capacity	Max. load	Metering scheme	Settlement period	Excess compen-sation	State subsidy	Tax incen-tives	Permit-ting window	DISCOM rating
States with the highest target fulfilment												
Kerala	1.7	0.8	210%	1 000 kW	100%	NM	Year	APPC	No	Duty	Single	B
Gujarat	6.4	3.2	200%	1 000 kW	res.: no limit; C&I: 50%	NM, GM	Billing cycle	Regula-ted	Capital (phased out)	No	Single	A+
Maharashtra	4.8	4.7	102%	5 000 kW	100%	NM, GNM, NB, VNM	Year	Regula-ted	No	Duty	Single	C
Rajasthan	2.0	2.3	88%	1 000 kW	100%	NM, NB, GM, VNM	Billing cycle / year	Regula-ted	Capital	Duty	No	B-
Haryana	1.1	1.6	69%	500 kW	100%	NM, GM	Year	Regula-ted	Capital	No	No	A
States with the lowest target fulfilment												
Punjab	0.6	2.0	28%	500 kW	res.: 100% C&I: 70%	NM, GNM, GM, NB, VNM	Year	Regula-ted	No	No	Single	A+
Bihar	0.2	1.0	22%	1 000 kW	100%	NM, GM	Year	No	Capital	No	Single	A
Uttar Pradesh	0.7	4.3	16%	2 000 kW	100%	NM, GM	Billing cycle	Regula-ted	Capital	Duty	Mixed	B-
Odisha	0.1	1.0	13%	500 kW	100%	NM, GM	Year	No	Capital	Duty	Single	A
West Bengal	0.1	2.1	3%	500 kW	100%	NM, GM, NB	Billing cycle / year	Regula-ted	No	No	Single	A

Notes: RE = renewable energy; Max. capacity = maximum allowed capacity of a rooftop system; Max. load = maximum allowed system capacity as compared to grid connection capacity; res = residential consumers; C&I = commercial and industrial consumers; Metering scheme = type of remuneration scheme: NM = net metering, GNM = group net metering, GM = gross metering, NB = net billing, VNM = virtual net metering; Settlement period = period allowed to settle imbalance between consumption and generation; Excess compensation = compensation tariff for electricity fed to the power grid: APPC = average power purchase cost of DISCOM, Regulated = tariff set by an appropriate administrative office; State subsidy = availability of additional subsidy on state level: capital = capital subsidy; Tax incentives = availability of tax incentives: duty = exemption related to electricity duty, tax = exemption related to tax; Permitting window = existence of a one-stop shop for permitting procedures; DISCOM rating = average performance rating of state's distribution companies in FY 2024-25 as per Power Finance Corporation.

Source: IEA analysis based on data from the Council on Energy, Environment and Water (2025), How are Indian States Enabling Rooftop Solar Adoption?

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Challenges

Despite recent progress, several barriers continue to constrain faster rooftop solar deployment:

Utility financial incentives: The financial structure of many distribution companies creates mixed incentives for rooftop solar deployment, as higher-paying residential and commercial consumers contribute disproportionately to utility revenue recovery. Concerns regarding revenue erosion have contributed to varying approaches towards rooftop solar implementation across states.

Administrative and regulatory fragmentation: Although approval procedures have improved significantly, implementation continues to differ across states and utilities. Variations in application processes, technical requirements, metering arrangements and approval timelines increase transaction costs and create uncertainty for consumers and developers.

Insufficient economic incentives for households: Residential electricity tariffs are often heavily cross-subsidised, reducing the financial benefits of self-generation compared with commercial and industrial consumers. Although PM Surya Ghar has significantly improved project economics, investment attractiveness remains dependent on state-level compensation mechanisms for exported electricity and available electricity consumption subsidies.

Access to financing and technical capabilities: Upfront investment costs remain a barrier for many households and small businesses despite available subsidies. Limited access to affordable financing, together with shortages of qualified installers and technical service providers in some regions, can slow market development.

Distribution network constraints: In areas with high rooftop solar penetration, local distribution infrastructure and transformer capacity may require upgrades to accommodate additional generation. Net-metering limits and export restrictions can also constrain deployment in some jurisdictions.

Outlook

Prior to the introduction of PM Surya Ghar, commercial and industrial consumers accounted for over two-thirds of rooftop solar deployment. Relatively high retail electricity tariffs, growing corporate sustainability commitments and attractive self-consumption economics have encouraged rooftop solar PV adoption across manufacturing, commercial real estate, retail and service sectors. The emergence of third-party ownership structures, renewable energy service business models and specialised financing products has further reduced upfront investment barriers and expanded access to rooftop solar among consumers unwilling to finance

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systems directly. Commercial and industrial consumers are expected to be responsible for about half of rooftop solar growth through 2030.

Assuming active policy-making to address identified challenges and improve project economics and growing familiarity with rooftop solar technologies, sustained market growth is expected to continue through 2030. New consumer financing models, including through digital solutions, new aggregation mechanisms for rooftop portfolios, peer-to-peer energy trading, local energy communities and other innovative solutions, will also play an increasingly important role as the distributed PV market expands and matures.

Solar PV use in agricultural segment and PM-KUSUM

Beyond rooftops, agricultural solarisation has become an increasingly important component of distributed solar development, with installed capacity reaching around 5.6 GW in 2025, almost half of which was added during 2024 and 2025.

Annual additions of around 1.7-2.0 GW are expected to continue through 2030, driven primarily by the PM-KUSUM scheme. Launched in 2019, the programme aims to reduce dependence on subsidised grid electricity and diesel-powered irrigation by promoting solar-powered agricultural pumps and decentralised solar generation. The scheme consists of three components: installation of stand-alone solar pumps (Component B), solarisation of existing grid-connected pumps (Component C), and development of small decentralised solar power plants connected to rural distribution networks (Component A).

The original programme targeted the deployment of 10 GW of decentralised solar power plants, the installation of 2 million stand-alone solar pumps and the solarisation of 1.5 million grid-connected agricultural pumps by 2022, later extended to 2026. The total solar capacity expected to be deployed under the scheme has been estimated at almost 35 GW. In addition to reducing electricity subsidy requirements and improving energy access, PM-KUSUM seeks to create new income opportunities for farmers through electricity sales to the grid.

Implementation of PM-KUSUM has progressed more slowly than originally anticipated. By November 2025, approximately 10 GW of capacity had been installed under all components of PM-KUSUM, including 0.7 GW of decentralised solar plants under Component A, as well as around 940 000 stand-alone solar pumps and more than 1 million solarised grid-connected individual and feeder-level pumps. Deployment has been concentrated primarily in solar pump installations; implementation of decentralised grid-connected generation projects has advanced more slowly because of land acquisition, procurement and offtake challenges.

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Overall deployment remains significantly below the original programme targets,. Adoption has also been constrained by financing requirements, administrative complexity, varying levels of state participation and difficulties co-ordinating multiple stakeholders. In several states, delays in subsidy disbursement, procurement processes and grid connection have slowed deployment. Nevertheless, the programme has established an important framework for integrating distributed renewable generation into the agricultural sector and remains one of the largest agricultural solarisation initiatives globally. Several states, like Maharashtra, Rajasthan and Gujarat, were successful in tackling implementation challenges through dedicated programmes and contracted significant capacity under KUSUM. Continued improvements in implementation, financing mechanisms and state-level participation are expected to support further deployment through 2030.

Agrivoltaics

Agrivoltaics, which combines agricultural production and solar PV generation on the same land, could provide an additional pathway for solar deployment while limiting competition for agricultural land. Systems typically use elevated or wider-spaced PV structures that allow crops to be cultivated underneath or between modules, although configurations vary depending on crops, climatic conditions and agricultural practices. In addition to improving overall land-use efficiency, partial shading from PV modules can reduce heat stress and water requirements for some crops, while electricity generation can provide farmers with an additional source of income. However, these benefits are highly site and crop specific, with excessive shading potentially reducing agricultural yields.

Agrivoltaics remains more expensive and complex than conventional ground-mounted PV. Elevated structures, wider module spacing and requirements to maintain access for agricultural machinery increase investment costs and generally reduce installed PV capacity per hectare. Projects also require careful selection of crops and system configurations.

Global agrivoltaics deployment is challenging to quantify, due to differences in definitions and reporting methodologies. The leading market is China with increasing deployment in France, Germany, Italy, Israel, the United States, Korea, and Japan.

India has significant potential, but deployment remains at an early stage. A recent national assessment by TERI estimates around 1.2-2.1 TW of potential on highly suitable agricultural land, with around half located in Maharashtra, Rajasthan, Andhra Pradesh, Madhya Pradesh, Karnataka and Uttar Pradesh. However, only

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around 38 MW across 36 projects was operational as of August 2025, with most projects remaining relatively small pilots or demonstrations.

Existing deployment has been supported partly through PM-KUSUM, which allows decentralised solar plants to be installed on elevated structures while agricultural activity continues underneath. Pilot projects are also being used to assess suitable configurations and crops. A Centre of Excellence on Agrivoltaics, established by the Ministry of New and Renewable Energy with Indian Council of Agricultural Research – Indian Agricultural Research Institute and National Institute of Solar Energy, is undertaking research on crop performance and system design, while several commercial and farmer-led projects have demonstrated the technical feasibility of combining electricity generation with continued agricultural production.

Policy support is expected to strengthen significantly. In 2026, the government announced plans to include a dedicated agrivoltaics component in the next phase of PM-KUSUM, potentially providing a route for deployment beyond individual demonstration projects.

Agrivoltaics is therefore expected to expand from its currently low base, although deployment through 2030 is likely to remain considerably smaller than conventional ground-mounted and distributed solar PV. Progress will depend on reducing the additional cost of elevated structures, developing standardised technical requirements, identifying suitable combinations of crops and PV configurations, and establishing business models that provide sufficient benefits to farmers. If these challenges are addressed, agrivoltaics could become increasingly important beyond 2030 as solar deployment expands and competition for suitable land increases.

Open-access procurement

Open-access policy has become an important driver of renewable electricity deployment in India, particularly for commercial and industrial consumers. By allowing large electricity users to procure power directly from generators through bilateral contracts, captive arrangements and third-party PPAs, open-access frameworks have supported rapid growth in solar PV and wind projects, especially in industrial states such as Karnataka, Maharashtra, Gujarat, Tamil Nadu and Rajasthan.

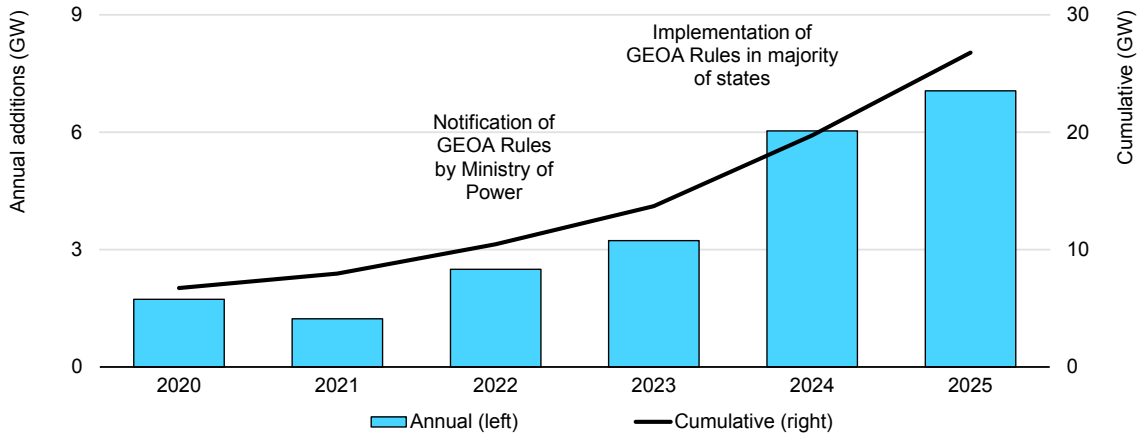
Policy schemes

The Electricity Act 2003 established the legal basis for open access in India's power sector. However, deployment remained limited because of high cross-

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subsidy surcharges, regulatory uncertainty, restrictive state-level implementation and relatively high cost of renewable power. Market growth accelerated after 2021 as rising industrial electricity tariffs, declining renewable technology costs and increasing corporate decarbonisation commitments improved the competitiveness of renewable open-access projects.

Renewable open-access annual solar PV and wind capacity additions and cumulative installed capacity, 2019-2025



IEA. CC BY 4.0.

Sources: IEA analysis based on data from the Institute for Energy Economics and Financial Analysis (2024), Impact of Green Energy Open Access Rules, 2022 and Mercom India (2025), Q4 and annual 2025 India Solar Open Access-Market-Report.

A major policy change came with the notification of the GEOA Rules in 2022. The rules reduced the minimum eligibility threshold from 1 MW to 100 kW, expanded access for smaller consumers and introduced a targeted 15-day administrative approval timeline. The framework also aimed to harmonise state-level regulations and clarify provisions related to banking and surcharge treatment. Since 2022, most states have adopted or partially aligned their regulations with the GEOA framework.

Solar open-access additions increased from around 2.5 GW in 2022 to over 7 GW in 2025, while cumulative installed solar capacity reached about 27 GW by the end of 2025. Overall, open-access procurement was a main driver of about 20% of utility-scale solar PV and wind capacity additions in 2020-2025 in India.

Challenges

Implementation of the GEOA Rules remains uneven, and important barriers remain. Surcharges continue to vary significantly across states and materially affect project viability. Regulatory uncertainty, delays in approvals and grid congestion remain key constraints in several markets. In addition, DISCOMs often resist the large-scale migration of industrial consumers to open-access

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arrangement, because the relatively high tariffs they are subject to are an important source of cross-subsidisation for residential and agricultural consumers.

Outlook

Open access is expected to be a main driver of about 20% of utility-scale solar PV and wind capacity additions in India by 2030. Continued market expansion will depend on further alignment of state regulations with the GEOA framework, improvements in DISCOM financial health and expansion of transmission infrastructure. The market is also starting to shift towards hybrid renewable projects combining solar PV, wind and storage to provide more fitting supply profiles for industrial consumers. Large-scale data centres are expected to become an increasingly important source of demand for such load-matching renewable power.

In 2026, SECI announced plans to introduce demand-aggregation renewable energy tenders and assess demand for virtual PPAs. The proposed model would aggregate renewable electricity demand from multiple commercial and industrial consumers before launching tenders, potentially improving procurement efficiency and reducing the risk of undersubscribed auctions. The initiative could also facilitate access to renewable procurement for smaller consumers that individually lack sufficient scale to contract renewable power directly. In addition, the model may support further growth in hybrid and firm renewable energy supply solutions tailored to corporate consumers.

Offshore wind

India has identified offshore wind as a potentially important component of its long-term renewable energy strategy, particularly in the context of rising electricity demand, land constraints in high-resource regions and the need for diversified renewable generation sources. Although no commercial-scale offshore wind projects have yet been commissioned, the government has progressively developed the regulatory and policy framework required to support future deployment.

Policy schemes

The first major policy milestone was the notification of the National Offshore Wind Energy Policy in 2015. The policy established the legal and institutional framework for offshore wind development within India's exclusive economic zone, designated the Ministry of New and Renewable Energy as the nodal ministry and assigned the National Institute of Wind Energy responsibility for resource assessment and site identification. India in 2018 announced offshore wind targets of 5 GW by 2022 and 30 GW by 2030, focusing primarily on Gujarat and Tamil Nadu, where offshore

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wind resources are strongest and existing wind industry and manufacturing ecosystems are already established. The National Institute of Wind Energy estimated technical offshore wind potential of approximately 36 GW off the coast of Gujarat and nearly 35 GW off Tamil Nadu, while international co-operation initiatives such as the Facilitating Offshore Wind Energy in India programme supported early resource mapping and project preparation activities.

A major policy development occurred in 2023 with the release of the Strategy for Establishment of Offshore Wind Energy Projects, which marked a transition from resource assessment towards implementation-oriented support mechanisms. The strategy introduced three development models:

- **Model A:** Government-supported projects supplying electricity to DISCOMs through competitive bidding with support from the Viability Gap Funding scheme.
- **Model B:** Privately developed projects supplying electricity through captive use, open-access or bilateral contracts without central financial support.
- **Model C:** Developer-identified offshore sites allocated through future seabed leasing mechanisms.

The strategy was complemented by the Offshore Wind Energy Lease Rules, announced in 2023, which clarified seabed leasing procedures and developer obligations, improving regulatory certainty for future projects.

In 2024, the Union Cabinet strengthened financial support for offshore wind by approving the Viability Gap Funding scheme, with a total allocation of INR 74.5 billion (USD 0.9 billion). Of this, INR 68.5 billion supports the first 1 GW of offshore wind projects in Gujarat and Tamil Nadu, while INR 6 billion is allocated for port infrastructure upgrades needed for installation and logistics. Port modernisation is critical, as India currently lacks specialised heavy-lift and assembly infrastructure for offshore turbine installation and maintenance.

Under Model A, the maximum Viability Gap Funding support is INR 81.28 million/MW (about USD 0.95 million/MW), estimated to reduce offshore wind generation costs by around USD 35–40/MWh. In parallel, the government has begun offshore wind measurements using lidar systems, transmission planning studies and port modernisation efforts. Offshore wind development is increasingly linked to broader industrial objectives, including domestic manufacturing, maritime infrastructure development and future green hydrogen production.

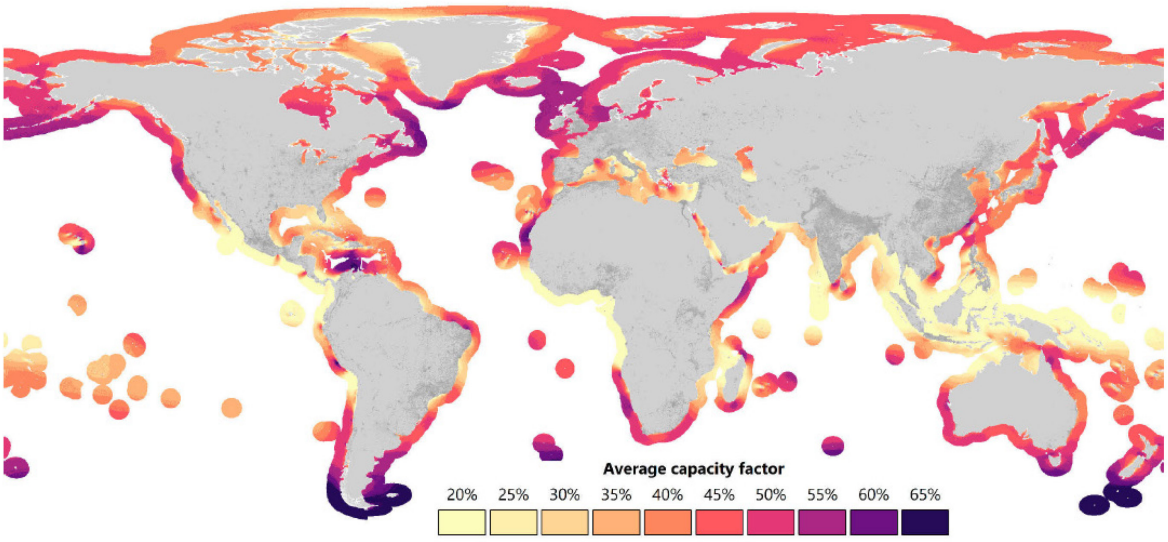
Challenges

Developer interest, however, remained weaker than initially expected because of concerns regarding project economics and risk allocation. During 2024-2025, SECI launched India’s first round of offshore wind seabed lease allocation for

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4 GW in Tamil Nadu, alongside Viability Gap Funding-supported 500 MW procurement round focused on Gujarat. However, both processes failed to attract sufficient developer participation, leading to the cancellation or postponement of proposed tenders and lease allocation rounds.

Average simulated capacity factors for offshore wind worldwide



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Note: Inland dots depict population density of more than 500, 2 000 and 8 000 people per km^2 with darker shades of grey.
Source: Reproduced from IEA (2019), Offshore Wind Outlook 2019.

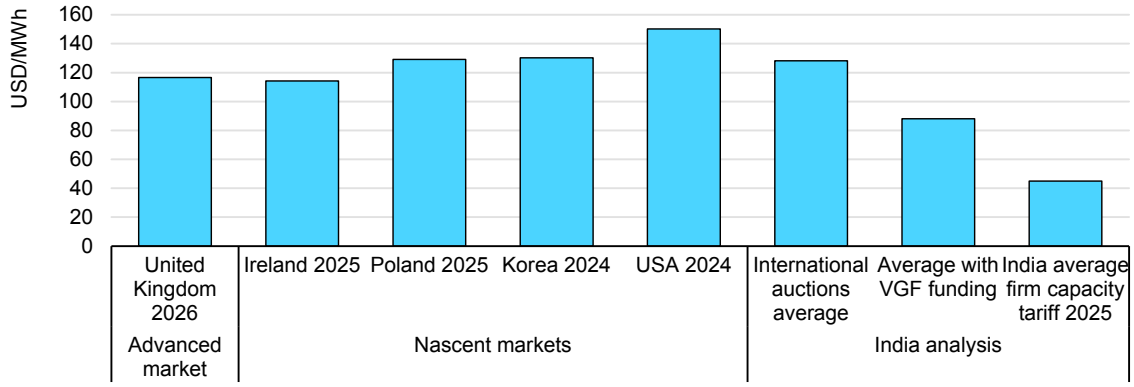
Offshore wind projects in India face significantly higher costs than competing renewable technologies, long development timelines, complex permitting procedures and infrastructure gaps. Uncertainty regarding responsibilities for offshore transmission development and future cost allocation mechanisms also continues to affect project economics and bankability. In addition, offshore wind conditions along much of India's coastline are generally weaker than in leading offshore wind markets such as the North Sea, resulting in lower expected capacity factors and higher electricity generation costs. Resource conditions are strongest off the coast of Tamil Nadu, comparable to the North Sea, while wind conditions in several other identified offshore areas are comparatively moderate by international offshore wind standards, reducing project competitiveness.

The competitiveness challenge is amplified by India's exceptionally low renewable energy costs. In 2025, average auction tariffs for utility-scale solar PV projects remained below USD 30/MWh, while onshore wind and hybrid or firm renewable energy systems were typically contracted at around USD 45/MWh. By contrast, auction prices observed during the past 2 years in emerging offshore wind markets such as Ireland, Korea and the United States generally ranged between USD 115/MWh and USD 150/MWh. Even in the United Kingdom, one of the

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world's most mature offshore wind markets, the latest Contracts for Difference allocation round (Round 7) resulted in offshore wind strike prices of approximately USD 115/MWh. This large cost differential significantly complicates offshore wind deployment in India's highly price-sensitive electricity market, even after accounting for planned Viability Gap Funding support.

Offshore wind auction results: average, potential tariff with VGF funding and average firm capacity tariff in 2025 auction in India



IEA. CC BY 4.0.

Note: VGF = Viability Gap Funding.
Source: IEA analysis based on IEA renewable power auctions global database.

In response, the government decided to conduct additional technical, commercial and regulatory assessments in co-operation with international partners and industry stakeholders to refine the policy framework and develop more effective support mechanisms for future auction rounds. Future policy adjustments are expected to focus on improving risk allocation, strengthening infrastructure planning and enhancing the commercial viability of initial projects.

Outlook

Concentrating initial deployment in the highest-quality resource areas in Tamil Nadu could also help improve project economics, accelerate industry development and demonstrate the commercial viability of offshore wind in India before broader expansion into lower-resource regions. Over the longer term, offshore wind may become increasingly relevant for supplying electricity to coastal industrial clusters and future green hydrogen production facilities. Nevertheless, taking into consideration the typical 5- to 10-year project lead times for offshore wind, commercial-scale deployment is not expected before 2030.

DISCOMs financial situation

Utility companies (DISCOMs) play a central role in India's electricity sector as the primary purchasers of electricity from generators and as suppliers to final

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consumers. As the main counterparties for renewable energy PPAs, their financial health directly affects renewable procurement, project bankability and investment conditions. It also influences the ability to invest in grid modernisation and the flexibility required for the integration of VRE sources.

Context

Historically, DISCOM finances deteriorated because electricity tariffs often remained below the actual cost of supply. Highly subsidised or free electricity supply for agriculture, high transmission losses, delayed tariff revisions, electricity theft, and weak billing and collection systems contributed to persistent operational deficits. Delays in reimbursement of government subsidies further weakened cash flows in several states.

In addition, many DISCOMs remain exposed to long-term fixed-cost payment obligations under coal-fired PPAs, including for plants operating at relatively low utilisation rates. These relatively inflexible contractual arrangements increasingly conflict with the growing share of lower-cost renewable generation in the electricity mix, creating additional financial pressure as DISCOMs continue paying fixed charges for thermal capacity while simultaneously procuring increasing volumes of renewable electricity.

Financially weak DISCOMs often delay signing renewable PPAs, postpone procurement decisions or seek tariff renegotiations because of concerns regarding future payment obligations. Delayed payments to renewable energy generators increase financing costs and weaken investor confidence, particularly for smaller project developers. Financially stressed DISCOMs have also occasionally resorted to renewable energy curtailment or delayed commissioning approvals. Although such interventions remain relatively limited compared with the overall scale of deployment, they have contributed to regulatory uncertainty in some states and increased perceived investment risks. During the 2010s, delays in signing PPAs and payments to generators increased financing costs and weakened investor confidence, leading to growing undersubscription of renewable energy auctions.

The financial condition of DISCOMs also influences the pace of renewable integration because financially constrained utilities may underinvest in the grid modernisation, smart metering, forecasting systems and distribution infrastructure required to accommodate growing shares of solar PV and wind generation. Improving DISCOM financial health will therefore become increasingly important as renewable penetration rises and power systems require greater operational flexibility and digitalisation.

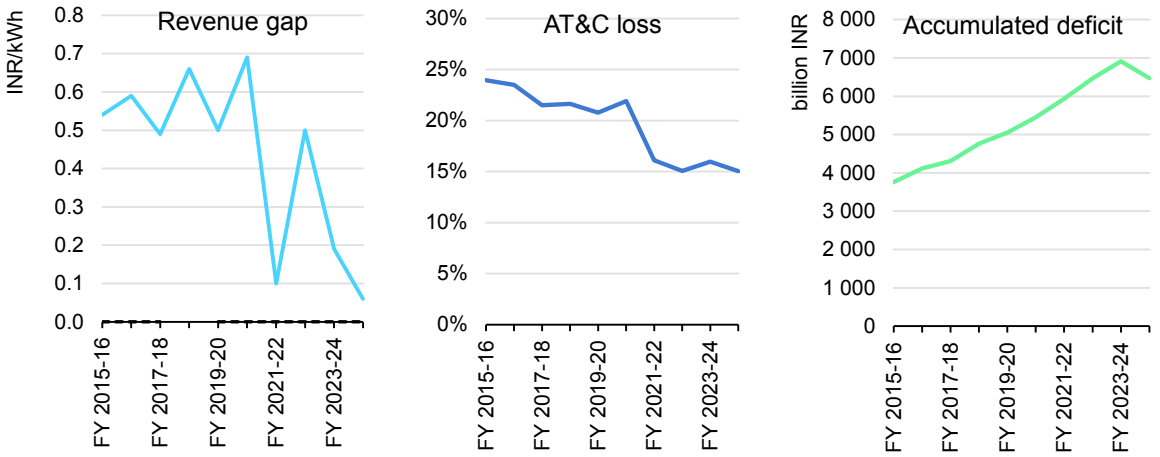
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Policy schemes

The government subsequently introduced multiple reform programmes aimed at improving operational efficiency and restructuring utility debt. The largest intervention was the Ujwal DISCOM Assurance Yojana, launched in 2015, under which state governments took over 75% of outstanding DISCOM debt, exceeding INR 4 trillion (USD 43 billion). The programme introduced operational reform targets related to aggregate technical and commercial (AT&C) loss reduction, tariff rationalisation and smart metering. In 2021, the government launched the Revamped Distribution Sector Scheme, with an approved outlay of approximately INR 3 trillion, focusing on prepaid smart meter deployment, distribution infrastructure upgrades and reduction of AT&C losses and average cost of supply–average revenue realised gaps. In response to undersubscription for renewable energy auctions, central agencies such as SECI and NTPC assumed responsibility for organising auctions and acting as intermediary power procurers.

The financial and operational performance of DISCOMs has improved significantly during the past decade, although challenges remain substantial. AT&C losses – which measure electricity losses resulting from technical inefficiencies, theft, unmetered consumption and poor bill collection – declined from around 23-24% in FY 2015-16 to approximately 15% in FY 2024-25.

Power utility companies average operational indicators, India, 2015-2025



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Note: Revenue gap = average cost of supply–average revenue realised, calculated as a gap on energy sold basis excluding regulatory income and revenue grant under UDAY for loan takeover.

Sources: IEA analysis based on data from India, Ministry of Power, Power Finance Corporation and NITI Aayog.

The average cost of supply–average revenue realised gap – which measures the difference between the average cost of supplying electricity and the average revenue recovered from consumers – also narrowed considerably, declining from around INR 0.54/kWh to INR 0.06/kWh in the same period. However, this

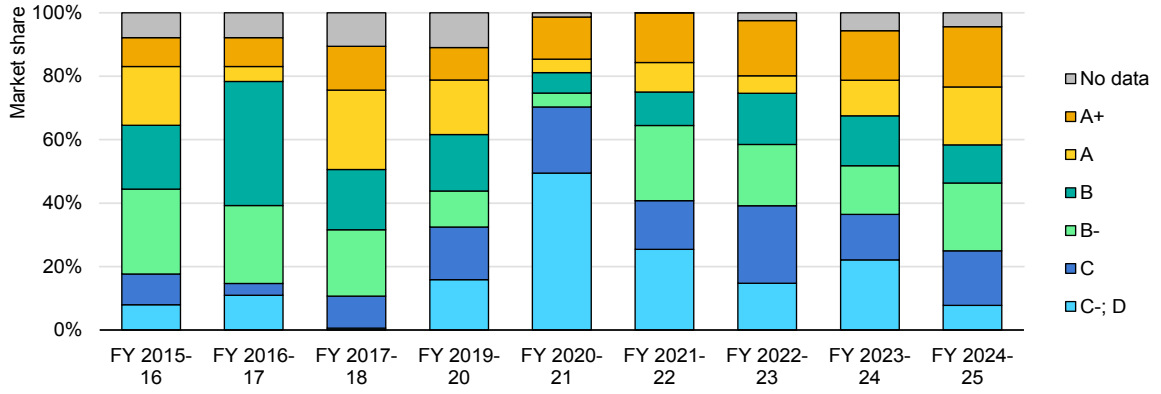
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improvement partly reflects accounting adjustments, subsidy support, takeover of losses by state governments and lower financing costs following debt restructuring measures rather than a complete resolution of underlying structural challenges.

Challenges

The Power Finance Corporation integrated rating exercise evaluates utilities based on operational and financial indicators, payment discipline, and subsidy accounting. Each company is assigned a grade raging from A+ (indicating the best performance) to D (indicating significant challenges). In FY 2024-25, DISCOMs responsible for almost 60% of electricity sales received ratings below A, while utilities accounting for approximately one-quarter of total electricity sales received the lowest ratings of C, C- or D. Nevertheless, these ratings represent a substantial improvement compared with FY 2020-21, when disruptions related to the Covid-19 pandemic caused utilities representing almost 70% of electricity sales to fall into the lowest rating categories.

Share of electricity sales by power utility company rating, India, 2015-2025



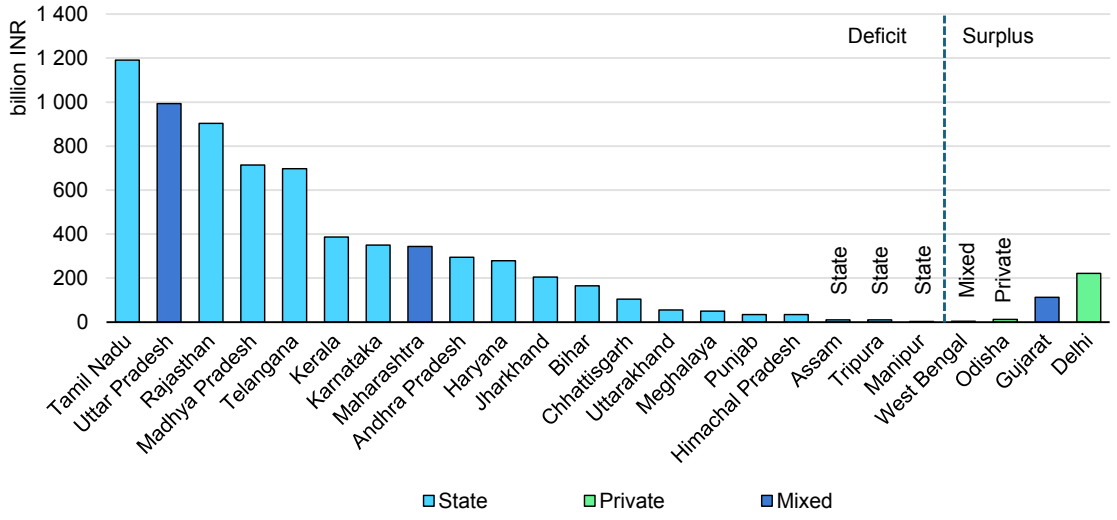
IEA. CC BY 4.0.

Sources: IEA analysis based on Power Finance Corporation and NITI Aayog.

Despite this progress, financial conditions remain weak compared with international standards. Even after recent improvements, India's average AT&C losses remain substantially higher than those typically observed in advanced electricity markets, where losses are often below 10%. In addition, the sector continues to carry a large accumulated deficit. By FY 2024-25, accumulated DISCOM losses remained around INR 6.47 trillion (approximately USD 70 billion), equivalent to roughly 1.8% of India's GDP. Although reported accumulated deficit declined for the first time in many years during FY 2024-25, the debt burden continues to constrain investment capacity and financial flexibility across much of the sector.

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Accumulated deficit or surplus and power utility companies' ownership, by state, India, 31 March 2025



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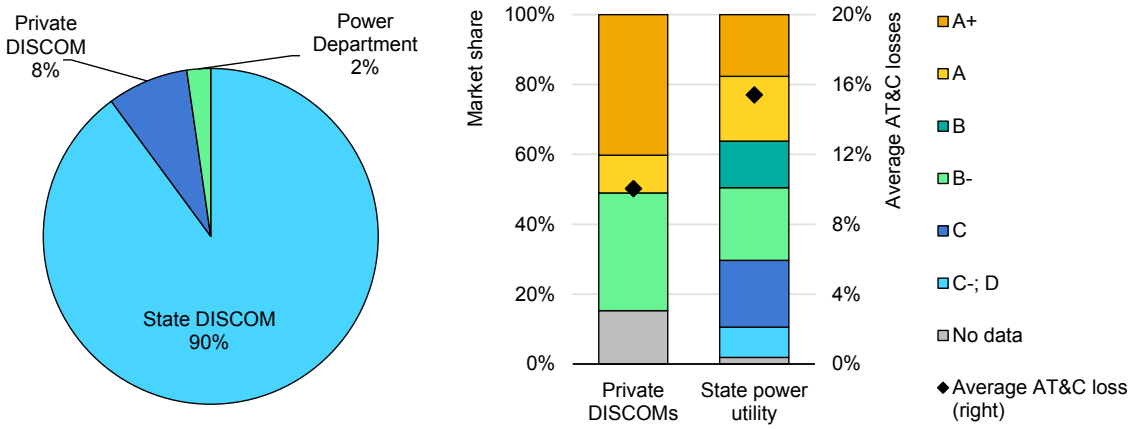
Notes: Privately owned DISCOMs' electricity sales share in mixed states. Uttar Pradesh, 3%; Maharashtra, 6%, West Bengal,18%; Gujarat, 10%.
Sources: IEA analysis based on data from Power Finance Corporation and NITI Aayog.

Financial performance also varies significantly between states. As of March 2025, approximately two-thirds of accumulated losses were concentrated in only five states: Tamil Nadu, Uttar Pradesh, Rajasthan, Madhya Pradesh and Telangana. By contrast, only a small number of states recorded accumulated surpluses, all of which had relatively large shares of private sector participation in electricity distribution.

India's distribution sector remains dominated by state-owned entities. More than 90% of electricity sales are supplied by state-owned DISCOMs and electricity departments; privately owned utilities account for less than 10% of total electricity sales. The operational performance of private DISCOMs has generally been stronger than that of state-owned utilities. Private utilities tend to report lower AT&C losses, stronger billing and collection performance, and better financial recovery indicators. Average AT&C losses among private DISCOMs are estimated at around 10%, compared with approximately 15% for state-owned utilities. In addition, around half of privately operated DISCOMs received ratings of A or A+ under the Power Finance Corporation integrated rating framework, and none received the lowest grades of C, C- or D. By contrast, around 30% of state-owned utilities fell into these lower rating categories. Private DISCOMs remain concentrated primarily in large urban and industrialised areas such as Delhi, Mumbai, Ahmedabad and Surat, where consumer density, billing efficiency and payment collection conditions are generally more favourable than in many rural and lower-income regions.

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Electricity sales market shares (left) and average ratings (right), by power utility company ownership, FY 2024-25



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Sources: IEA analysis based on data from Power Finance Corporation and NITI Aayog.

Outlook

Privatisation of electricity distribution could be a potential pathway for improving operational efficiency and financial discipline. However, India's experience with private participation remains relatively limited and concentrated in economically stronger urban markets with favourable consumer profiles and higher revenue collection potential. As a result, the extent to which the stronger performance indicators achieved by private DISCOMs can be replicated across financially weaker, rural or agriculture-dependent states remains uncertain.

The rapid expansion of competitively priced renewable energy creates an important opportunity for DISCOMs to reduce average power procurement costs and improve long-term financial performance. Utility-scale solar PV and hybrid renewable systems are already being contracted at tariffs below the average cost of coal-based electricity supply in many states. However, the ability of DISCOMs to fully benefit from lower-cost renewable generation will increasingly depend on addressing the challenge posed by inflexible long-term contracts with fossil fuel generators.

Consequently, tariff rationalisation, subsidy reform, improved governance, greater contractual flexibility and continued infrastructure modernisation are likely to remain necessary to achieve long-term financial sustainability across India's distribution sector and strengthen its ability to support large-scale renewable energy deployment and integration.

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System integration

Variable renewable energy integration phase assessment

Phase assessment framework

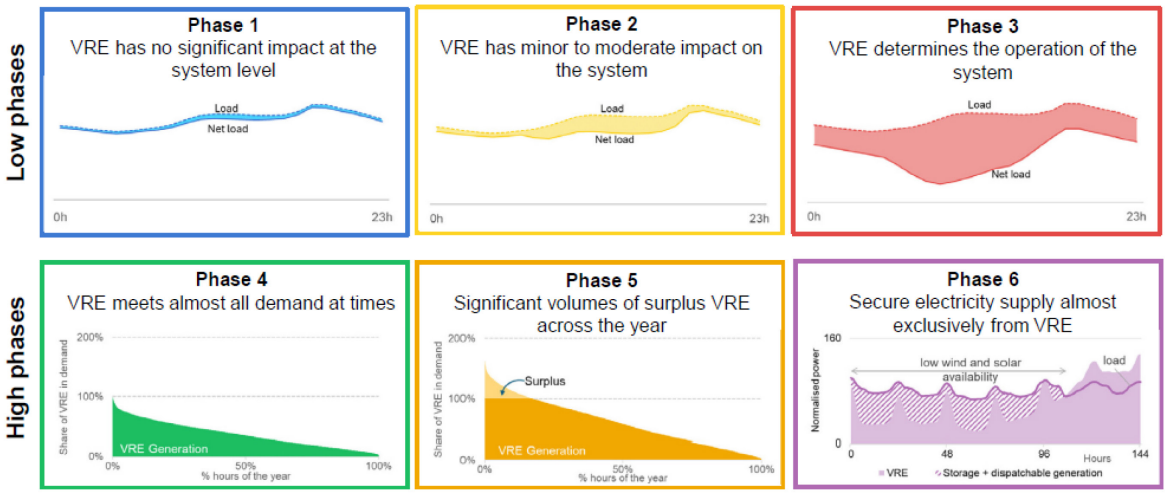
The IEA framework on phases of VRE integration provides a structured way to assess how solar PV and wind affect power system operation as their shares increase. The framework does not classify systems only by annual VRE share. Instead, it considers how VRE changes the operation of the system: the frequency of high instantaneous VRE shares, the difference between demand and net demand, ramping requirements, periods of surplus VRE, the need for flexibility, and the ability of the grid and conventional fleet to maintain secure operation. The framework is therefore well suited to India, where solar and wind deployment is geographically concentrated and the challenges faced by different regional grids may differ from those observed at the national level.

The framework distinguishes six phases of increasing system impact. In Phases 1-3, VRE has relatively low impacts on the power system, and most challenges can generally be addressed through targeted changes to existing assets, operating practices and regulatory arrangements. In Phases 4-6, VRE increasingly shapes system operation, requiring deeper changes in flexibility, grid operation, system services, and market or regulatory design. Phases 4-6 are considered high phases of VRE integration, where a more fundamental transformation of the power system is required.

The assessment process combines quantitative indicators with expert judgement. The quantitative part uses hourly demand and generation data to evaluate indicators such as VRE output relative to demand, net demand patterns, ramping requirements, minimum net demand periods, surplus indicators and the extent to which non-VRE generation is required to change its operation patterns. These indicators are used to identify whether the system is still mostly experiencing localised impacts, whether VRE is beginning to shape daily operation, or whether periods of very high instantaneous VRE output are already creating stability and flexibility challenges.

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IEA VRE integration framework phases



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Note: VRE = variable renewable energy.
Source: IEA (2024), Integrating Solar and Wind.

The classification should be read as a diagnostic tool rather than a precise engineering study. It helps identify the dominant type of integration challenge in each regional grid and the broad package of measures that should be prioritised. It does not replace detailed grid studies, operational security studies, protection studies or stability assessments. This distinction is particularly important for issues such as inertia, system strength and voltage stability, which require more granular operational and network data than an hourly phase assessment can provide.

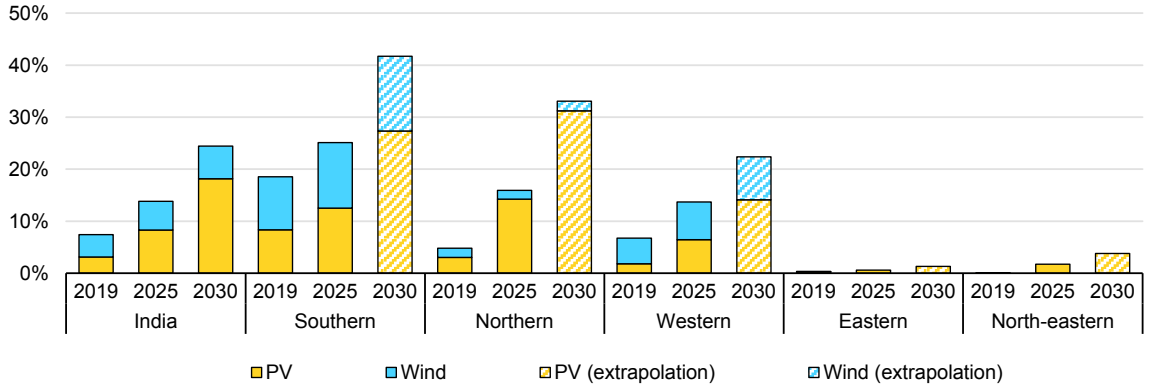
India's grid regions assessment

In India, the rapid expansion of VRE, namely solar PV and wind power, is fundamentally changing the operation of the electricity system. VRE penetration doubled over the past 5 years, increasing from 7% of electricity generation in 2019 to 14% in 2025, and is expected to reach approximately 26% by 2030[8]. Solar PV accounts for most of this growth, with its share of generation projected to rise from around 8% in 2025 to 19% in 2030. However, the deployment of VRE is not uniform across India, resulting in substantial regional differences in integration challenges.

[8] Forecasted VRE share in 2030 is a result of IEA modelling. According to the Report on Optimal Generation Mix 2030 from Central Electricity Authority, in FY 2029-30 solar PV and wind generation share is projected to reach 30%. The differences between the IEA forecast and Central Electricity Authority projections result from different modelling assumptions regarding the pace of renewable technologies deployment, total electricity demand and effective capacity utilization factors. IEA analysis assumes following average capacity utilization factors in 2030: solar PV = 18% (AC), onshore wind = 24%, hydropower = 38%, bioenergy = 41%.

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VRE generation share by India power grid region, 2019-2025



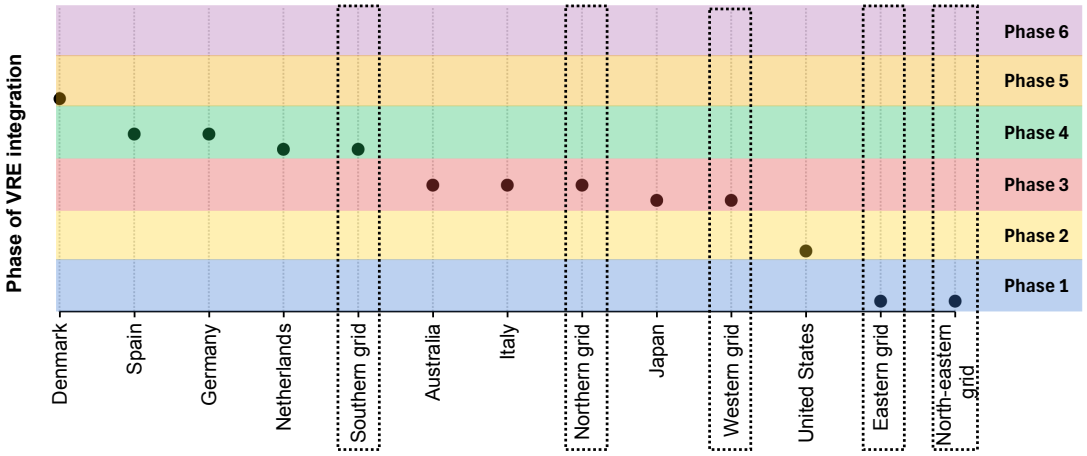
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Note: The estimation of regional VRE shares for 2030 is based on extrapolation of current deployment, without bottom-up deployment analysis.

Sources: IEA analysis based on data from NITI Aayog and the Central Electricity Authority.

Therefore, for India, the framework was applied at regional grid level rather than only at national level. This is important because the operational impacts of VRE depend on where solar and wind are connected, the shape of regional demand, the availability of flexible resources, and the strength of interconnections with neighbouring regions. A national average can hide concentrated integration challenges in regions with high solar and wind deployment.

Countries and India grid regions in phases of renewable integration, 2025



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The phase assessment shows that India's regional grids are not exposed to the same level of challenges in VRE integration. This variation reflects the uneven geography of solar and wind deployment and the differences in demand profiles, the availability of flexible resources and the strength of inter-regional exchanges. The regional view is therefore important: India may appear to be in a moderate phase of VRE integration at the national level, but some grids are already facing operational conditions associated with higher phases of integration.

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Southern region

The southern region, comprising wind-rich states such as Tamil Nadu, Karnataka and Andhra Pradesh, recorded VRE penetration of approximately 25% in 2025. The relatively balanced contribution of solar PV and wind generation helps moderate integration challenges by providing a more diversified generation profile. If current deployment trends continue, VRE penetration in the region could exceed 40% by 2030.

The southern grid appears to be the most advanced among the Indian regions assessed and may be entering Phase 4, the first of the advanced stages of VRE integration. In this phase, VRE no longer only affects ramping and dispatch; it can also dominate system operation during specific hours. Periods of very high solar and wind output may require the system to operate securely with lower levels of conventional generation online, increasing the importance of real-time operation, system services and stability management. Priority measures should therefore include additional transmission capacity, improved forecasting, storage, more flexible operation of the conventional fleet, demand response, clear curtailment protocols, and enhanced ancillary services.

The regional assessment may also mask more advanced challenges in individual states with high concentrations of solar or wind. In these areas, local grid conditions, including voltage control, congestion, system strength and the availability of reliability services, should be assessed in greater detail. High solar PV output may also put downward pressure on electricity prices during midday periods, strengthening the case for short-duration storage, demand shifting and other solutions that increase the use of low-cost renewable electricity when it is available.

Western region

The western region hosts the largest installed VRE capacity in India. However, because of the region's larger electricity demand and system size, VRE penetration only reached approximately 14% in 2025. The relatively balanced contribution of wind and solar PV facilitates integration and limits operational challenges compared with more solar-dominated systems. VRE penetration in the region is expected to increase to approximately 22% by 2030.

By 2025, the western grid appears to be in Phase 3, although the concentration of VRE generation in states such as Gujarat and Maharashtra may mean that some areas are already experiencing conditions closer to late Phase 3 or even Phase 4. This concentration can also create congestion on local transmission corridors before the wider regional system reaches more advanced phases of integration.

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Priority actions should therefore include core Phase 3 measures, such as improving VRE forecasting, moving scheduling and dispatch closer to real time, reinforcing transmission corridors from renewable-rich areas, and enabling more flexible operation of the thermal fleet. The region should also start preparing for the higher instantaneous VRE shares more typical of Phase 4. These measures include storage, demand-side resources, enhanced system services and clearer operating protocols for periods of high VRE output. These measures should be implemented ahead of need, rather than only in response to curtailment or congestion.

Northern region

The northern region is experiencing the fastest increase in VRE penetration, driven primarily by rapid solar PV deployment in Rajasthan. VRE generation tripled during the past 5 years to approximately 16% of regional electricity supply and could double again by 2030. Because most of this growth comes from solar PV, integration challenges are expected to increase more rapidly than in regions with a more balanced technology mix.

The northern grid's assessment is strongly influenced by rapid solar PV growth, particularly in Rajasthan. Although the region as a whole appears in an earlier phase than the southern grid, renewable-rich areas may already face more advanced local challenges, including transmission congestion, ramping needs and periods of high solar output.

Large seasonal and daily variations in demand can further accentuate these challenges as solar deployment increases. Priorities for this region should include improving the visibility of distributed and utility-scale solar, strengthening forecasting and dispatch tools, reinforcing transmission from renewable-rich areas, and ensuring that storage, new demand growth, and inter-regional transfers can support VRE integration.

Eastern grid

The eastern grid appears to be at an earlier phase of VRE integration than the southern and western grids. VRE currently has a limited effect on system-wide operation, while thermal generation continues to dominate the regional mix. This gives the region time to prepare, but foundational measures should not be delayed until VRE begins to affect dispatch more visibly.

Priorities include updating technical requirements for new VRE plants, improving operational visibility, planning grid reinforcement ahead of new renewable energy zones, strengthening dispatch practices, and increasing the flexibility of the remaining thermal fleet.

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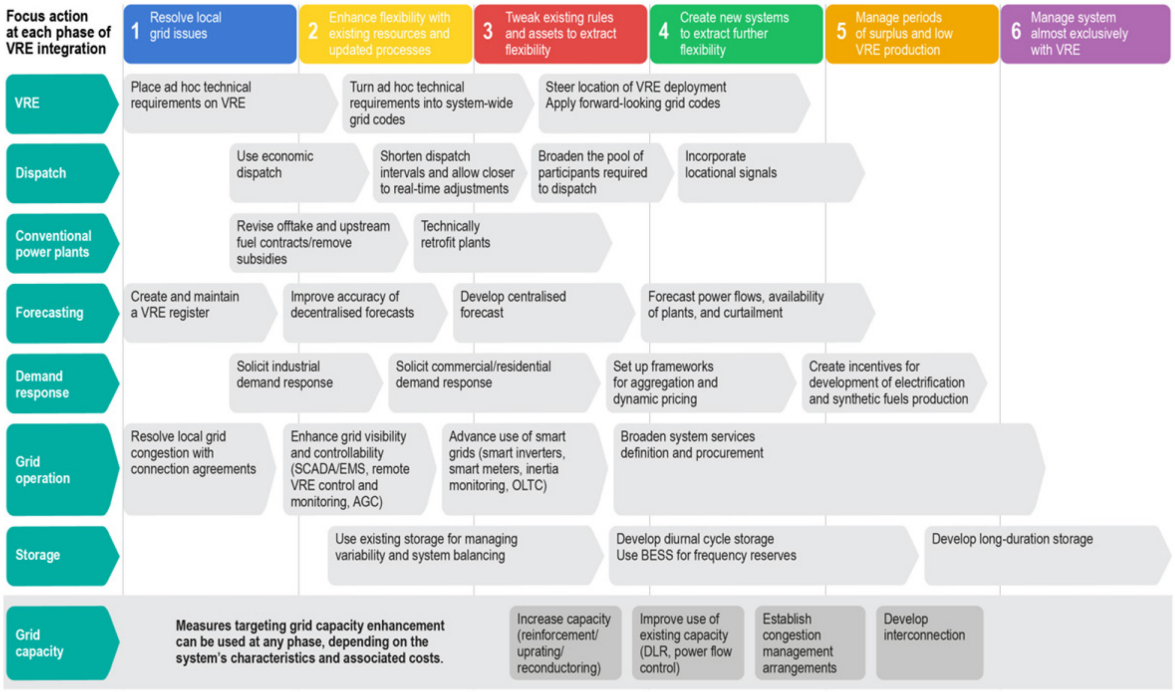
North-eastern grid

The north-eastern grid also remains at an early phase of VRE integration. The immediate challenges are less about managing high VRE shares and more about preparing the system for future deployment. The focus should therefore be on increasing VRE capacity in parallel with targeted reinforcement of internal transmission corridors, stronger grid monitoring and control, and sufficient flexible resources, including hydropower where available and flexible thermal generation.

VRE integration measures

With the increasing share of wind and solar PV, India's electricity system is expected to face growing integration challenges. However, international experience demonstrates that high shares of VRE can be integrated reliably and cost-effectively through a combination of technical, operational, regulatory and market-based measures.

VRE integration measures from recent decades of global experience organised by phase



IEA. CC BY 4.0.

Notes: AGC = automatic generation control; BESS = battery energy storage system; DLR = dynamic line rating; EMS = energy management systems; OLTC = on-load tap changers; SCADA = supervisory control and data acquisition; VRE = variable renewable energy. The proposed set of focus actions by phase represents a timeline of priorities, though specific system contexts may require adjustments to address their particular challenges.

Source: IEA (2025), Integrating Solar and Wind in Southeast Asia.

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The most immediate challenge is the management of net load variability, defined as the electricity demand after accounting for wind and solar generation. As solar PV deployment expands, midday net demand declines and evening demand ramps become steeper, increasing the need for flexible resources capable of responding quickly to changing system conditions.

Improving the flexibility of coal-fired power plants

Coal-fired power plants continue to provide the majority of electricity generation in India and increasingly need to operate more flexibly to accommodate variable renewable output. Many plants were designed for baseload operation and have limited capability to ramp output rapidly or operate efficiently at low utilisation rates. Flexible operation should also be supported by PPA frameworks, which currently often include high fixed-capacity payments and provide limited incentives for flexible dispatch. Improving coal plant flexibility has therefore become an important component of India's renewable integration strategy. In 2023, the Central Electricity Authority issued Flexible Operation Regulations, requiring coal power plants to reach the capability of operating at 40% minimum load, and to increase their ramp-rates; however, implementation remains uneven, particularly among state-owned plants.

Accelerating energy storage deployment

Storage deployment is another key solution. Battery energy storage systems and PSH can absorb excess solar generation during periods of high output and supply electricity during evening demand peaks. India has already begun procuring renewable energy projects combined with storage through hybrid and firm capacity auctions. More than 14 GW of stand-alone battery storage capacity, predominantly with two-hour duration, was awarded through competitive tenders during 2024-25, and 70-80 GW could be installed by 2035 according to the Central Electricity Authority Long-Term National Resource Adequacy Plan. In 2025, the Central Electricity Authority recommended that future solar tenders incorporate co-located battery storage, with storage capacity equivalent to at least 10% of solar capacity and a two-hour duration. In addition, more than 16 GW of pumped storage capacity is currently under construction with a target of installing 100 GW by 2035 set in the Central Electricity Authority Roadmap to 100 GW of Hydro Pumped Storage Projects by 2035-36. Together, these investments are expected to play an increasingly important role in maintaining system reliability and reducing renewable curtailment as VRE penetration rises.

Expanding ancillary service markets

Another important area of reform is the development of ancillary services and balancing markets. As the share of variable renewable generation increases,

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maintaining frequency stability, operating reserves and other system services becomes increasingly important. Historically, these services were provided primarily by conventional generators through administrative arrangements. In recent years, India has progressively expanded market-based mechanisms to support system flexibility and renewable energy integration. Key developments include the introduction of the real-time market, implementation of the Security Constrained Economic Dispatch framework, successive reforms to ancillary services regulations and the gradual transition towards market-based procurement of balancing reserves. Together with improved forecasting and scheduling requirements for wind and solar projects, these reforms enhance the ability of system operators to manage short-term fluctuations in renewable generation while reducing overall system costs. As VRE penetration rises further, ancillary service markets should play an increasingly important role in unlocking flexibility from a broader range of resources, including storage, demand response and renewable power plants.

Improving modelling and forecasting capaciblities

More accurate weather forecasting, including high-resolution modelling of cloud cover, solar irradiation and wind conditions, can significantly improve renewable generation forecasts and reduce system balancing requirements. In addition, advanced digital modelling and power system planning tools can support investment decisions, optimise system operation in real time and help identify future transmission, storage and flexibility needs.

Developing grids

The concentration of renewables deployment in a limited number of states requires continued expansion of inter-state transmission infrastructure and efficient operation of power markets to facilitate electricity transfers across regions. The Green Energy Corridor programme and associated transmission investments have already played an important role in reducing congestion and enabling renewable integration, but additional investments will be required as renewable deployment accelerates. The Transmission Plan for Integration of over 900 GW Non-Fossil Fuel Capacity by 2035-36, published in March 2026 by the Central Electricity Authority, lays out long-term grid development plans to accommodate projected VRE capacity of over 660 GW.

Managing the demand side

Demand-side flexibility is also expected to become increasingly important. Industrial demand response, agricultural load management, electric vehicle charging and smart metering can help align electricity consumption more closely with periods of high renewable generation. Although deployment remains at an

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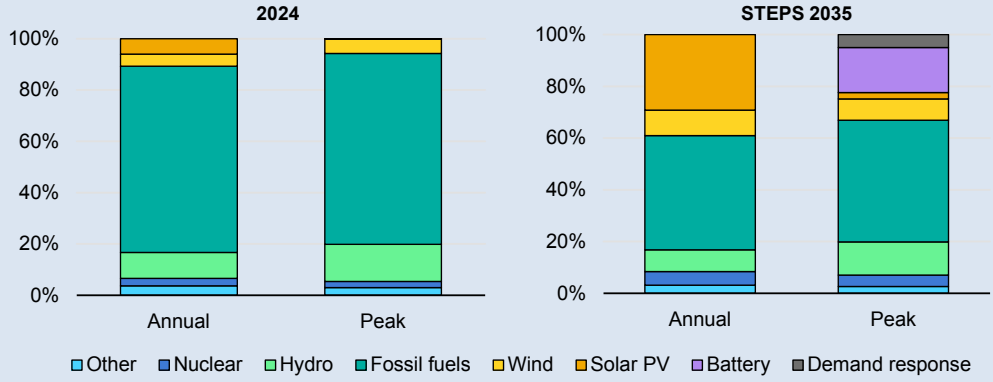
early stage, these measures could become increasingly valuable as renewable penetration continues to increase and system flexibility requirements become more pronounced. As of September 2026, four states – Maharashtra, Karnataka, Rajasthan and Assam – have introduced dedicated regulatory frameworks for demand flexibility or demand response. Maharashtra, Karnataka and Rajasthan have gone further by establishing quantified Demand Flexibility Portfolio Obligations for distribution utilities, requiring them to progressively make a specified share of peak demand available as flexible demand.

Outlook for battery storage in India

Battery storage deployment in India is set to accelerate rapidly over the second half of this decade, driven by rising power system flexibility needs, declining costs and robust policy support. At the beginning of 2026, installed utility-scale battery storage capacity was only 350 MW, of which 280 MW came online in 2025. However, deployment is expected to pick up markedly, with more than 1 GW of capacity expected to come online in 2026 and annual utility-scale additions approaching 6-8 GW by 2030.

Battery storage is particularly well suited to India's evolving power system. As solar PV accounts for a growing share of electricity supply, batteries can shift output from periods of high daytime solar generation into the late afternoon and night, when demand typically peaks. Beyond short-duration flexibility, battery storage also increasingly provides capacity adequacy.

Annual electricity supply mix and peak residual load hours India in 2024 and in 2035 in STEPS scenario



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Notes: *Other* includes bioenergy, geothermal and other renewables. *Hydro* includes reservoir, run-of-river and pumped storage. *Peak residual load* is defined as the top 100 hours of the residual load (i.e. demand less generation by variable renewables) over a year. Data for 2024 are presented, as these were the most recent data available at the time of writing.

Source: IEA (2025), World Energy Outlook 2025.

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By 2035 in the World Energy Outlook 2025's Stated Policies Scenario (STEPS), batteries supply nearly a quarter of the electricity needed in critical hours when peak electricity demand coincides with low renewable electricity generation. Batteries can also provide fast-response balancing, ancillary services and congestion management, helping maintain grid stability over timescales from seconds to several hours. These functions become more valuable as variable renewables expand, particularly in large renewable energy zones where solar deployment is concentrated and local networks can be constrained, such as Gujarat, Rajasthan, Karnataka and Maharashtra.

While the amount of battery storage projects announced and tendered is growing rapidly, completed projects are just starting to gain momentum. In mid-2025, around 12.5 GW of utility-scale battery storage projects were under tender, with a further 3.3 GW in the pipeline. By January 2026, the development pipeline had reached around 111 GWh, equivalent to roughly 35 GW of capacity. Large-scale projects are now beginning to emerge. By May 2026, a cumulative 3.4 GWh of battery storage had been commissioned in Khavda, Gujarat, linked to one of the world's largest renewable energy developments.

India's national planning envisages a much larger role for battery storage over the next decade. The National Electricity Plan sees battery storage capacity rising to nearly 9 GW by 2026-27 and almost 50 GW by 2031-32, alongside a broader increase in non-fossil capacity consistent with India's target of around 500 GW of non-fossil capacity by 2029-30.

Policy support for battery storage has strengthened in recent years. India's 2018 Wind-Solar Hybrid Policy provided an early framework for hybrid renewable projects, with battery storage used to reduce variability and support firm supply. Dedicated storage procurement followed: In March 2022 India issued guidelines for the procurement and use of battery storage as a generation, transmission and distribution asset, including for ancillary services, and in April 2022 SECI launched the country's first-of-its-kind 500 MW/1 000 MWh stand-alone battery storage tender. Storage has also progressively been embedded in renewable procurement through hybrid, round-the-clock, peak supply and firm dispatchable renewable power tenders. Dedicated guidelines for firm and dispatchable renewable power with storage were issued in June 2023.

Growth in battery storage projects has also been supported by the Energy Storage Obligation, established in July 2022, which requires distribution companies and certain open-access and captive consumers to meet a rising share of electricity consumption from renewable energy supplied with or through storage. The obligation increases from 1% of electricity consumption in FY 2023-24 to 4% by FY 2029-30, with at least 85% of stored electricity required to originate from

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renewable sources. Financial support has expanded as well: India first approved a viability gap funding scheme for battery storage in September 2023, covering up to 40% of a project's capital cost. At first targeting only 4 GWh of projects, the initial funding envelope was later increased to 13.2 GWh, and by June 2025 the Ministry of Power had approved a further 30 GWh scheme. India has also extended a waiver of inter-state transmission system charges for storage projects until 30 June 2028, benefiting pumped storage projects awarded and battery storage projects commissioned before that date. Falling costs – battery costs have come down globally by more than 90% since 2010 – have reinforced these policy measures by improving the economics of projects and by allowing public funding to support a larger volume of capacity than initially envisaged.

India's reliance on long-term power procurement is shaping the business models for battery storage. Most electricity is procured by distribution companies through long-term contracts, so contract-based procurement remains central to battery storage deployment. Stand-alone battery storage projects are typically procured as storage assets, remunerated through capacity or availability payments, and can be located where they provide the greatest system value, including peak supply, balancing, congestion management and ancillary services. Co-located projects pair batteries with solar PV, wind or hybrid renewable generation, usually under renewable PPAs or integrated tariff structures, to shift output into higher-value periods, meet peak or firm supply obligations and reduce curtailment risk. Higher penalties for deviations between scheduled and actual renewable generation could further increase the value of storage in firming output and managing grid stability.

The main challenge for India's battery storage market is converting tendered projects into operational projects. As of January 2026, around 27.3 GWh of the 111 GWh tendered pipeline had been delayed by more than a year, remained unsold or had been cancelled after contracts had been awarded. Some of this reflects normal development timelines, as projects can take up to 2 years from award to commissioning, but it also points to practical bottlenecks around financing, grid connection, equipment procurement and project delivery.

Improved auction and contract design, accelerated permitting and faster grid connection are critical to converting India's battery storage pipeline into operating capacity. Tenders need to discourage bids that are too low to deliver, and contracts should provide reliable revenues and reflect the value of the different services that batteries can provide. Permitting and grid connection processes also need to keep pace with the pipeline, so projects with awarded contracts can secure sites, approvals and network access without long delays. These steps will determine whether India can successfully scale annual deployment to multiple gigawatts.

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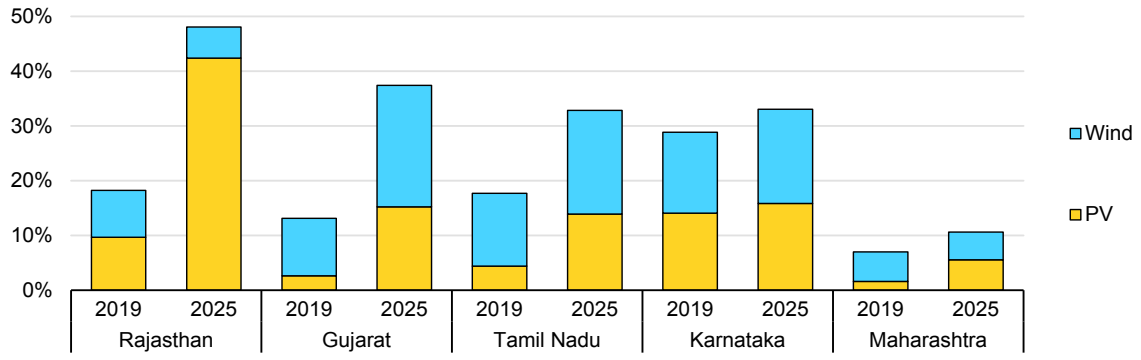
VRE generation curtailment

State-level VRE penetration

In addition to system-wide integration challenges associated with rising shares of VRE, India faces increasing geographical concentration of solar PV and wind deployment. Renewable capacity additions have been heavily concentrated in five states – Rajasthan, Gujarat, Tamil Nadu, Karnataka and Maharashtra – which together account for the majority of installed solar PV and wind capacity. While this concentration allows developers to benefit from superior renewable resources and existing infrastructure, it also increases local integration challenges and the risk of renewable energy curtailment.

VRE penetration has increased rapidly in these states over the past 5 years. In Rajasthan, the share of solar PV and wind generation in electricity supply increased by a factor of 2.6 to almost 50% in 2025, with around 90% of VRE generation coming from solar PV. In Gujarat, VRE penetration tripled to exceed 35%, while in Tamil Nadu it doubled to around one-third of generation. Karnataka reached a similar level, although growth occurred more gradually. These penetration levels are comparable to those observed in some of the world's most advanced VRE markets, including Germany, Spain and the United Kingdom.

VRE generation share by state, India, 2019-2025



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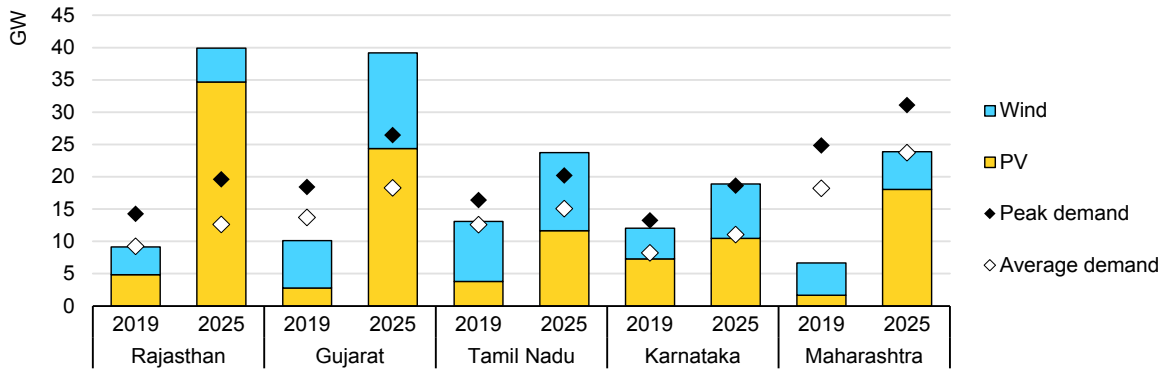
Sources: IEA analysis based on data from NITI Aayog and the Central Electricity Authority.

The scale of the integration challenge is further illustrated by the relationship between renewable capacity and electricity demand. In Rajasthan, installed solar PV and wind capacity exceeded peak demand by a factor of two in 2025 and was approximately three times larger than average demand. Gujarat exhibits a similar pattern, while installed VRE capacity exceeded peak demand by around 50% in

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Tamil Nadu. During periods of high renewable output, these states increasingly depend on transmission infrastructure to export surplus electricity to neighbouring regions.

PV and wind installed capacity (AC) and average and peak power demand, by state, India, 2019-2025



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Sources: IEA analysis based on data from NITI Aayog, the Central Electricity Authority and Grid-India.

Estimated curtailment

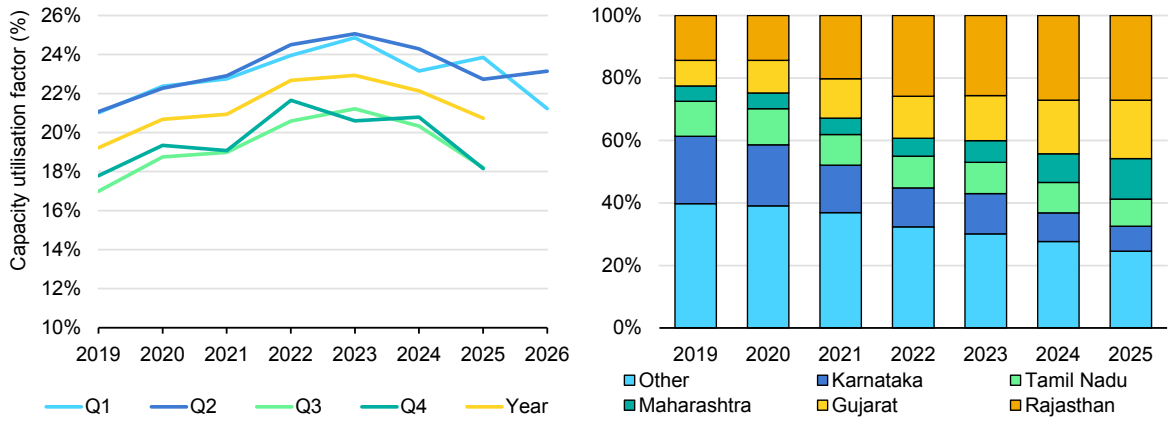
Growing integration constraints are also visible in the use of India's solar PV fleet. Between 2020 and 2023, the average capacity utilisation factor[9] of solar PV projects increased from about 19.2% to 22.9%, as installations became increasingly concentrated in Rajasthan and Gujarat – the Indian states with the highest solar irradiation. Since 2024, however, capacity utilisation started to decline, reaching 20.7% in 2025, despite further increase in capacity share installed in these two states, which together accounted for more than 45% of national solar PV capacity that year.

While weather conditions and project characteristics also influence utilisation rates, the decline suggests that curtailment and other integration constraints are becoming increasingly important. If the difference were attributed entirely to curtailment, there would have been about 15 TWh[10] of forgone solar PV generation in 2025, equivalent to 10% of potential solar output. Although actual curtailment levels are likely lower, the trend highlights growing pressure on the power system to absorb the rapidly expanding renewable generation.

[9] Capacity utilization factor calculation has been based on reported solar PV generation divided by installed capacity of ground-mounted solar PV systems.
[10] Potential electricity generation curtailment has been calculated based on comparison of actual monthly capacity utilization factors in 2025 and an average from years 2022-2024.

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Solar PV: average quarterly capacity utilisation factor (left) and state share of installed capacity (right), India, 2019-2026



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Note: Capacity factors calculated based on reported monthly electricity generation and installed capacity of ground-mounted solar PV systems.
Source: IEA analysis based on data from NITI Aayog and the Central Electricity Authority.

The challenge is amplified by the increasing dominance of solar PV in India's renewable portfolio. Solar generation is highly correlated across neighbouring regions, creating large midday surpluses followed by steep evening ramps. Unlike wind generation, which is generally more geographically and temporally dispersed, solar PV requires greater flexibility from transmission networks, storage facilities, thermal power plants and demand-side resources.

Without sufficient investments in flexibility, curtailment risks are likely to increase further during the second half of the decade. Current deployment trends imply continued concentration of utility-scale solar PV in Rajasthan and Gujarat, where renewable generation is expected to grow significantly faster than local electricity demand.

Countermeasures

India has already undertaken several measures to address these risks. Large-scale investments under the Green Energy Corridor programme have expanded the ability to transfer renewable electricity across regions, and transmission infrastructure continues to be developed at one of the fastest rates globally, with typical project timelines of approximately 2-4 years. Battery energy storage systems, PSH, more flexible thermal power plant operation, demand-side response and expanding ancillary services markets are expected to play an increasingly important role in absorbing surplus renewable generation and limiting curtailment. The rapid growth of hybrid renewable projects and storage-linked procurement schemes indicates that the market is already adapting to these emerging system integration requirements.

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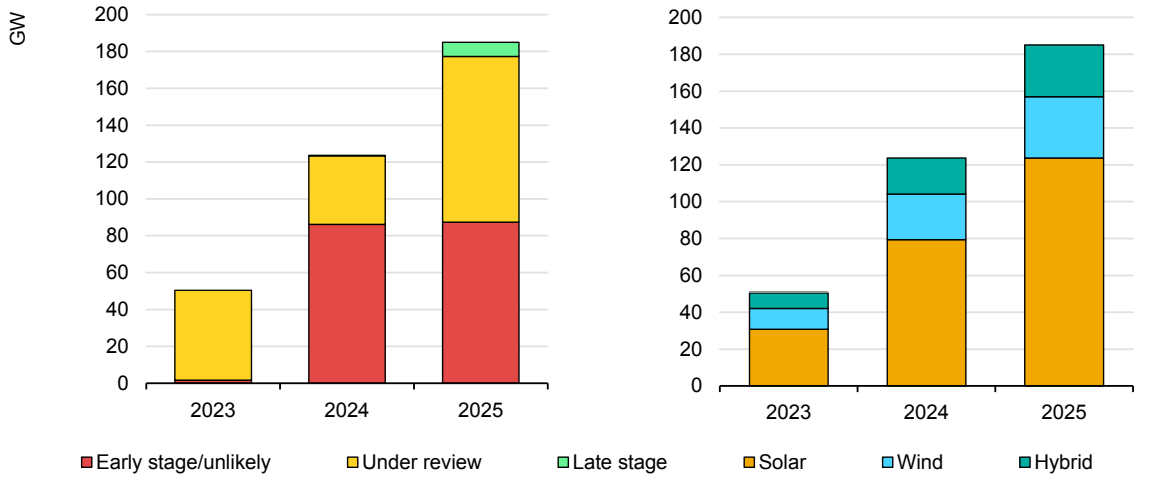
Grid connection queues

Monitoring grid connection queues provides valuable information about future renewable energy development and transmission needs. In India, where renewable deployment is concentrated in a limited number of states and transmission infrastructure requires long lead times, queue data is an important leading indicator of future investment activity and potential network constraints. Although not all queued projects ultimately reach construction, trends in applications provide useful insights into future deployment patterns and help system planners identify regions where additional transmission capacity may be required.

Current status

General Network Access framework (GNA) was introduced under India's transmission connectivity framework in 2022 and became operational following implementation of the revised Indian Electricity Grid Code in 2023. The GNA replaced the earlier project-specific transmission access regime by allowing generators and consumers to obtain transmission access independently of specific PPAs or identified beneficiaries. This provides greater flexibility for renewable energy projects, particularly those supplying electricity through competitive markets, open-access arrangements and future procurement mechanisms.

Renewable energy capacity in connection queues by project stage and technology, India, 2023, 2024 and 2025



IEA. CC BY 4.0.

Notes: Maturity stage considerations: *Late stage* = connectivity status is effective; *under review* = connectivity status is partly effective or to be made effective or a firm general network access date is available; *early stage/unlikely* = not effective and no firm general network access date is available.
Source: IEA analysis based on data from the publications of the Central Transmission Utility of India Ltd.

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Following the introduction of GNA, applications for new solar PV, wind and hybrid projects increased rapidly. The growth reflected both the strong expansion of India's renewable energy pipeline and incentives for developers to secure transmission access early in the project development cycle. Grid connection queues expanded from approximately 50 GW in 2023 to more than 180 GW in 2025. Stand-alone solar PV projects account for the majority of queued capacity, stand-alone wind projects represent around 20%, and hybrid projects represent approximately 15%. Around half of the queued capacity has planned connection dates extending to 2030; the remaining projects have yet to receive confirmed connection timelines.

Challenges

The rapid increase in connection requests presents challenges for both developers and system planners. Large queues can delay project implementation, increase uncertainty regarding commissioning schedules, and complicate transmission planning. In addition, queue growth may overstate the actual project pipeline because some applications are speculative or submitted before key project development milestones have been secured. Similar challenges have emerged in several other major renewable energy markets as project development activity has expanded faster than transmission infrastructure.

Countermeasures

To improve queue management and reduce speculative applications, the Central Electricity Regulatory Commission has introduced several amendments to the GNA framework. These include:

- Tighter monitoring of land acquisition, financial closure and overall project milestone-based processing.
- Reinforced application fees and bank guarantees.
- Clear financial consequences upon withdrawal or blocking of grid capacity.
- Restrictions on changing project parameters after securing connectivity.

As a result, transmission access has been revoked for a limited number of projects since 2022, amounting to less than 20 GW in total. The revocations remain relatively small compared with the overall queue size, indicating that most developers continue to progress projects towards implementation. In cases where developers have demonstrated credible progress and ongoing investment commitments, extensions have generally been granted.

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In addition, in July 2026, the Central Electricity Regulatory Commission introduced a one-time mechanism to address more than 22 GW of transmission grid connectivity allocated to renewable projects that had not secured PPAs. The measure enables developers to restructure or surrender connectivity rights, helping release transmission capacity tied up by stalled projects and improve utilisation of the inter-state network.

Alongside queue management reforms, India has increasingly adopted a more proactive approach to transmission planning. Anticipatory transmission development linked to renewable energy zones and long-term generation forecasts aims to reduce future bottlenecks and better align transmission expansion with renewable deployment. This approach is expected to become increasingly important as renewable capacity additions accelerate towards 2030.

To further improve transparency and streamline application procedures, the Central Transmission Utility released a comprehensive revised procedure for connectivity and GNA applications in April 2026. The framework provides greater clarity regarding application processing, calculation methodologies, project monitoring requirements and enforcement mechanisms. In addition, all connectivity and GNA applications are now processed through the National Single Window System, creating a unified digital platform intended to improve transparency, reduce administrative complexity and facilitate more efficient queue management.

Hybrid renewable power systems

Combining VRE sources with battery storage can provide firm, dispatchable capacity that is comparable to conventional generation technologies when systems are appropriately dimensioned and operated. By smoothing short-term fluctuations in wind and solar output and shifting generation to periods of higher demand, renewable-plus-storage hybrids can reliably meet predefined load requirements and supply electricity during peak demand hours. In India, hybrid electricity systems combining solar PV, onshore wind and battery energy storage can deliver round-the-clock power at costs comparable to new coal-fired generation in many regions. This section provides a summary of optimal firm renewable power dispatch modelling developed by the IEA for each main and subgrid area of India.

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IEA optimal firm renewable power dispatch modelling

An optimisation simulation was conducted to identify the lowest levelised cost of electricity for a hybrid system combining solar PV, onshore wind and battery storage. The analysis is based on actual weather data of the past five years and calculates hourly generation and energy storage charge or dispatch for various combinations of annual, monthly and peak-hour (six hours per day) demand fulfilment criteria. The model runs independently for each point along a grid mesh consisting of latitude and longitude pairs and finds the least-cost hybrid solution fit for regional weather patterns. During the simulation, the storage of the hybrid system can only charge from the coupled renewable generation assets, meaning that charging of the battery from the grid is not allowed. Surplus electricity beyond load and storage requirements is not financially valued. Unused energy may be used or curtailed if renewable generation exceeds export or storage capacity, in line with operational constraints. Financial and technical assumptions are based on current IEA and International Renewable Energy standards and expressed in real terms aligned to weather year 2025.

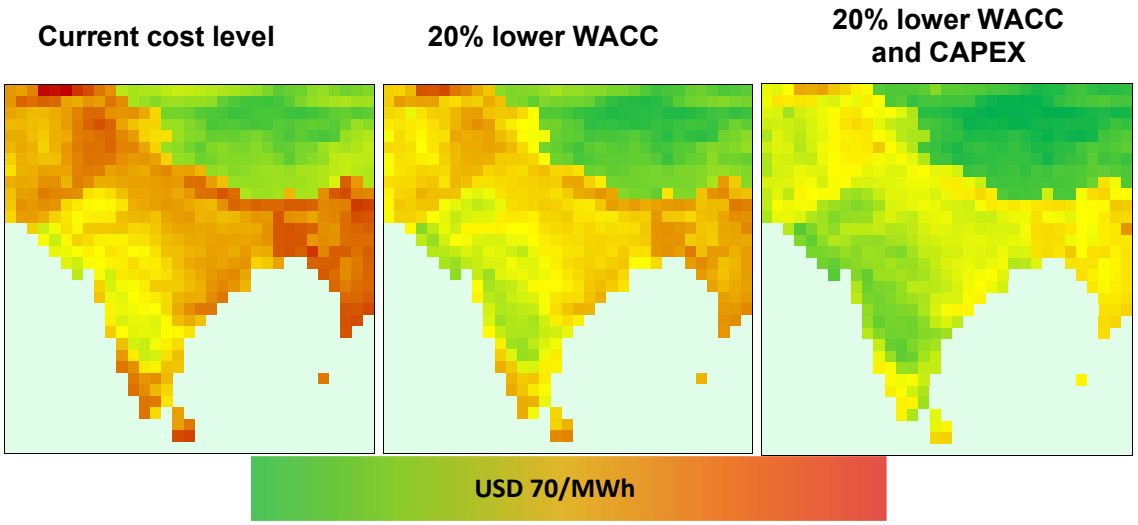
Regional overview

The lowest costs from firm renewable generation can be achieved in the western and southern grid zones. These regions benefit from high and stable wind generation output all year round, coupled with stronger solar irradiation. A 20% reduction from today's weighted average capital and initial capital expenditure cost can extend this cost competitiveness to parts of all major grid zones.

The availability of low-cost battery storage is one of the key drivers of hybrid generation affordability, as it reduces the need to excessively oversize renewable generation capacity. However, meeting the delivery requirements typically used in renewable hybrid auctions – 80% annual, 75% monthly and 90% peak-hour coverage – still requires significant overbuilding of variable renewable capacity. During periods of high simultaneous output from solar PV and onshore wind, particularly in the pre-monsoon and monsoon seasons, excess generation of around 20-40% can occur. This surplus electricity can be sold on wholesale markets at opportunity cost. It can also be used to charge seasonal storage or to supply flexible, non-time-critical demand. Examples include electric vehicle charging, water heating and other flexible loads.

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Heatmap of LCOEs of a hybrid renewable system (solar PV, onshore wind and BESS) supplying round-the-clock demand requirements of annual 80%, monthly 75% and peak 90%, 2025



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Notes: BESS = battery energy storage system; CAPEX = capital expenditures; LCOE = levelised cost of electricity; WACC = weighted average cost of capital. Geographical coverage: Eastern longitudes from 65 to 97; northern latitudes from 6 to 37. Green represents lowest LCOE areas (~30-70 USD/MWh); red represents the highest cost range (~70-120 USD/MWh); yellow represents the estimated LCOE of around ~70 USD/MWh. All monetary calculations are in real terms, with a basis year of 2025. The *demand fulfilment requirement* percentage refers to the hybrid system's annual average capacity factor, representing the share of the demand requirement the system is expected to meet over the course of a year, a month or daily peak hours (defined as six hours per day; two in the morning and four in the evening).

Increasing firm dispatch capability above annual coverage of 80% requires seasonal energy storage capacity to bridge any extended durations when both solar and wind generation output is low. For example, pumped hydropower, with sufficient storage capacity, can complement the hybrid systems to cover the remaining demand gap. Green certificates are also an option in India to fulfil load requirements up to a given threshold.

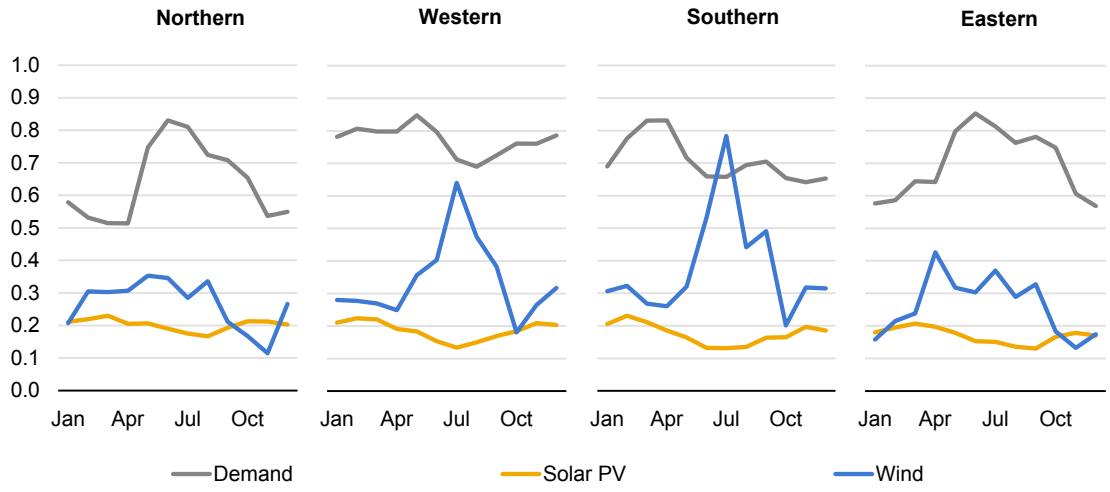
National demand and weather patterns per grid zone

India is a vast country with distinct weather conditions in each of its grid zones, influencing both the demand and supply of electricity. Therefore, each major grid region needs to be evaluated separately. The northern grid zone covers the largest demand share, representing around a third of India's annual total. The zone's average demand profile is shaped by a diverse electricity load from industry, agriculture and urban centres. From June to September average electricity consumption can increase by up to 40% as the need for space cooling and agriculture overlap. Around a quarter of the national electricity demand originates from the western grid region of India. The local annual load profile in the western grid is more consistent across the year due to continuous demand from high commercial activity and energy-intensive industries in Maharashtra and Gujarat. In the southern grid zone, volatility in the seasonal load profile is also relatively

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low, with a peak observable pre-monsoon. About another quarter of India's national annual demand is based in this region. The eastern grid zone represents around 10% of the country's yearly demand. The annual profile is similar to that of the northern region, peaking during the monsoon season.

Normalised annual demand and solar PV and onshore wind capacity profiles in India, 2025



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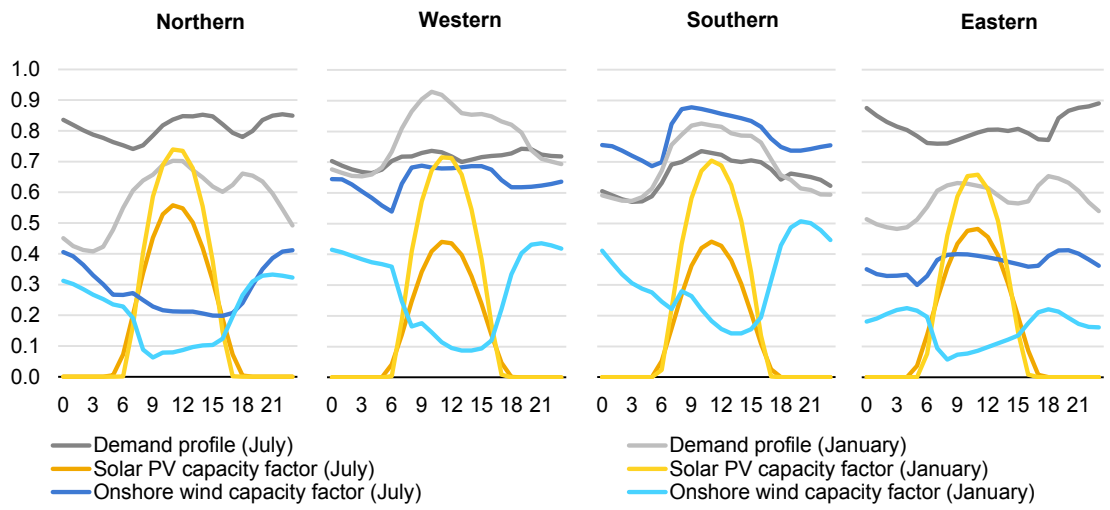
Notes: The analysis relies on hourly demand and weather data from the last five years, separately for the northern, western, southern and eastern grid regions. The north-eastern region was left out of the current analysis, as it represents less than 2% of the national demand and has very unfavourable conditions for wind generation.

Sources: IEA analysis based on India Climate & Energy Dashboard, MERRA-2 global hourly data set available from Renewables Ninja, (CC BY-NC 4.0.); S. Pfenninger and I. Staffell (2016). Long-term patterns of European PV output using 30 years of validated hourly reanalysis and satellite data. Energy 114, 1251–1265, https://doi.org/10.1016/j.energy.2016.08.060 ; I. Staffell and S. Pfenninger (2016). Using bias-corrected reanalysis to simulate current and future wind power output. Energy 114, 1224–1239, https://doi.org/10.1016/j.energy.2016.08.068.

The annual distribution of solar irradiance is consistent nationally. Optimal locations for solar PVs are available in each grid zone. Annual capacity factors of around 18% or higher can be considered for new solar PV installations. During months outside of monsoon season, solar PVs have higher normalised output profiles due to lower average cloud cover, with pre-monsoon months – January to May – yielding highest capacity factors in a year. Differences between monsoon and non-monsoon months in daily peak solar output can vary by around 20-30%. Sunlit daytime hours are also relatively consistent throughout the year, typically beginning around 05:00-06:00 and lasting until approximately 16:00-17:00 local time.

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Normalised hourly demand and solar PV and onshore wind generation capacity profiles in India, January and July 2025



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Sources: IEA analysis based on India Climate & Energy Dashboard, MERRA-2 global hourly data set available from Renewables Ninja, (CC BY-NC 4.0.); S. Pfenninger and I. Staffell (2016). Long-term patterns of European PV output using 30 years of validated hourly reanalysis and satellite data. Energy 114, 1251–1265, https://doi.org/10.1016/j.energy.2016.08.060 ; I. Staffell and S. Pfenninger (2016). Using bias-corrected reanalysis to simulate current and future wind power output. Energy 114, 1224–1239, https://doi.org/10.1016/j.energy.2016.08.068.

Wind generation potential, however, is significantly more versatile among grid zones and seasons. In the western and southern zones, the monsoon season offers high output from wind generation, in many hours above 50% of the wind turbines' nominal capacity. Daytime hours also shape wind generation patterns, as daily output peaks often complement those of solar PV. However, during non-monsoon months in the western and southern zones, and for most of the year in the northern and eastern zones, wind capacity factors are significantly lower, typically in the range of 10-30%. Given this unique combination of weather effects across India, the optimal mix of generation and storage assets varies significantly zone by zone.

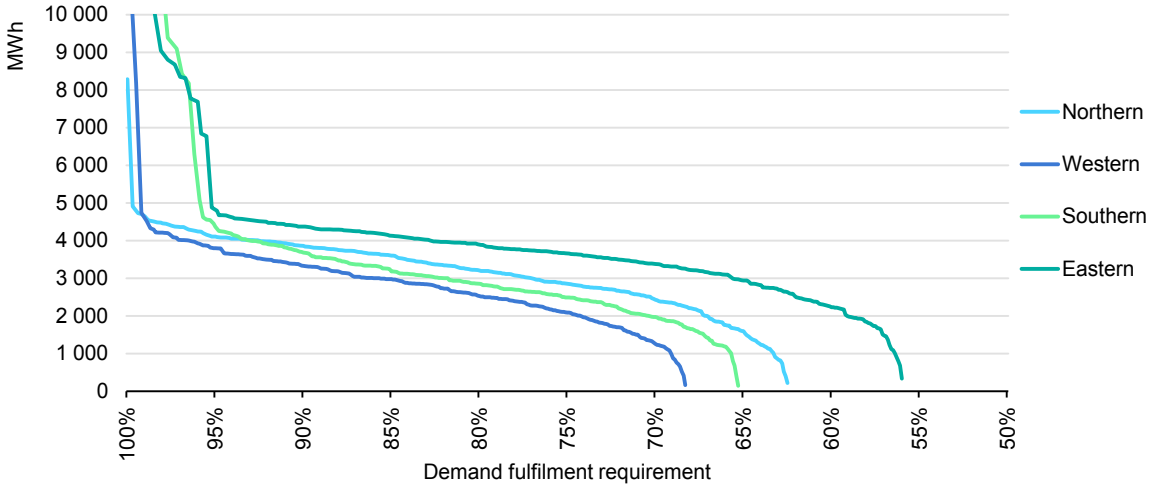
Energy storage size estimation

The size of the necessary energy storage capacity is determined by the daily and seasonal volatility of generation compared with the load profile requirement. The energy storage system must reach an adequate state of charge each day to reliably complement renewable generation the following day. The characteristic daily output profile of solar PV in India can generate surplus electricity with a regularity that enables consistent daily recharging. In many regions of India, solar PV generation is stronger in non-monsoon months and somewhat lower during monsoon season due to increased cloud coverage. Seasonal volatility can cause prolonged periods – multiple days or weeks – of low solar generation. These extended gaps can only be partially served by short-term battery storage systems

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economically. Coupling the system with wind capacity can complement solar-based generation and dampen output volatility. Wind generation tends to peak during nighttime hours and reaches its highest levels during the monsoon season. The optimal balance between solar PV, wind and battery storage varies by geography. Designing systems around locally optimal resource combinations reduces the need to overbuild any individual technology to meet firm supply targets.

Necessary energy storage to cover 300 MW round-the-clock firm baseload at given annual demand fulfilment requirement (%), by 600 MW solar PV and 600 MW onshore wind, India, 2025



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Notes: Example calculation for a project consisting of a hybrid combination of 600 MW solar PV and 600 MW onshore wind capacity, located within each grid zone in India. The demand fulfilment requirement refers to the hybrid system's annual average capacity factor the system is expected to meet over the course of a year.

Across the four main grid regions in India, a combination of solar PV and wind generation alone, without energy storage, can achieve an annual average capacity factor of 55-70%, enabling round-the-clock demand to be met at this level of fulfilment. This requires installing about twice the solar PV and onshore wind generation capacity relative to the baseload hourly power requirement.

In general, the increase in wind generation capacity lowers the need for storage, as wind can generate electricity in every hour of the day. Higher wind generation output per installed capacity enables higher load coverage to be met without storage in the western and southern regions (above 65%). However, higher solar generation per installed capacity enables more reliable recharging of the batteries between days in the northern and western regions. As a result, solar PV enables higher load coverage fulfilment, without extensive storage overbuild (above 95%). Demand fulfilment threshold, which remains economically feasible for such a hybrid system setup, is slightly lower on average in the southern and eastern grid zones (below 95%).

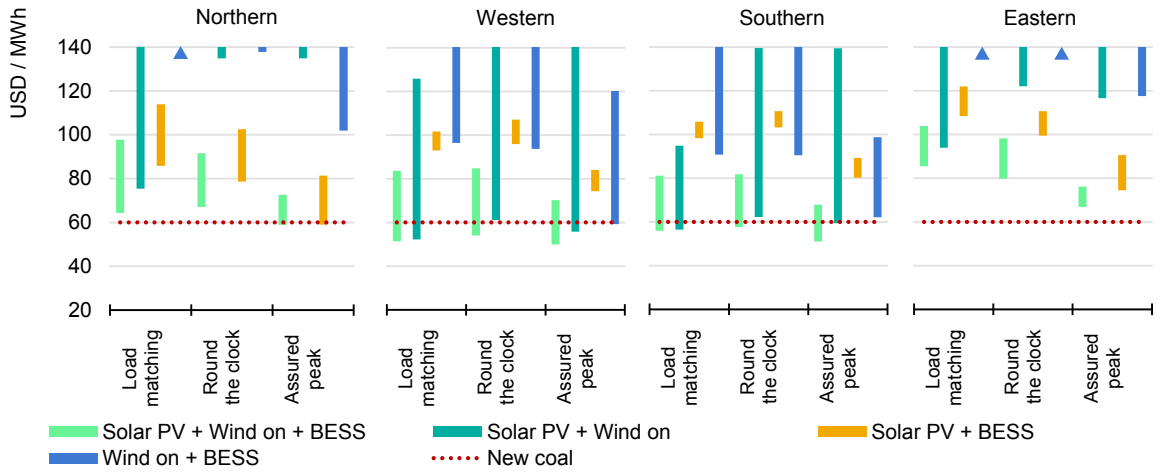
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Levelised cost of electricity for firm renewable generation

A hybrid system integrating solar PV, wind and battery storage optimally can deliver the lowest-cost outcome in most requirement scenarios, with a levelised cost of electricity (LCOE) below 70 USD/MWh. In general, load matching and round-the-clock auction requirements can be fulfilled at a similar LCOE rate (demand fulfillment ratios of 80% annual, 75% monthly and 90% peak-hour coverage). Assured peak auction requirements are typically paired with lower annual demand fulfillment criteria (around 40%), which can easily be covered by sufficient daily battery recharging from solar generation on most days of the year in most regions.

Hybrid systems combining only two technologies can also come close to the optimal price level, but costs depend heavily on the weather patterns of the grid zone. In the western and southern grid zones, pairing solar PV with wind – without storage – can achieve LCOEs generally USD 5-20/MWh higher than those of optimised hybrid solutions. In the northern and somewhat in the eastern grid zones, solar PV coupled with storage can achieve similar cost levels.

Estimated LCOE to fulfil various hybrid auction requirements to cover 300 MW nominal load, in each grid zone in India, 2025



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Notes: Wind on = onshore wind; BESS = battery energy storage system. *Load matching* refers to covering the average grid zone hourly profile throughout a year, with a monthly demand fulfilment ratio of 75%. *Round the clock* refers to fulfilling a baseload profile at annual 80%/monthly 75%/peak 90% coverage. *Assumed peak* refers to fulfilling a baseload profile at annual 40%/monthly 0%/peak 90% coverage, and daily peak hours generation requirements (defined as 6 hours per day: 2 in the morning and 4 in the evening). *New coal* refers to the estimated LCOE of a newly built coal power plant, according to the IEA World Energy Outlook 2025. All monetary values are expressed in real terms, using 2025 as the base year.

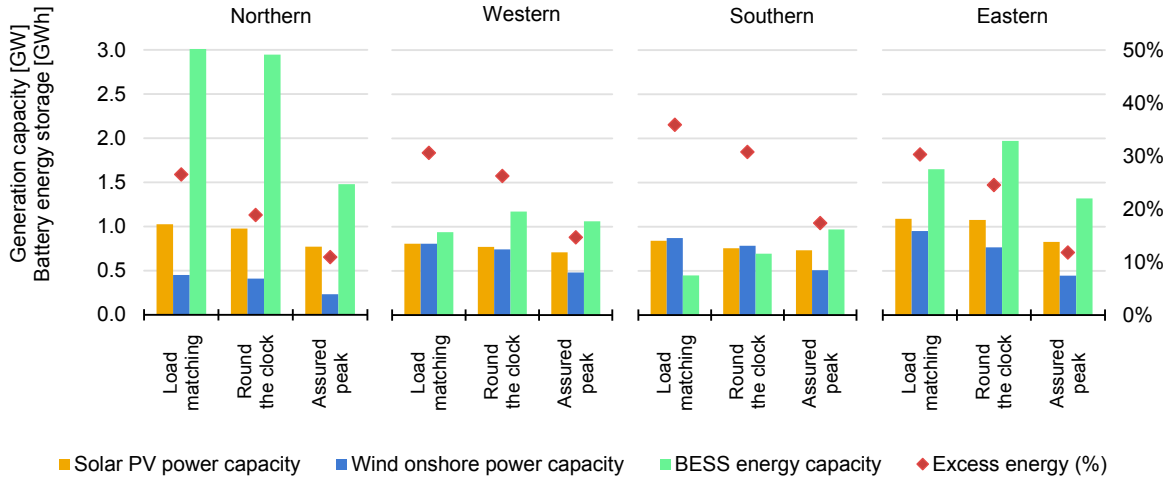
The auction requirement element with the highest cost impact is the monthly demand fulfilment ratio, typically present in the load matching and round-the-clock auctions. As there are considerable seasonal variations in wind as well as hourly

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variations in solar output, both generation assets are necessary to supply firm coverage in every month of the year. Peak coverage can be supplied by shifting the intraday generation of solar, and annual requirements can be fulfilled through high wind generation during the monsoon months.

In general, supplying an average load of 300 MW requires generation capacity of around 600-1 200 MW of solar PV (2-4 times the hourly load) and 300-600 MW of onshore wind (1-2 times the hourly load), coupled with 900-3 000 MWh of energy storage (3-10 hours of average load). In the northern and eastern grid zones, higher battery energy capacity is necessary, due to lower local wind generation. The battery storage capacity in these zones should be equivalent to around 5-10 hours of demand, compared to only 2-5 hours in the western and southern zones. Higher energy storage capacities result in lower excess energy generation (which is generated when primary demand is already met and storage is already fully charged). Optimal solar PV, wind and BESS hybrid setup can fulfil a load matching requirement at monthly 75% coverage; a baseload profile at annual 80%, monthly 75% or peak 90% coverage; and an assured peak at annual 40%, monthly 0% or peak 90% coverage.

Capacity split per technology required to fulfil various auction requirements to cover 300 MW nominal load, by a hybrid of solar PV, onshore wind and BESS, in each grid zone of India, 2025



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Notes: BESS = battery energy storage system. *Load matching* refers to covering the average grid zone hourly profile throughout the year, with a monthly demand fulfilment ratio of 75%. *Round the clock* refers to fulfilling a baseload profile at annual 80%/monthly 75%/peak 90% coverage. *Assumed peak* refers to fulfilling a baseload profile at annual 40%/monthly 0%/peak 90% coverage, and daily peak hours generation requirements (defined as 6 hours per day: 2 in the morning and 4 in the evening).

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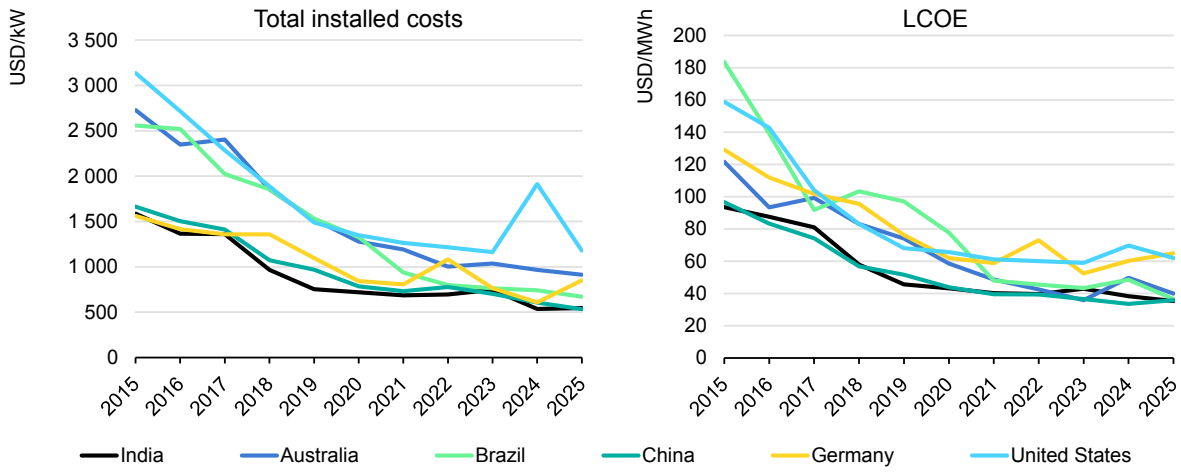
Competitiveness

International costs comparison

India has emerged as one of the world's most competitive markets for renewable electricity generation. Over the past decade, the country achieved some of the lowest installed costs and LCOE globally for utility-scale solar PV and among the lowest for onshore wind. This competitiveness was enabled by ambitious long-term deployment targets, large-scale procurement volumes and a policy framework that progressively reduced investment risks and improved market visibility.

Competitive auctions played a particularly important role in reducing renewable electricity costs by introducing transparent price discovery, standardised procurement frameworks and long-term revenue certainty. Additional measures – including inter-state transmission charge waivers, development of renewable energy parks, Green Energy Corridor investments and streamlined permitting procedures – further improved project economics. India also benefited from strong renewable resource availability, growing domestic manufacturing capabilities and rapidly declining global technology costs.

Utility-scale solar PV total installed costs (left) and LCOE (right), 2015-2024



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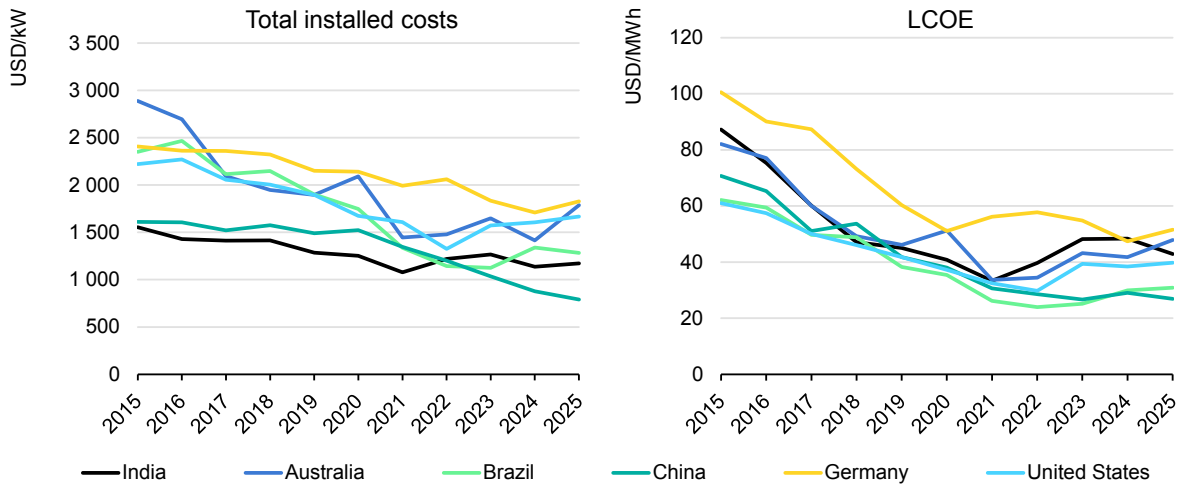
Source: IEA analysis based on data from the IRENA (2026), Renewable power generation costs in 2025.

Strong solar irradiation in western and southern states, particularly Rajasthan and Gujarat, allowed solar PV projects to achieve high capacity factors compared with many international markets. Falling global equipment prices – especially for PV modules, which typically account for around 30-40% of total project costs – significantly reduced investment costs over the past decade. Large-scale

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deployment and competitive procurement accelerated these cost reductions further. India's large and expanding project pipeline also supported the development of domestic engineering as well as procurement and construction capabilities, which reduced balance-of-system costs. Maintaining balance between import restrictions and incentives for domestic manufacturers allowed Indian developers to maintain access to low-cost PV equipment.

Onshore wind total installed costs (left) and LCOE (right), 2015-2024



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Source: IEA analysis based on data from the IRENA (2026), Renewable power generation costs in 2025.

India also achieved relatively low onshore wind investment costs compared with international markets, supported by strong domestic manufacturing capabilities and a long-established wind industry. Local production of turbines, towers, blades and other components reduced dependence on imported equipment and supported relatively competitive project costs.

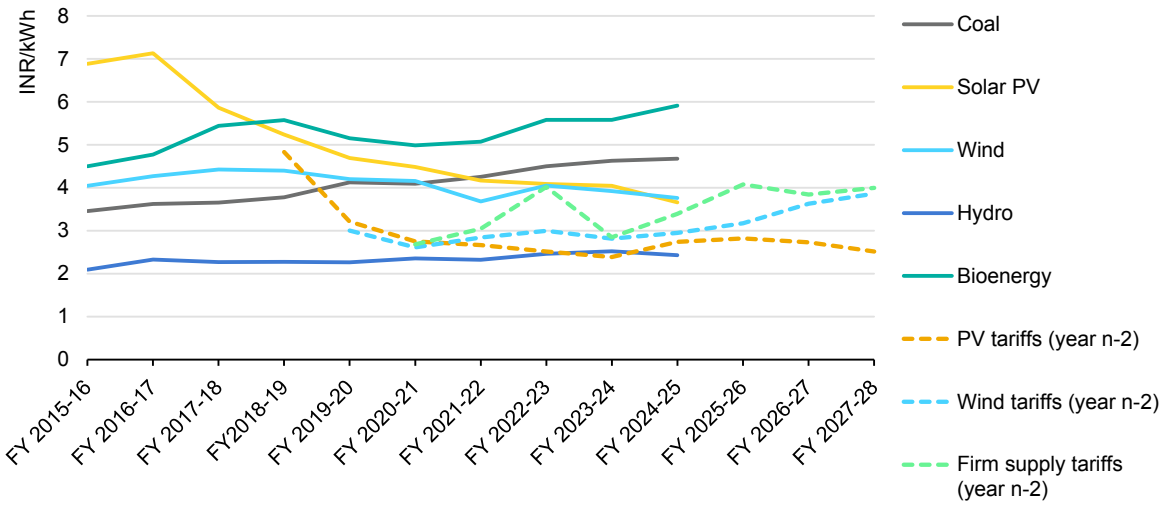
However, the LCOE of onshore wind remained higher than that of solar PV. Unlike solar PV, where high-quality resources are available across large parts of the country, economically attractive wind resources are concentrated in limited areas, particularly in Tamil Nadu, Gujarat, Karnataka, Maharashtra and Rajasthan. Increasing competition for suitable land, grid connection constraints and more challenging project development conditions in high-resource areas limited further reductions in wind generation costs. In addition, a significant share of India's wind fleet consists of older projects commissioned under feed-in tariff regimes with higher historical costs and lower turbine efficiencies.

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Costs of supply in India

Coal remains the dominant source of electricity generation in India and the largest contributor to average power procurement costs for many DISCOMs. Despite continued expansion of domestic coal production, coal-based generation costs increased by more than one-third during the past decade, reaching approximately INR 4.7/kWh in FY 2024-25. Rising costs were driven by higher fuel expenses, increasing transportation costs, environmental compliance investments and growing use of imported coal in some regions. Declining utilisation rates of coal-fired power plants in several states also contributed to rising average supply costs by increasing fixed-cost recovery per unit of electricity generated.

DISCOMs' average electricity supply costs by technology and renewable power auction tariffs, 2015-2027



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Note: Solar PV, wind and firm supply tariffs represent auction results from two years prior to a year indicated in the figure.
Sources: IEA analysis based on data from NITI Aayog and IEA renewable power auctions global database.

Existing hydropower plants remain among the lowest-cost electricity sources in India. This reflects their very long operational lifetimes, their low operating costs after commissioning and the multipurpose nature of many projects, which may also support irrigation, flood control and water management. In several cases, infrastructure costs are partially shared across these broader economic functions, lowering the effective electricity generation cost over time.

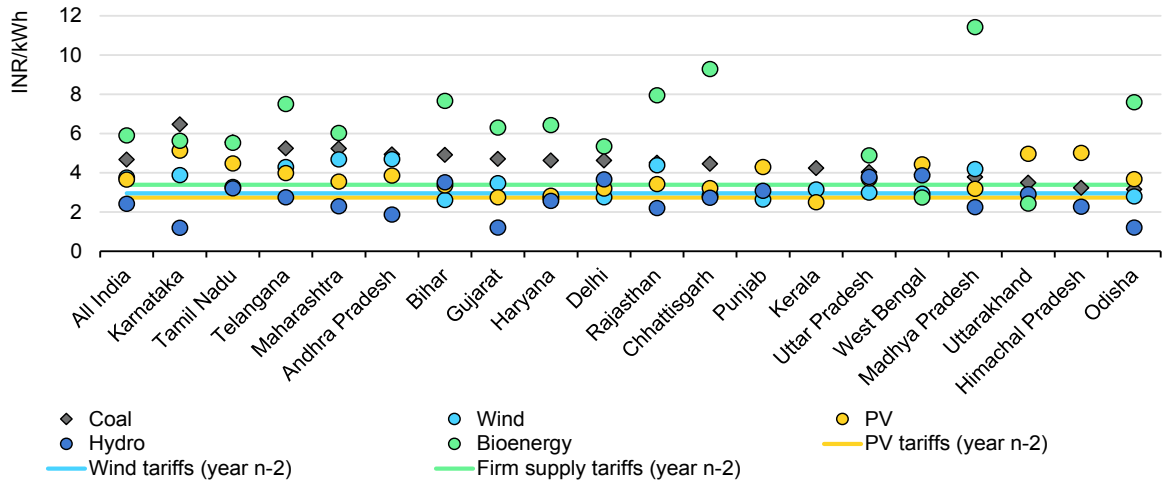
By contrast, bioenergy remains the most expensive major renewable generation source in India, with average supply costs reaching almost INR 6/kWh in FY 2024-25. Relatively small plant sizes, difficulties securing stable feedstock supply, high transportation costs and seasonal variations in biomass availability contribute to relatively low-capacity utilisation factors and resulting high generation costs.

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Average solar PV procurement costs for DISCOMs declined sharply during the past decade as low-cost projects increasingly entered the generation mix. Average solar PV supply costs fell by around 50% between FY 2015-16 and FY 2024-25, reflecting declining capital costs, falling module prices and rapid deployment of low-cost utility-scale projects. Wind supply costs declined more slowly because savings from technology cost reductions were partly offset by land, grid connection and resource quality constraints, and older and more expensive projects still account for a relatively large share of the operating fleet. Repowering of older wind sites with larger and more efficient turbines could improve future wind competitiveness in high-resource regions.

For newly contracted projects, renewable energy has become substantially cheaper than conventional generation. Average solar PV auction tariffs observed during 2023-2024 were around 40% lower than the average cost of coal-based electricity supply. Even hybrid and firm renewable energy systems combining solar PV, wind and storage were typically contracted at tariffs approximately 20% below average coal power supply costs. Rapid declines in battery storage costs have improved the competitiveness of dispatchable renewable energy systems, particularly for evening peak supply applications. The increasing competitiveness of hybrid and firm renewable energy systems indicates that renewable electricity remains economically attractive even when additional storage and balancing requirements are included.

DISCOMS's average electricity supply costs by technology and by state, renewable power auctions tariffs, FY 2024-25



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Note: Solar PV, wind and firm supply tariffs represent auction results from two years prior to a year indicated in the figure.
Sources: IEA analysis based on data from NITI Aayog and IEA renewable power auctions global database.

Electricity supply costs vary substantially between Indian states depending on local resource availability, fuel access and generation mix. States with access to domestic coal production generally benefit from lower coal supply costs. For instance, coal-based electricity procurement costs in Karnataka are approximately

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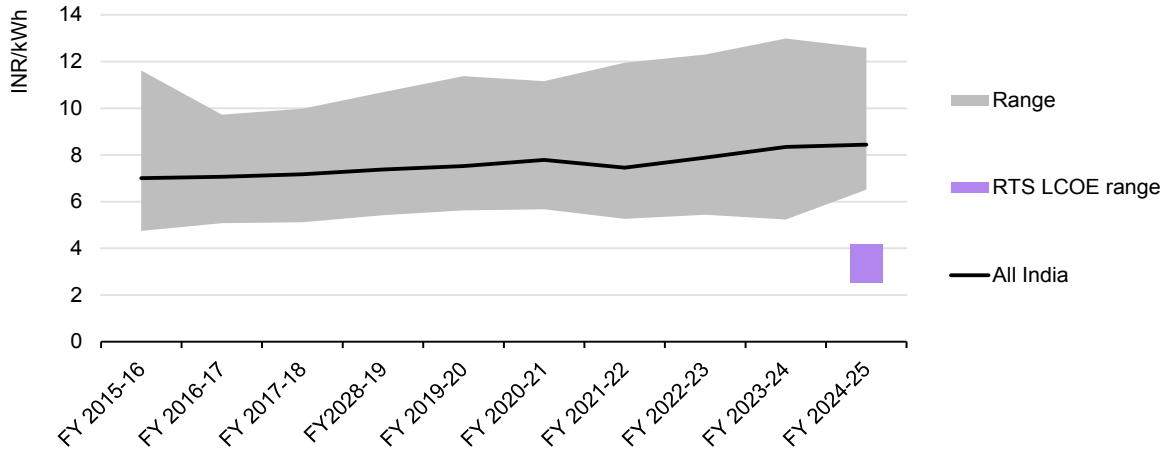
twice as high as in Odisha, India's largest coal-producing state. On the other hand, inter-state transmission charge waivers improve the competitiveness of renewable electricity procurement for states importing renewable power from resource-rich regions.

As a result, renewable energy deployment can provide particularly large economic benefits in states with relatively high conventional power costs, including Karnataka, Tamil Nadu, Telangana, Maharashtra, Andhra Pradesh, Bihar and Gujarat. Many of these states also rank among India's largest renewable energy markets, reflecting both favourable renewable resources and strong economic incentives for renewable procurement.

Competitiveness in consumer groups

The economics of renewable electricity are particularly attractive for commercial and industrial consumers because of India's cross-subsidised tariff structure. Industrial consumers pay some of the highest electricity tariffs in the country to subsidise residential and agricultural consumers. Average industrial tariffs increased by around 20% during the past decade, reaching approximately INR 8.4/kWh in FY 2024-25, although tariff levels vary significantly between states, ranging from around INR 6/kWh to more than INR 12/kWh depending on local tariff structures and supply costs.

Average electricity tariff for industrial consumers and large-scale rooftop PV systems LCOE range, 2015-2028



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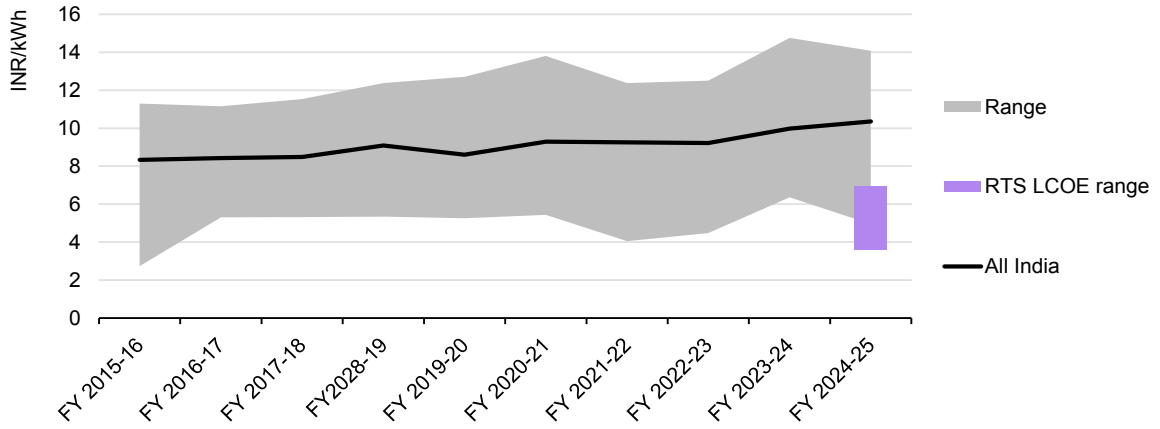
Notes: RTS = rooftop solar. Solar PV, wind and firm supply tariffs represent auction results from two years prior to a year indicated in the figure.
Source: IEA analysis based on data from NITI Aayog.

As of FY 2024-25, average industrial tariffs were approximately four times higher than the estimated LCOE of large-scale rooftop solar PV systems, roughly three times higher than average utility-scale solar PV auction tariffs and around 2.5 times higher than tariffs for hybrid or firm renewable energy systems. Although this comparison does not fully account for transmission charges, cross-subsidy

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surcharges or grid maintenance costs embedded in final consumer tariffs, the widening gap between retail electricity prices and renewable generation costs has become a major driver of open-access renewable procurement and corporate PPAs. Renewable projects are therefore increasingly able to compete outside traditional long-term DISCOM procurement frameworks.

Average electricity tariff for commercial consumers, rooftop PV systems LCOE range, 2015-2025

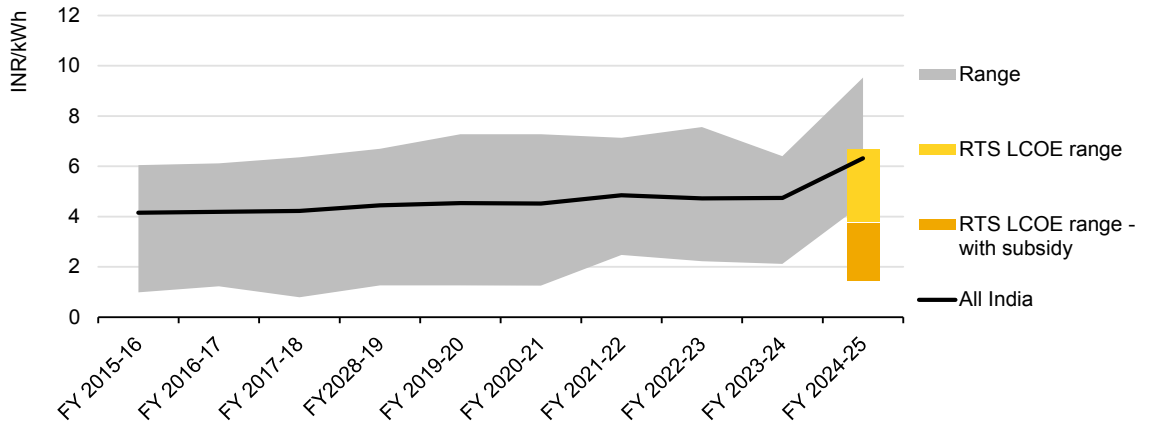


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Note: RTS = rooftop solar.
Source: IEA analysis based on data from NITI Aayog.

Commercial consumers face even higher electricity tariffs, exceeding INR 10/kWh on average in FY 2024-25 after increasing by approximately 25% during the past decade. For commercial consumers, the estimated LCOE of small-scale rooftop solar PV systems is typically less than one-third of retail electricity tariffs, creating particularly strong economic incentives for self-generation and rooftop solar adoption.

Average electricity tariff for residential consumers, rooftop PV systems LCOE range, 2015-2025



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Note: RTS = rooftop solar.
Source: IEA analysis based on data from NITI Aayog.

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By contrast, residential electricity tariffs remain heavily subsidised and are often below the average cost of electricity supply. The relatively low level of residential tariffs historically limited the economic attractiveness of rooftop solar PV systems because the estimated LCOE of small residential systems was often comparable to retail electricity prices.

However, the PM Surya Ghar programme, introduced in 2024, substantially improved project economics through direct investment subsidies. With subsidy support, the effective cost of residential rooftop solar generation can decline to around 40% of average residential electricity tariffs. Final investment attractiveness, however, depends strongly on state-level remuneration mechanisms, including net metering, net billing and compensation for exported electricity. Under current policy conditions, subsidised residential rooftop solar systems typically achieve investment payback periods of around 3-5 years. Access to low-cost financing remains an important factor affecting actual adoption, particularly for lower-income households.

Overall, renewable energy deployment in India is increasingly driven not only by policy targets and environmental objectives but also by strong underlying economic competitiveness across multiple technologies, consumer segments and regions.

Cost of capital for renewable projects

The cost of capital is a key determinant of investment decisions in the power sector. It reflects the return required by debt and equity investors to compensate for perceived investment risks. Higher perceived risks raise financing costs, as investors demand higher returns to offset the probability of project underperformance, payment delays or default. The cost of capital is particularly important for renewable energy technologies because they are highly capital intensive. Most project costs are incurred during development and construction, while operating costs remain relatively low over the lifetime of the asset. As a result, the economic viability of renewable energy projects depends strongly on how future revenues are discounted relative to upfront capital expenditures. Higher financing costs reduce the present value of future revenues and increase the electricity price required for projects to recover investments and generate acceptable returns.

As a result, the cost of capital is one of the largest components of the LCOE for utility-scale renewable energy projects. This issue is particularly significant in emerging market and developing economies, where a combination of macroeconomic, financial and regulatory risks often increases financing costs well above levels observed in advanced economies.

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According to the IEA Cost of Capital Observatory, the median cost of capital for utility-scale solar PV projects in India reached 10.8% in 2024, compared with an estimated range of 5.5-7% in advanced economies. A 1 percentage point increase in the cost of capital for a typical 100 MW solar PV project can increase generation costs by approximately 7-10%, whereas the impact on fossil fuel power generation costs is typically lower, at around 3-5%. Although onshore wind is not explicitly covered by the Observatory, available evidence indicates that financing conditions for onshore wind projects in India are broadly similar to those for solar PV.

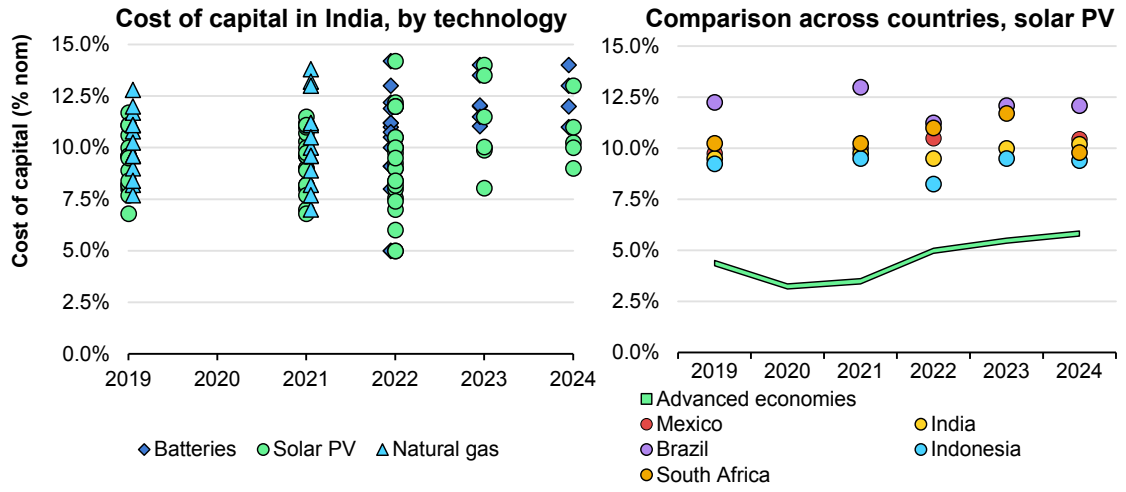
Despite the rapid expansion of renewable deployment during the past decade and increasing familiarity of Indian financial institutions with renewable energy financing, the cost of capital for renewable projects in India remained higher than for fossil fuel generation in 2024. The median cost of capital for natural gas-fired power generation was estimated at approximately 9.5%. Larger balance sheets, stronger credit ratings and longer-established financing relationships among conventional power developers contributes to relatively lower financing costs for fossil fuel projects, while renewable deployment remains more fragmented among smaller developers.

Risk factors affecting the cost of capital can broadly be divided into two categories: country-level risks and project- or sector-specific risks. Country-level risks include macroeconomic conditions, inflation, currency volatility and sovereign risk, while project-level risks relate to regulatory stability, permitting procedures, counterparty risks and project bankability.

For renewable energy investments in India, the most significant risk factors span both categories and include foreign exchange risks, regulatory uncertainty and concerns regarding the bankability of PPAs. The poor financial health of many DISCOMs remains one of the largest project-level risks affecting renewable investments. Delayed payments from DISCOMs to generators frequently exceeded six months in many states during the past decade. The risk of payment delays, curtailment or renegotiation of contracted tariffs increases uncertainty for investors and lenders, raising debt service requirements and financing costs across the power sector.

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Cost of capital for utility-scale solar PV across major markets, 2019-2024



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Source: IEA analysis based on data from the IEA (2025), Cost of Capital Observatory and Hatton et al. (2025), Historical and Future Projected Costs of Capital.

Although the cost of capital for renewable projects in India has historically been approximately twice as high as in advanced economies, the gap narrowed gradually during the 2020s. Strong renewable resource potential, relatively low project development costs and competitive procurement frameworks enabled renewable energy projects in India to maintain globally competitive LCOEs despite elevated financing costs. However, the high costs of capital substantially increase the total investment required to achieve India's renewable deployment targets for 2030.

India implemented a broad range of policy measures aimed at reducing investment risks and improving project bankability. Competitive auctions introduced long-term revenue visibility and transparent price discovery, while central government agencies such as SECI reduced counterparty risks by acting as intermediary power procurers between project developers and DISCOMs. Reforms targeting delayed DISCOM payments, including late payment surcharge rules and enhanced payment discipline mechanisms, also helped improve investor confidence.

Additional de-risking measures included multiple payment security mechanisms for renewable PPAs, such as mandatory letters of credit and the establishment of payment security funds to cover temporary DISCOM payment defaults. The central government also facilitated land access, transmission connectivity and permitting through renewable energy parks and Green Energy Corridor investments. Public financial institutions such as the Indian Renewable Energy Development Agency additionally played an important role in improving access to financing for renewable developers.

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Despite this progress, financing conditions for renewable projects in India remain less favourable than in several other emerging markets. Ongoing financial stress among DISCOMs, foreign exchange risks and regulatory uncertainty continue to increase perceived investment risks. Improving the financial health of DISCOMs through tariff reforms, debt restructuring and stronger payment discipline remains important for reducing financing costs. Foreign exchange risks could also be mitigated through greater availability of local currency financing and currency hedging mechanisms supported by governments or multilateral development banks.

Further improvements in regulatory stability and long-term policy visibility could also help reduce financing costs. Clearer long-term policy trajectories, stable procurement frameworks and more consistent implementation of renewable energy policies across states would improve investor confidence and reduce perceived regulatory risks. Lowering financing costs will remain an important factor for reducing renewable electricity costs and mobilising the large-scale investments required to achieve India's longer-term energy transition objectives.

Renewable energy investment trends in India

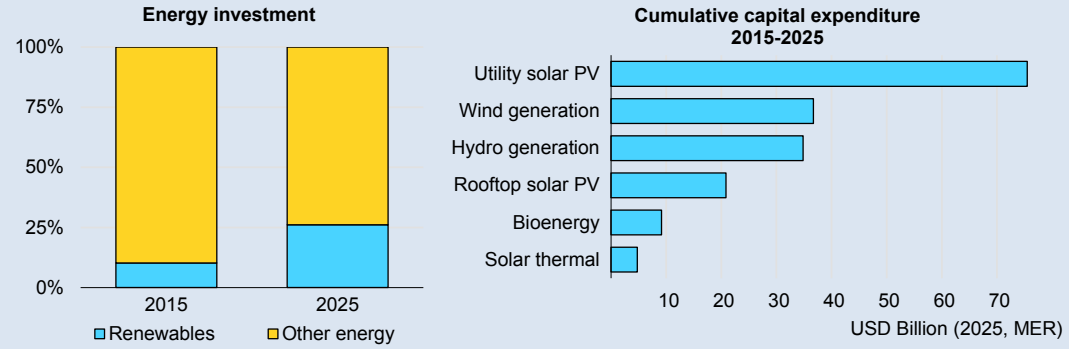
Energy investment in India hit an all-time high of USD 167 billion in 2025, having grown at an annual average growth rate of 6% over the past decade. Much of this growth has been led by renewables, which grew fivefold in this period, far above the 1.5 times growth seen for the rest of the energy sector. Today, renewables account for over one-quarter of all energy sector investment in India, up from one-tenth in 2015.

Among renewables, utility-scale solar PV capacity that came online between 2015 and 2025 accounted for a capital expenditure of USD 75 billion. Rooftop solar PV accounted for an additional USD 20 billion cumulatively in this period. Modern bioenergy – which includes both biofuels and biogas supply and use – accounted for approximately USD 10 billion.

The costs of the underlying renewable energy technologies have been falling, delivering disproportionately higher capacity growth. For example, the cost to install utility-scale solar PV in India fell by nearly 60% between 2015 and 2025. In this period, total annual utility-scale solar investment grew sixfold, even as capacity additions grew seventeen-fold.

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Energy investment and cumulative capital expenditure for renewable energy in India, 2015-2025



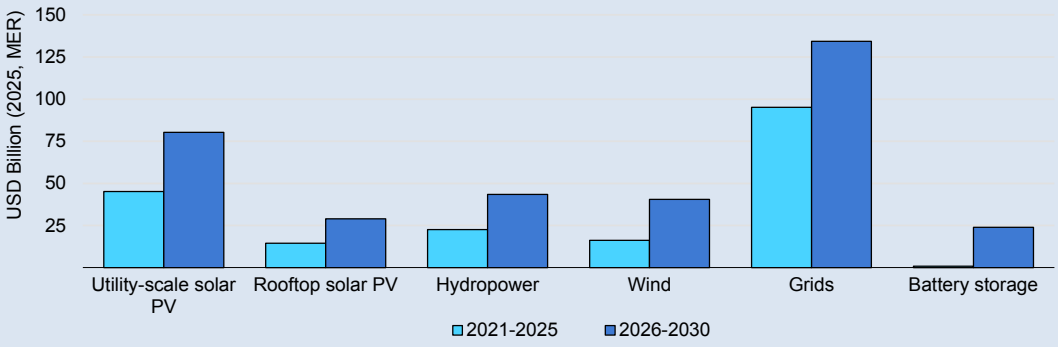
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Notes: MER = market exchange rate. Capital expenditure here refers to the total project cost at the time that it becomes operational. Bioenergy includes supply and power generation.

Source: IEA (2026), World Energy Investment 2026.

Despite this, growing renewable energy deployment in India is associated with rising capital requirements, even as cost reductions in the underlying technologies lower the capital requirements over time. Installation costs for utility-scale solar PV are projected to decline by 25% between 2025 and 2030. Installation costs for other technologies, including wind, fall as well, although slower. The total capital expenditure associated with the cumulative capacity additions between 2026 and 2030 nonetheless nearly double across key renewables technologies, supporting a proportionally larger buildout of new capacity compared with the previous 5-year period. In sum, the added solar PV, wind and hydropower capacity in India between 2026 and 2030 is associated with approximately USD 200 billion of capital expenditure.

Cumulative capital expenditure associated with capacity additions for key renewable power generation technologies, and grids and storage in India



IEA. CC BY 4.0.

Notes: MER = market exchange rate. Capital expenditure here refers to the total project cost at the time that it becomes operational.

Source: IEA (2026), World Energy Investment 2026.

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In addition to these generation technologies, the capital expenditure associated with transmission and distribution grows by 40% over the previous 5-year period. This growth is a result of broad-based demand drivers that include renewables-specific evacuation needs and grid modernisation. Battery storage sees a nearly thirty-fold growth from a low base to cumulatively reach USD 25 billion between 2026 and 2030. Grids and storage together account for USD 160 billion in capital expenditure in this period.

Clear policy signals and national ambitions have helped crowd in capital within India's renewable energy sector. Private finance – largely domestically sourced – has historically taken the leading role in India's renewable energy investment landscape, with the exception of hydropower, which is largely financed by public sources. Development finance institutions, while accounting for a small share (<5%) of overall finance for renewables investment, have played an important role in sending the right signals to other investors and unlocking private capital. These development finance institution-led instruments include first-loss guarantees and other blended finance structures that help improve the bankability of projects to crowd in private capital. They also include elements of concessionality, including below-market rate borrowing costs and longer repayment periods.

As India seeks to increase international investment in the renewable energy sector, reducing the cost of capital through risk mitigation remains critical. Tools to manage currency risks from fluctuating exchange rates also play a vital role. The continued role of development finance institutions and sector-specific reforms and interventions therefore prove to be vital as India moves into its next stage of the buildout of renewable energy infrastructure.

Manufacturing and supply chains

Solar PV

Historically, India relied heavily on imported equipment to support domestic solar PV deployment, particularly modules sourced from China. However, a combination of industrial policy measures, rapid market growth and geopolitical concerns regarding supply chain concentration increasingly shifted policy focus towards domestic manufacturing development and supply chain diversification, helping India emerge as one of the world's largest solar PV manufacturing hubs.

India's solar PV manufacturing strategy evolved progressively over time. Early policy support focused primarily on domestic content requirements in selected government-supported projects, but large-scale manufacturing expansion

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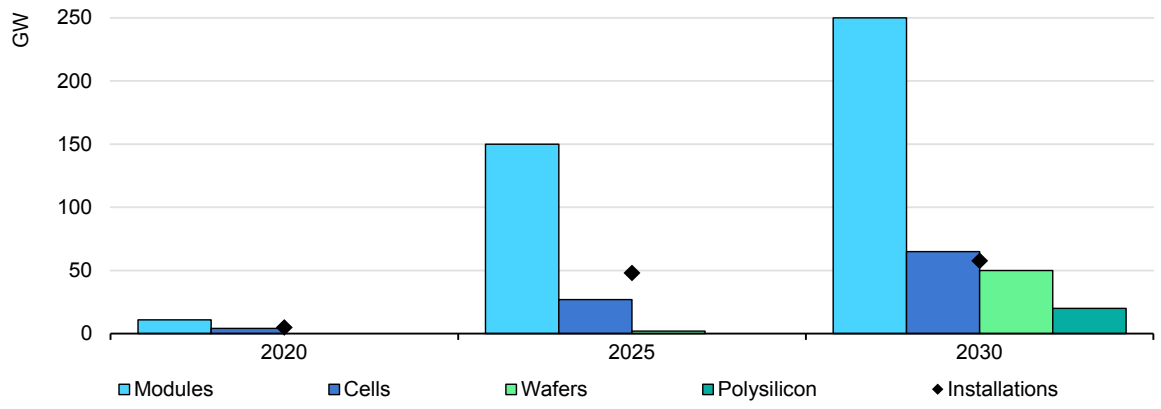
accelerated after 2020 through a broader industrial policy framework combining production incentives, import protection and market access requirements.

Policy schemes

One of the most important policy mechanisms was the PLI scheme for high-efficiency solar PV manufacturing. The first PLI tranche, approved in 2021, allocated INR 45 billion (USD 0.6 billion) to support integrated polysilicon-to-module manufacturing capacity. A second tranche, approved in 2022, significantly expanded the programme, increasing the total allocated support to INR 240 billion (USD 2.9 billion).

India also strengthened import protection measures. Basic customs duties introduced in 2022 imposed tariffs of 40% on imported solar modules and 25% on imported cells. In parallel, the ALMM framework increasingly restricted access to government-supported projects to approved domestic manufacturers. Initially applied only to modules used in government and government-assisted projects, ALMM requirements were gradually expanded and implementation timelines adjusted multiple times in response to domestic supply availability and concerns regarding short-term shortages. Requirements for domestic cells apply from June 2026, and similar provisions for wafers are expected to follow in 2028.

Solar PV manufacturing capacity and installations, India, 2020-2030



IEA. CC BY 4.0.

Note: Solar PV installations presented in DC capacity.
Sources: IEA analysis based on data from InfoLink Consulting, BNEF and S&P.

Historically, India imported the vast majority of solar PV modules used in domestic installations, with China accounting for more than 90% of imports by 2022. Between 2023 and 2025, the share of imports sourced from China declined to around 60-75%, partly because of increasing imports from Southeast Asian manufacturing hubs, particularly Viet Nam, which benefited from customs duty exemptions. Average annual module imports remained around USD 3 billion

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during 2021-2024 but declined sharply to approximately USD 1.5 billion in 2025 as domestic manufacturing capacity expanded.

Manufacturing expansion trends

India's solar module manufacturing capacity expanded from approximately 22 GW in 2022 to around 150 GW in 2025, and 225 GW in September 2026, significantly outpacing growth in domestic solar PV installations. Nominal manufacturing capacity became equivalent to around three times annual domestic installations and is expected to increase further to approximately 250 GW by 2030, or around four times projected annual installations.

However, a substantial share of India's manufacturing base consists of smaller-scale producers operating older production lines focused on less competitive technologies. Production therefore remains concentrated among a smaller group of large integrated manufacturers producing higher-efficiency modules at larger scale and higher utilisation rates. Most newly commissioned manufacturing facilities in India are based on TOPCon (tunnel oxide passivated contact) technologies, allowing domestic producers to align more closely with prevailing global manufacturing trends and partially bypass older generations of technology. Nevertheless, India remains highly dependent on imported manufacturing equipment, process technologies and technical know-how, particularly from China, across most stages of solar PV the supply chain.

Upstream supply chain development progressed more slowly. Although approximately 48 GW of solar cell manufacturing capacity was awarded under the two PLI tranches, only around 27 GW had been commissioned by the end of 2025. As a result, a large share of demand created by India's rapidly expanding module manufacturing sector continued to be met through imports. Solar cell imports increased from approximately USD 0.4 billion in 2020 to around USD 2.5 billion in 2025, with roughly 70% sourced from China.

Planned implementation of ALMM requirements for solar cells significantly accelerated investment announcements in domestic cell manufacturing, with more than 16 GW of additional capacity under construction by the end of 2025. Taking into account announced projects, India's cell manufacturing capacity is expected to exceed 60 GW by 2030. Nevertheless, cell manufacturing development continues to face challenges related to technology access, financing requirements and competition from lower-cost imports.

Wafer manufacturing remains at an even earlier stage. India commissioned its first wafer manufacturing facility, with approximately 2 GW of annual capacity, in 2025. Although delayed compared with initial policy ambitions, capacity is expected to expand significantly towards 2030, potentially reaching around 50 GW based on announced projects. Planned implementation of ALMM requirements for wafers

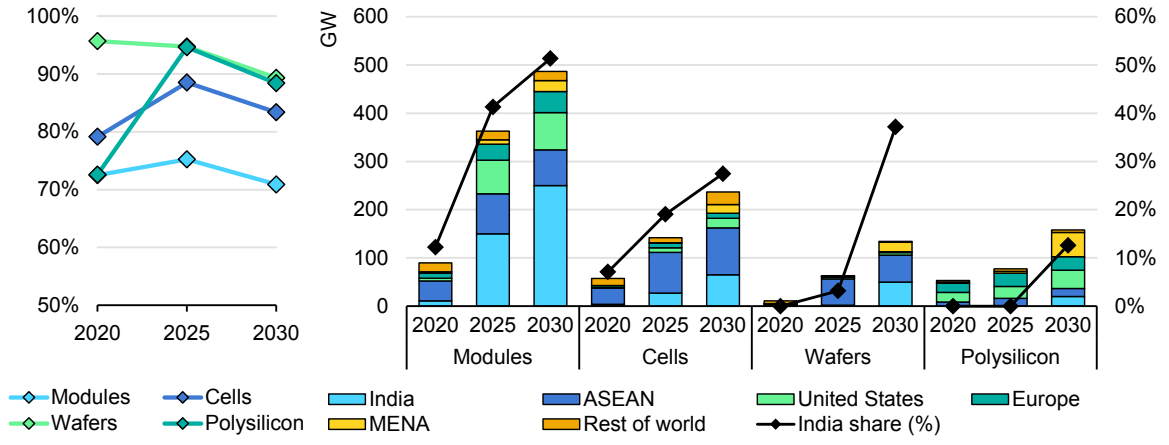
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became one of the main drivers of investment interest. However, wafer manufacturing projects continue to face challenges related to technology transfer, process know-how, scale-up risks and competitiveness against established international producers. Upstream manufacturing segments also require substantially larger capital investments and more complex industrial processes than module assembly, increasing execution and financing risks.

Polysilicon manufacturing remains the least developed segment of India's solar PV supply chain. As of 2025, no operational polysilicon production facility existed in the country despite integrated projects supported under the PLI framework. Concerns regarding competitiveness against imported polysilicon, high energy requirements and limited access to advanced production technologies constrained project development. However, continued policy focus on supply chain localisation and ongoing discussions regarding possible future support mechanisms for upstream manufacturing are expected to support gradual expansion towards 2030. Current forecasts indicate that India could develop sufficient polysilicon production capacity to support approximately 20 GW of integrated module production annually by the end of the decade.

As a result, India achieved sufficient nominal module manufacturing capacity to potentially cover domestic demand by 2025 but remained heavily dependent on imports across upstream segments. Domestic production capacity could potentially cover nearly all module demand and around half of cell demand, while domestic wafer and polysilicon production remained minimal. By 2030, India is expected to achieve full self-reliance in modules and cells and approximately 80% self-sufficiency in wafers, although dependence on imported polysilicon is likely to remain substantial.

China's share in global solar PV manufacturing capacity (left) and non-China solar PV manufacturing capacity and India share (right), 2020-2030



IEA. CC BY 4.0.

Note: ASEAN = Association of Southeast Asian Nations; MENA = Middle East and North Africa.
Sources: IEA analysis based on data from InfoLink Consulting, BNEF and S&P.

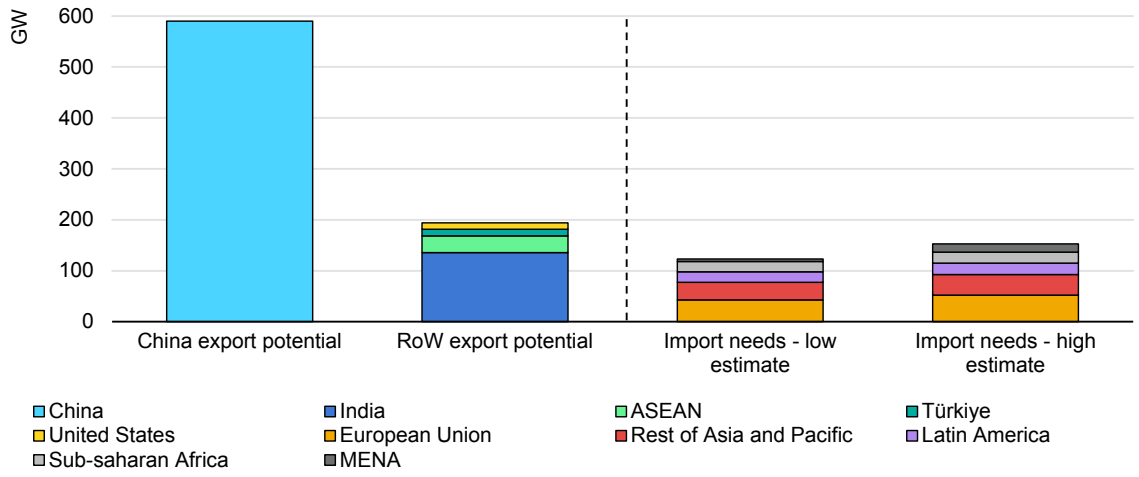
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International competition

India's manufacturing expansion occurred within the context of rapidly growing global solar PV overcapacity. By 2025, global manufacturing capacity across the solar PV supply chain exceeded 1 200 GW, compared with approximately 630 GW of annual installations (DC). China remained the dominant global manufacturer, accounting for approximately 75% of global module manufacturing capacity, around 90% of cell capacity and approximately 95% of wafer and polysilicon manufacturing capacity. Global overcapacity and China's dominant market position are not expected to change substantially by 2030.

However, India emerged as the largest PV production hub among manufacturers outside China, with a 40% share in modules and 20% in cells. By 2030, India is expected to further strengthen its position and account for approximately 50% of global non-China module manufacturing capacity, around 30% of non-China cell capacity, 40% of non-China wafer capacity and approximately 15% of non-China polysilicon capacity.

Expected solar PV modules export potential and import demand, 2030



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Note: ASEAN = Association of Southeast Asian Nations; CUF = capacity utilisation factor; MENA = Middle East and North Africa; RoW = rest of world.

Sources: IEA analysis based on data from InfoLink Consulting, BNEF and S&P.

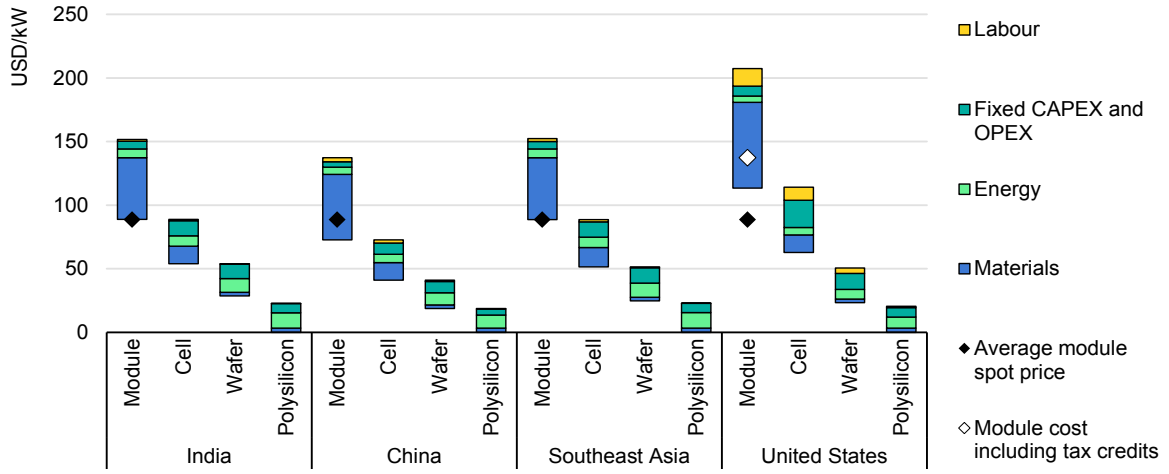
India's manufacturing investment boom, particularly in modules, increasingly outpaces projected domestic demand, creating the potential for India to become a major export-oriented manufacturing hub. After accounting for domestic demand, India is expected to have approximately 135 GW of spare module manufacturing capacity available for exports by 2030, the second-largest export potential after China. However, with almost 600 GW of spare capacity, China is likely to continue to dominate the market. In 2030, global module manufacturing

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capacity potentially available for export could reach about 780 GW, while global import demand is estimated at around 130-160 GW.

As a result, Indian manufacturers are expected to face intense competition in international markets. Access to export markets may increasingly depend not only on cost competitiveness but also on evolving trade policies, local-content requirements and supply chain security regulations in importing regions. Supply chain diversification policies in major markets such as the European Union could create opportunities for Indian exporters, particularly as governments increasingly seek to reduce dependence on Chinese imports. Nevertheless, competition is expected to remain strong because of the historically low export prices offered by Chinese manufacturers and the continuing global manufacturing overcapacity.

Solar PV levelised cost of production, 2025



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Notes: CAPEX = capital expenditure; OPEX = operating expenditure. Levelised cost of production corresponds to the price that would have to be charged per unit of production to achieve a net present value of zero for a given investment. Assumes a vertically integrated supply chain. Assumes domestic production of polysilicon and intermediate components.
Source: IEA (2026), Energy Technology Perspectives 2026.

India is expected to achieve relatively competitive manufacturing costs by international standards. Low labour costs, relatively low energy prices and the increasing scale of planned manufacturing facilities are estimated to allow integrated domestic production costs to reach approximately USD 0.15/W, only around 10% higher than estimated manufacturing costs in China and significantly below estimated costs in the European Union and the United States without subsidies. However, these estimated production costs remain 70% above recent global spot market prices, highlighting continuing challenges for manufacturers operating in a highly oversupplied and price-competitive global market.

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Outlook

Overall, thanks to co-ordinated industrial policy, India is evolving into an increasingly important global manufacturing and export hub. However, its long-term competitiveness will depend on improving upstream integration, increasing utilisation rates, securing export markets and remaining competitive in a significantly oversupplied global manufacturing environment.

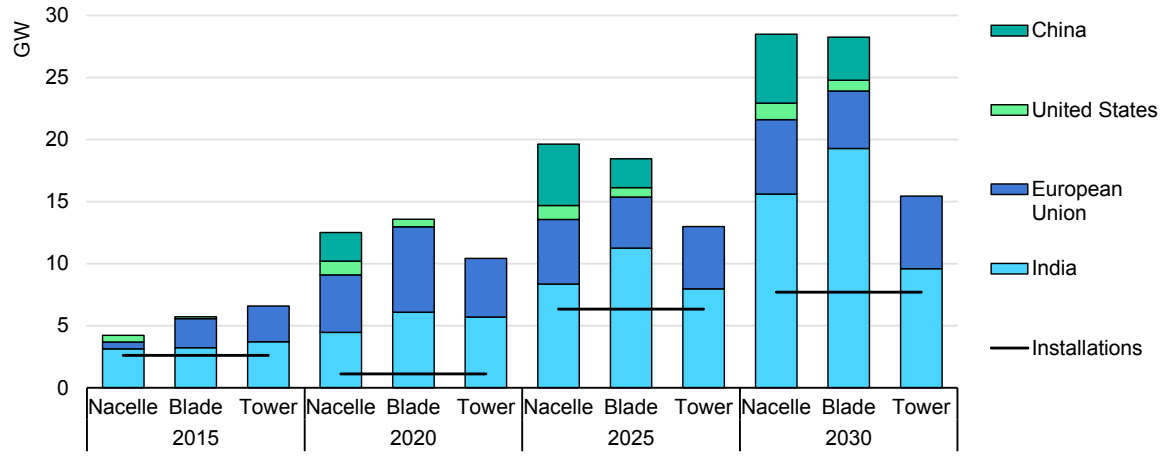
Wind

Supported by a large domestic market, early policy support for wind power deployment and a strong industrial base, India developed substantial manufacturing capabilities across the wind supply chain well before the recent expansion of solar PV manufacturing. Today, India hosts production facilities for nacelles, blades, towers, generators, gear-boxes, castings, forgings and other key components, serving both domestic and international markets.

Manufacturing expansion trends

The development of India's wind manufacturing sector closely followed the growth of its domestic wind market. During the 2000s and early 2010s, policy measures supported rapid deployment of wind projects and created stable demand for locally manufactured equipment. As a result, India had already become a significant manufacturing base by 2015, with domestic companies establishing integrated manufacturing capabilities and extensive servicing networks.

India onshore wind manufacturing capacity by company headquarters, 2015-2030



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Sources: IEA analysis based on data from BNEF and S&P.

The industry became increasingly international during the second half of the 2010s. By 2020, most leading global wind turbine manufacturers had established

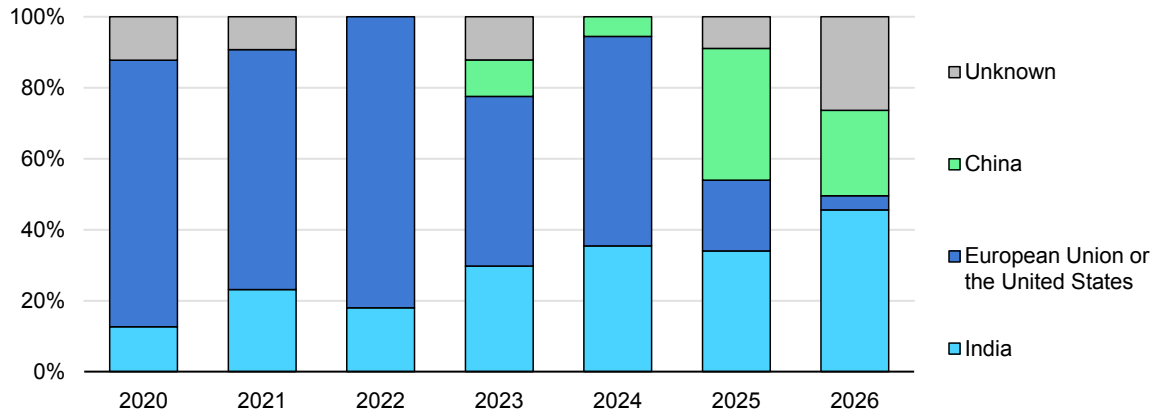
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production facilities in India. These companies increasingly integrated Indian factories into their global supply chains; these facilities both served domestic demand and acted as an export platform for nacelles, blades and towers. The combination of relatively low manufacturing costs, engineering capabilities and an established supplier ecosystem made India one of the most attractive wind manufacturing locations outside China.

Despite periods of relatively slow domestic deployment following the transition from feed-in tariffs to competitive auctions, manufacturing capacity continued to expand. The industry increasingly benefited from exports and expectations of stronger domestic growth.

By 2025, India's manufacturing capacity reached almost 20 GW for nacelles, approximately 18 GW for blades and around 13 GW for towers. Capacity expansion was driven by investments from both domestic manufacturers and international companies, including growing participation by Chinese original equipment manufacturers seeking overseas growth opportunities in response to slowing deployment growth and manufacturing overcapacity in China. Based on announced projects, manufacturing capacity is expected to increase further by 2030 to more than 28 GW annually for nacelles and blades and around 15 GW for towers. The majority of this expansion is expected to come from domestic manufacturers. Compared with expected annual installations of approximately 6-7 GW during 2026-30, India would be able to supply all domestic demand for major wind turbine components through local manufacturing.

Market shares in India wind turbine installation by OEM headquarters, 2020-2026



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Note: OEM = original equipment manufacturer.
Sources: IEA analysis based on data from BNEF and S&P.

The competitive landscape of the Indian wind market has also evolved considerably in recent years. Domestic manufacturers have steadily increased their market share, supported by investments in larger turbine platforms,

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expanded manufacturing capacity and improved project execution capabilities. The share of annual installations supplied by Indian original equipment manufacturers increased from approximately 13% in 2020 to around one-third in 2025. Based on announced contracts and project pipelines, this share could increase further to approximately 45% in 2026.

Much of this growth is expected to come at the expense of European and US manufacturers, some of which have reduced manufacturing activities in India as part of broader efforts to focus on core markets and improve profitability. At the same time, Chinese manufacturers have expanded their presence in the Indian market and increasingly compete for contracts in hybrid and utility-scale projects.

The Indian wind industry is also undergoing a technological transition towards larger turbines. During 2022-2024, most newly installed turbines were in the 3-4 MW range. However, manufacturers are increasingly introducing 4 MW and 5 MW platforms, reflecting global trends towards larger and more productive turbines. Both domestic and international manufacturers have announced new models targeting these higher power ratings. Larger turbines generally improve project economics by increasing capacity factors, reducing balance-of-plant costs and improving the use of land and transmission infrastructure. This transition is expected to continue throughout the forecast period, similar to developments already observed in most mature wind markets.

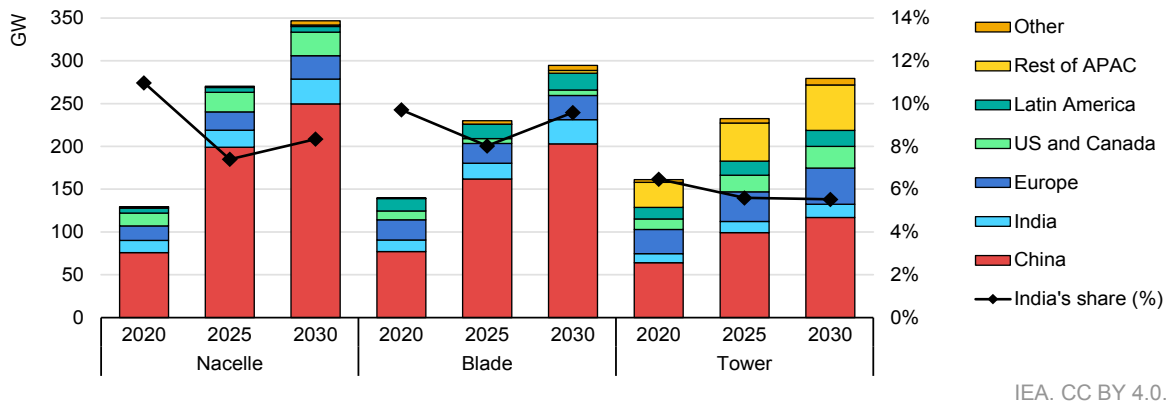
International competition

In the global context, in 2025, India ranked among the leading wind turbine manufacturing locations globally, accounting for approximately 6-8% of worldwide capacity across major turbine components. India’s blade manufacturing capacity ranked second globally, nacelle assembly capacity ranked third and tower manufacturing capacity ranked fourth. India’s overall nacelle manufacturing capacity is currently comparable to that of Europe as a whole, and capacity for blades is not far behind. Planned investments and factory expansions are expected to further strengthen India’s position within global wind supply chains by 2030.

Despite substantial manufacturing capacity, exports of complete turbines from Indian original equipment manufacturers have remained relatively limited. Domestic manufacturers have primarily focused on expanding their position within the Indian market and ramping up production after several years of relatively low domestic installations. In contrast, European, US and Chinese manufacturers continue to rely heavily on exports supported by larger international project portfolios and more established global service networks.

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Global onshore wind manufacturing capacity by country and region, and India's share, 2020-2030



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Note: US = United States, APAC = Asia and Pacific.
Sources: IEA analysis based on data from BNEF and S&P.

A rapidly growing group of emerging wind markets is creating new export opportunities. Outside China, Europe and North America, annual wind installations are expected to increase from approximately 14 GW today to around 40 GW by 2030. Many of these markets are highly price sensitive and increasingly seek to diversify equipment sourcing beyond Chinese suppliers. India is well positioned to benefit from this trend owing to its relatively competitive manufacturing costs, large industrial base and growing experience with utility-scale wind deployment.

Several factors could support the international competitiveness of Indian manufacturers. Labour costs remain significantly lower than in advanced economies, while a large domestic market enables economies of scale and supports supply chain development. Furthermore, India's growing experience in manufacturing larger turbine platforms should improve its ability to compete in international tenders. Manufacturers will need to continue investing in research and development, turbine performance improvements and international servicing capabilities to compete effectively with established global players.

Offshore wind opportunities

India's plans to develop offshore wind also create new opportunities for the domestic manufacturing sector. The development of offshore projects will require new capabilities in turbine engineering, foundations, underwater grid connections, marine logistics, specialised vessels and port infrastructure. Building a local offshore supply chain could therefore support industrial development beyond the existing onshore wind sector and provide domestic manufacturers with opportunities to expand their technological capabilities and service offerings.

International experience suggests that developing local offshore wind supply chains requires careful policy design. Excessively stringent local-content

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requirements can increase project costs and delay deployment, particularly in nascent markets where domestic capabilities remain limited. Successful offshore wind strategies therefore typically balance the objectives of cost efficiency, timely project delivery and gradual development of local industrial capabilities. As India prepares for its first offshore wind projects, achieving this balance will be important both for increasing project competitiveness and for maximising long-term industrial benefits.

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Chapter 2. Renewable heat, transport and fuels

Renewable heat

Demand structure

India's thermal energy consumption trends differ markedly from those of colder economies. Heat demand is concentrated in industry, while buildings have very limited space and water heating needs but rising cooling needs. Rapid growth in cooling demand is becoming a defining feature of India's energy system: cooling already accounts for slightly more than 10% of India's total annual electricity demand. Cooling also contributed around 60 GW to peak electricity load in 2024, while air conditioner sales reached around 14 million units and around one in five households own an air conditioning unit. As a result, renewable thermal strategies in India differ from those in colder countries and have greater emphasis on solar water heating, efficient electric water heating, renewable-powered cooling and district cooling. The main renewable heat transition in absolute terms lies in industry.

In the building sector, the main niche for modern renewable heat deployment is water heating, with modern bioenergy and solar water heaters representing the most established technology. India's solar thermal market declined by 24% in 2024, yet total installed solar thermal capacity reached nearly 15 GWh, making India the sixth-largest solar thermal market globally and placing it close to established markets such as Brazil or Germany. Further expansion faces barriers such as falling rooftop solar PV costs and solar PV-supportive net-metering arrangements, which can make electric water heating paired with solar PV more attractive in some segments.

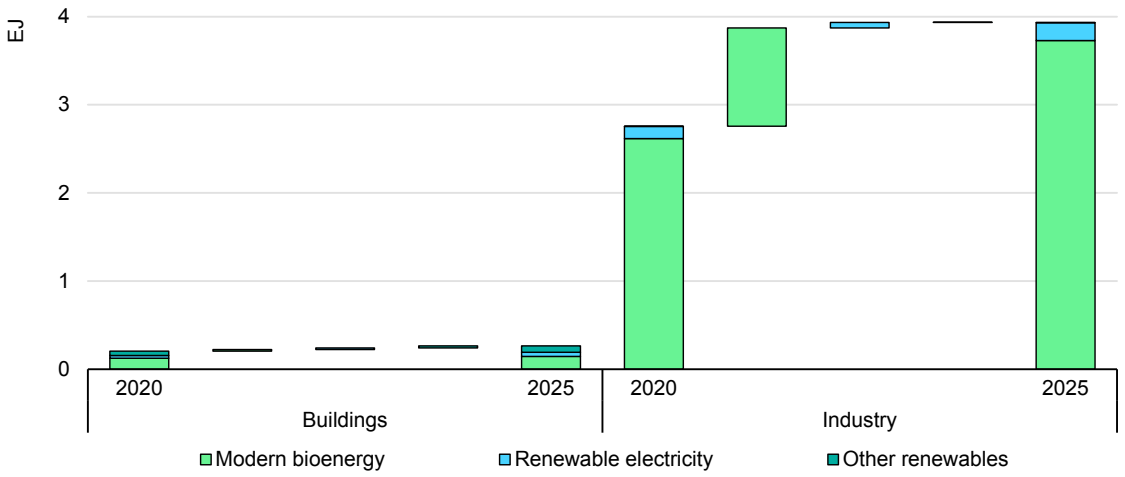
India has made significant progress on access to clean cooking over the past decade: the share of the population with access has more than doubled since 2010, supported by the PM Ujjwala Yogna scheme. However, the traditional use of biomass and biogas for cooking remains an important source of fuel in buildings, mainly in rural areas due to its zero-cost availability. Traditional use of biomass accounts for roughly half of total final energy consumption. Further progress on clean cooking could also support renewable heat uptake, particularly through modern bioenergy and renewable electricity.

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India's industrial heat demand is concentrated in energy-intensive sectors – notably, iron and steel; cement; chemicals and petrochemicals, including fertilisers; and oil refining – alongside important contributions from food processing, textiles, and pulp and paper. These sectors' temperature needs vary widely and impact the choice of the decarbonisation solution: food processing, textiles and parts of the chemicals sector often rely on low- and medium-temperature heat and steam, meaning that electrification, solar energy, process heat, and modern bioenergy can play a larger near-term role. Iron and steel, cement, and oil refining require high-temperature heat that is harder to decarbonise and would require fundamental process changes. Steel can be electrified with mature arc furnaces but requires scrap or iron to be produced with hydrogen. Cement and refining are more likely to depend on biomass (possibly combined with carbon capture, utilisation and storage), renewable hydrogen (also as a feedstock) and alternative production methods over time.

Over the past 5 years, India's annual heat demand increased by approximately 25% (+4 EJ), driven almost entirely by rapid industrialisation, particularly in manufacturing and biomass-based agro-industries, which have significantly increased process heat requirements. Both fossil fuel and renewable heat consumption have increased. Fossil fuels continue to meet most of India's industrial heat demand, accounting for around 70%; the remaining 30% is mostly met by bioenergy, used mainly in the non-metallic minerals, food and tobacco, and pulp and paper sectors.

Changes in the use of modern bioenergy, renewable electricity and other renewables in buildings and industry, 2020 and 2025



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Source: IEA analysis based on IEA data only.

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Recent relevant policy developments

Recent policy developments in India point to a stronger and more differentiated framework for renewable thermal energy in both industry and buildings.

In the **industry** sector:

- The Carbon Credit Trading Scheme is emerging as the main framework for India's compliance carbon market. It provides the basis for the compliance mechanism under the Indian Carbon Market, with obligated entities required to meet greenhouse gas emission-intensity targets and able to trade carbon credit certificates depending on whether they over- or underachieve these targets. The scheme is also expected to gradually take over from the Perform, Achieve and Trade scheme for relevant sectors and entities, with nine energy-intensive sectors identified for gradual transition.
- The National Bio Energy Programme supports the supply and use of renewable fuels for industrial heat. Under the Ministry of New and Renewable Energy's Biomass Programme, financial assistance was available through FY 2025-26 for briquette and pellet manufacturing plants and biomass-based non-bagasse cogeneration projects in industry. Continuation of the programme after March 2026 is subject to budget approval.
- India also promotes waste heat recovery and energy efficiency as part of the Energy Conservation Act, which provides a broader policy framework supporting energy efficiency measures.
- A recent roadmap prepared by the Global Green Growth Institute and the CII-Green Business Centre under the guidance of the Bureau of Energy Efficiency, Ministry of Power, outlines a phased 2026-31 pathway for electrifying selected industrial heat uses. It focuses on technologies such as high-temperature heat pumps, mechanical vapour recompression, electric boilers and battery energy storage.

In the **buildings** sector:

- The Ministry of New and Renewable Energy's Biogas Programme supports the deployment of biogas plants for clean cooking, lighting, thermal and small power needs, particularly in rural areas.
- PM Surya Ghar Muft Bijli Yojana scheme provides capital subsidies for residential rooftop solar PV supporting the electrification of household energy uses including water heating.
- Since 2019, the India Cooling Action Plan has set a non-binding target to reduce cooling energy requirements by 25-40% by 2037-38, alongside goals on cooling demand and refrigerant transition. In 2025, India's District Cooling Roadmap was published, aimed at accelerating the deployment of district cooling systems.

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Outlook for renewable heat in India

Outlook for buildings

Final energy consumption for heat in India's buildings is set to contract by 6% (-0.5 EJ) by 2030, reflecting a continuation of the main drivers observed over the past decade: expanding access to clean cooking, more efficient appliances and a gradual shift away from the traditional use of biomass. The decline in final energy consumption should therefore not be interpreted as a reduction in cooking and heating but as the result of replacing inefficient traditional biomass use with modern, efficient cooking fuels and technologies. As a result, in this projection, the fuel mix shifts strongly away from traditional biomass, which falls by 19%. Fossil fuel use increases by 0.25 EJ, largely reflecting higher use of liquefied petroleum gas and other modern cooking fuels, while modern renewables increase by 40% (+0.1 EJ). Nearly half of this renewable growth comes from renewable electricity, with the remainder split almost evenly between modern bioenergy, also linked primarily to cooking, and solar thermal for water heating.

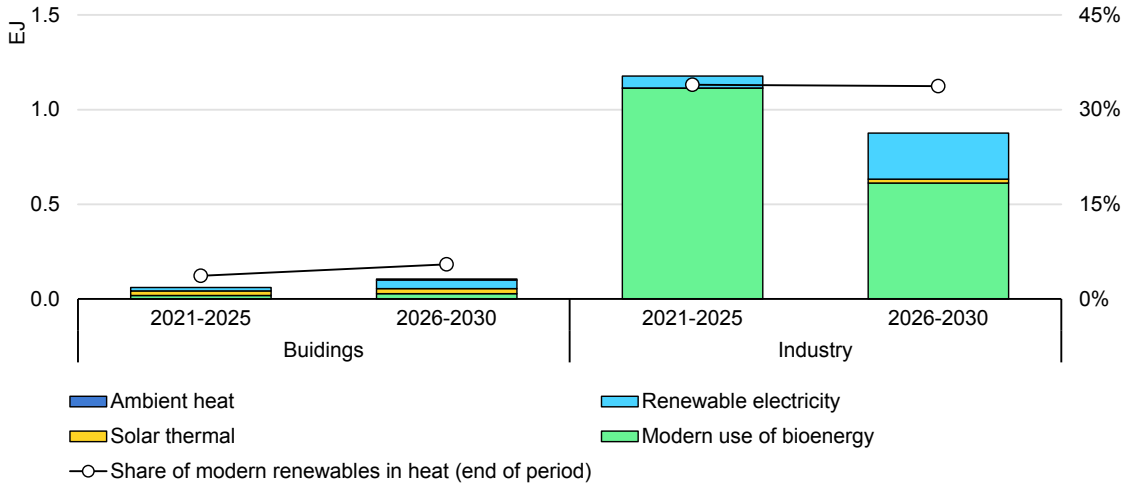
Outlook for industry

Industrial heat demand in India is projected to increase by around 23% (+2.7 EJ) by 2030, largely driven by continued industrialisation. This pace of growth is slower than the increase observed over the previous 5 years, suggesting that industrial heat demand continues to expand rapidly, although with some signs of moderation.

The composition of heat supply in this projection, however, changes only marginally: fossil fuels continue to cover around 70% of industrial heat demand, while renewables maintain a share of around 30%. Renewable heat demand expands by around 22% (+0.9 EJ), but this growth is still dominated by modern bioenergy, which remains the backbone of renewable industrial heat and accounts for around 90% of renewable heat supply by 2030. Newer renewable options grow quickly, but from very small starting points. Renewable electricity more than doubles, driven partly by slightly higher electrification of heat uses, and by the increasing renewable share of electricity generation. Solar thermal increases fivefold, yet remains marginal in absolute terms, while geothermal plays only a very limited role. Overall, the outlook points to strong growth in renewable heat volumes, but limited diversification beyond bioenergy.

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Historical and projected increases in Indian renewable heat use, 2020-2030



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Source: IEA analysis based on IEA data only.

District cooling

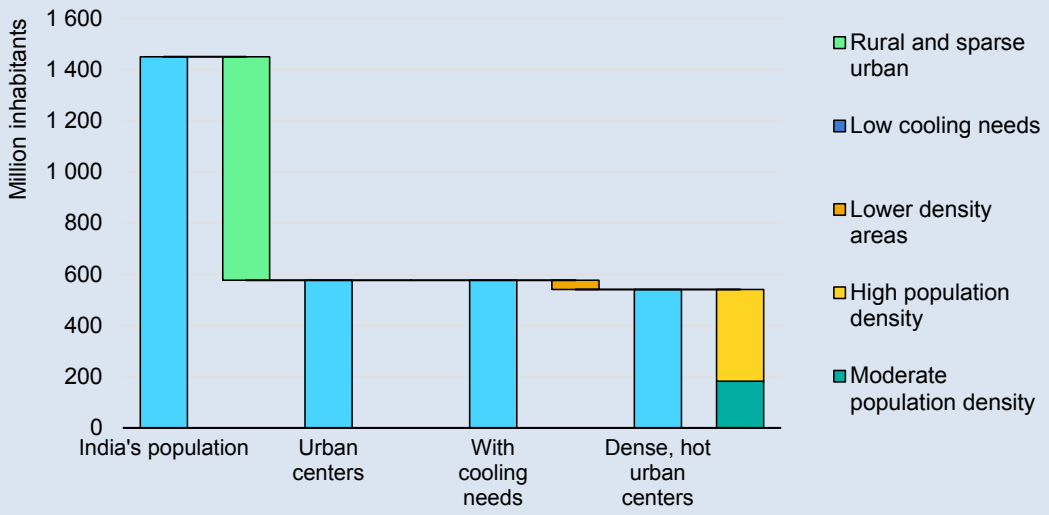
District cooling remains limited globally, with deployment concentrated in a few regions such as the Middle East, most notably the United Arab Emirates, and only a small number of systems in Europe and North America. However, interest is growing as cooling demand rises and urban centres become denser. Pilot projects and early-stage networks are emerging across Southeast Asia and other warm climate regions.

India stands out as a particularly strong case for district cooling. A large and growing share of its population lives in dense urban areas exposed to high temperatures and rising cooling demand across both residential and commercial buildings. Rapid urbanisation, increasing incomes and expanding access to air conditioning are driving sharp increases in electricity demand for cooling, particularly during peak periods. District cooling offers a system-level solution to deliver cooling more efficiently, reduce peak loads and optimise infrastructure use in rapidly growing cities.

Today, around 600 million people in India live in urban areas with high population density and significant cooling demand. Local cooling plans are therefore an essential tool: they help identify where district energy networks are a competitive alternative by mapping demand patterns, available resources and future development zones.

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Population in India filtered by urban centres, cooling needs and density



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Notes: Population and density data are based on the Global Human Settlement Layer Urban Centre Database (R2024A), which includes data on 11 422 quality-controlled urban centres worldwide. Urban centres are defined as contiguous areas with at least 50 000 inhabitants and a minimum population density of 1 500 people per square kilometre. Cooling and heating demand is approximated using population and humidity-weighted cooling degree days (base 18°C) and heating degree days (base 18°C) derived from the IEA's Weather, Climate and Energy Tracker. Population is filtered based on urbanisation, heating and cooling needs, and density thresholds to identify areas where district cooling and district heating and cooling is more likely to be cost-competitive.

Source: Pesaresi, M. et al. (2024), Advances on the Global Human Settlement Layer by joint assessment of Earth Observation and population survey data.

Renewable transport

Deployment trends in India

Renewable energy in transport has been steadily increasing in India as the country seeks to reduce crude oil imports, improve energy security, and lower emissions in the sector. The deployment of clean energy technologies in the transport sector also provides important economic development opportunities across the value chain, especially in rural communities, through the production and distribution of renewable fuels and electric vehicle (EV) manufacturing.

The rapid deployment of liquid biofuels – primarily ethanol in road transport – has been a key driver in the growing share of renewable energy in the transport sector. Between 2020 and 2025, ethanol consumption increased almost sixfold, rising from less than 2 billion litres per year in 2020 to over 11 billion litres per year in 2025 – making India the world's fourth-largest consumer of liquid biofuels.

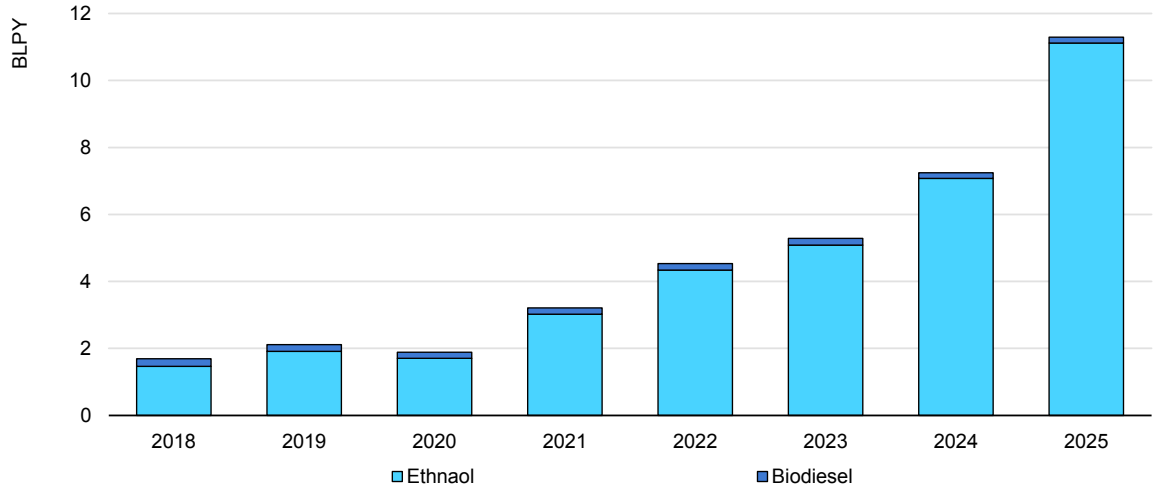
Such rapid growth has been supported by a comprehensive suite of policies. These have included strong supply-side measures such as preferential tax for

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ethanol producers under the Scheme to Enhance Ethanol Distillation Capacity and financial loan support for biorefineries under the Scheme to Enhance Ethanol Distillation Capacity, as well as demand-side measures such as blending mandates set out under India's National Policy on Biofuels, targeting a 20% ethanol blending rate by FY 2025-26 and a 5% biodiesel blending rate by 2030. Innovation and market development-oriented policies such as Pradhan Mantri JI-VAN Yojana, provide funding for demonstration projects producing ethanol from new feedstock and technologies. In addition, India permitted export of second generation ethanol in 2025, reducing producers' risk associated with high reliance on domestic market.

However, while part of India's growing deployment of renewable energy in transport over the last several years, biodiesel's growth has remained limited in comparison to ethanol. Demand-side measures, such as the 5% blending targets set under the National Policy on Biofuels, have been implemented; however, the collection and distribution of used cooking oil, the primary feedstock used in producing biodiesel, remains fragmented and disaggregated. This has limited access to feedstock for biodiesel producers. In addition to these logistical challenges, policy support for biodiesel has not been as robust or comprehensive as for ethanol. To help address these challenges in the short term, India is supporting research in isobutanol blending with diesel to increase the share of renewable energy in the domestic diesel pool. As isobutanol can be produced alongside ethanol, this approach would allow India to leverage its well-established ethanol production value chain while biodiesel feedstock constraints are addressed over the medium term.

Liquid biofuel demand in India, 2018-2025



IEA. CC BY 4.0.

Note: BLPY = billion litres per year.
Source: IEA (2026), India Bioenergy Market Report.

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India is poised to increase its use of liquid biofuels within the aviation sector as part of its strategy to develop domestic production of sustainable aviation fuel (SAF). The country has introduced short-term blending targets applicable for international flights. The targets are set to begin with a 1% SAF blend starting in 2027, rising to 2% in 2028 and reaching 5% by 2030. These incremental targets reflect India's commitment to advancing renewable energy use in aviation and supporting the growth of domestic SAF manufacturing capacity.

The electrification of transport has been increasing alongside the use of liquid biofuels. EV sales have grown to 11% of all new vehicle sales in 2026. In addition, India leads global demand growth in electrified three-wheeler vehicles. This growth has been supported by strong policy measures such as the Faster Adoption and Manufacturing of Electric Vehicles (FAME) Scheme, in force until March 2024, and PM Electric Drive Revolution in Innovative Vehicle Enhancement (PM E-DRIVE) Scheme notified in September 2024. Schemes include a suite of supply- and demand-oriented measures, such as tax reductions on the purchase of vehicles for consumers, PLI for manufacturers to lower production costs, and support for battery innovation.

Outlook for renewable transport in India

Renewable energy in the transport sector will continue increasing due to growing demand from the road and aviation sectors. This demand growth is driven by a mix of regulatory and policy measures supporting environmental and energy security objectives, while also creating new economic opportunities in EV manufacturing, liquid biofuel production and regional exports.

Road transport

India's vehicle fleet is projected to expand by more than 450 million vehicles by 2030. Electrification of road transport is expected to continue to increase, accounting for nearly 30% of new vehicle sales by the end of the decade. The PM E-DRIVE Scheme, as well as the PLI scheme for automobile and auto components and the PLI scheme on advanced chemistry cell battery storage, which provide funding for manufacturing of automobile components and batteries are expected to drive this growth.

The production of liquid biofuels is also expected to grow as overall fuel demand increases in road transport. In the main case – which assumes current policies continue to be implemented for ethanol and biodiesel, market conditions remain consistent, and feedstock challenges continue for biodiesel producers – liquid biofuels supply is expected to grow by more than 35% between 2025 and 2030, from just over 11 billion litres per year to 16 billion litres per year. Ethanol is anticipated to make up almost all this growth, driven by continuing achievement of

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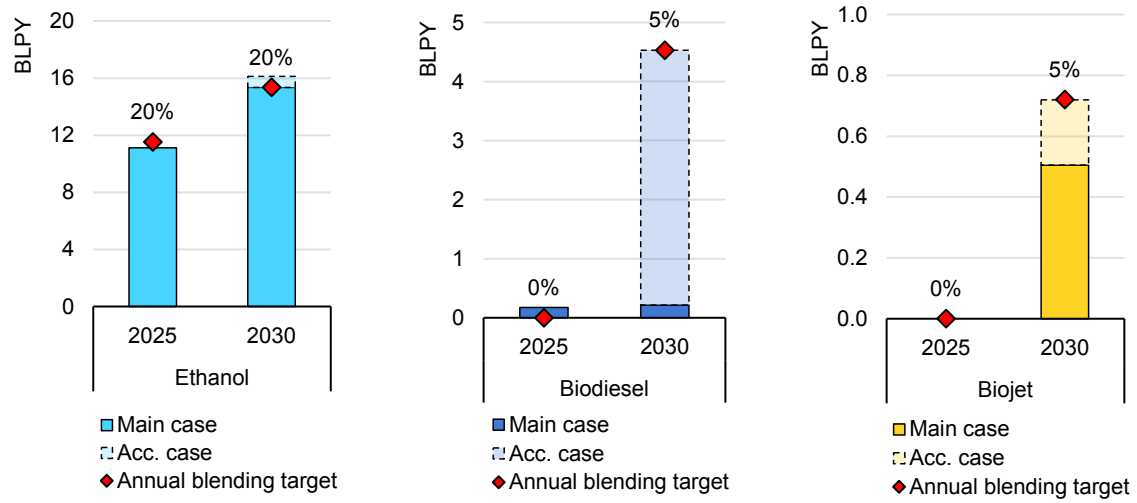
20% blending rate and further implementation of a strong suite of supportive policies. Biodiesel growth remains limited due to continued feedstock challenges.

In the accelerated case, ethanol blending targets continue to be met, and biodiesel targets are achieved by resolving feedstock constraints and expanding production capacity. Under these conditions, liquid biofuel use increases by more than 80% between 2025 and 2030, from just over 11 billion litres per year to more than 20 billion litres per year.

Ethanol supply grows 45%, in the accelerated case, from 11 billion litres per year to more than 16 billion litres per year, with greater demand anticipated from the deployment of flexible-fuel vehicles capable of operating on E85, supported through the PLI scheme for flexible-fuel engines, and an assumed blending increase to 21%. Current ethanol production capacity is sufficient to support such supply level but would require facilities to operate at more than 80% capacity; any additional growth in ethanol demand beyond this would likely require additional investments in ethanol production capacity.

Biodiesel supply grows more than twenty-fold between 2025 and 2030 in the accelerated case, from less than 500 million litres per year to more than 4 billion litres per year as India reaches its 5% blending target. Supply increase is achieved by improving the collection and distribution of existing and new feedstocks (e.g. used cooking oil, oil crops), doubling current biodiesel production capacity, and deploying other supportive supply and demand policies, as has been implemented for ethanol.

Liquid biofuel supply forecast, main and accelerated cases, India, 2025-2030



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Notes: BLPY = billion litres per year. Blending targets are based on total, gas, diesel and kerosene demand. *Main case* refers to the forecast main case. *Acc. case* refers to the forecast accelerated case.

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Aviation transport

Demand for renewable energy in aviation transport is expected to grow through 2030. In 2024, India had more than 228 million domestic air passengers and 64.5 million international air passengers. By 2030, domestic air traffic alone could reach 300 million domestic passengers. SAF is currently the only technically viable option to reduce emissions in aviation; therefore, with India's 5% blending target by 2030, SAF demand is anticipated to increase.

In the main case, India biojet[11] production grows to more than 500 million litres per year by 2030. This assumes that various announced projects begin producing SAF by the end of the decade. Several Indian oil marketing companies have begun expanding production of co-processing. For instance, Indian Oil is planning to produce 38 million litres per year at its Panipat refinery in Haryana from used cooking oil after having received an International Sustainability & Carbon Certification CORSIA in 2025. Production capacity is also expected to increase with advances in technology such as Indian Oil's announced partnership with LanzaJet to develop an additional 109 million litres per year of SAF production capacity at the Panipat refinery, using alcohol-to-jet technology, with production expected to begin by early 2028.

In the accelerated case, biojet production could exceed 700 million litres per year. This assumes India's 5% SAF blending target is achieved by 2030 through increasing access to oil and fat feedstocks for use in commercially available technology, such as hydroprocessed esters and fatty acids. In addition, emerging technologies, such as alcohol-to-jet, are scaled up to commercial levels to leverage other sources of feedstock (e.g. corn, sugarcane). Production capacity beyond what is currently announced is also scaled up through supportive supply, demand and innovation policies to ensure sufficient supply from different feedstocks and technologies.

Biogases

Biogases are important for India's fast-growing gas market. They are produced from domestic resources, which helps improve energy security and reduce imports of fossil fuels. They also support economic development and create jobs, especially in rural areas, while lowering greenhouse gas emissions. These benefits align closely with India's national energy and climate objectives, enabling the country to leverage its domestic resources to support cleaner energy growth. India's abundant agricultural residues and organic waste provide a strong resource base for the production of biogases.

[11] Biojet is an SAF produced primarily from biomass feedstocks. SAF can also be produced from low-emission hydrogen and carbon dioxide (e.g. synthetic fuels). This report only includes SAF produced from biomass (e.g. biojet).

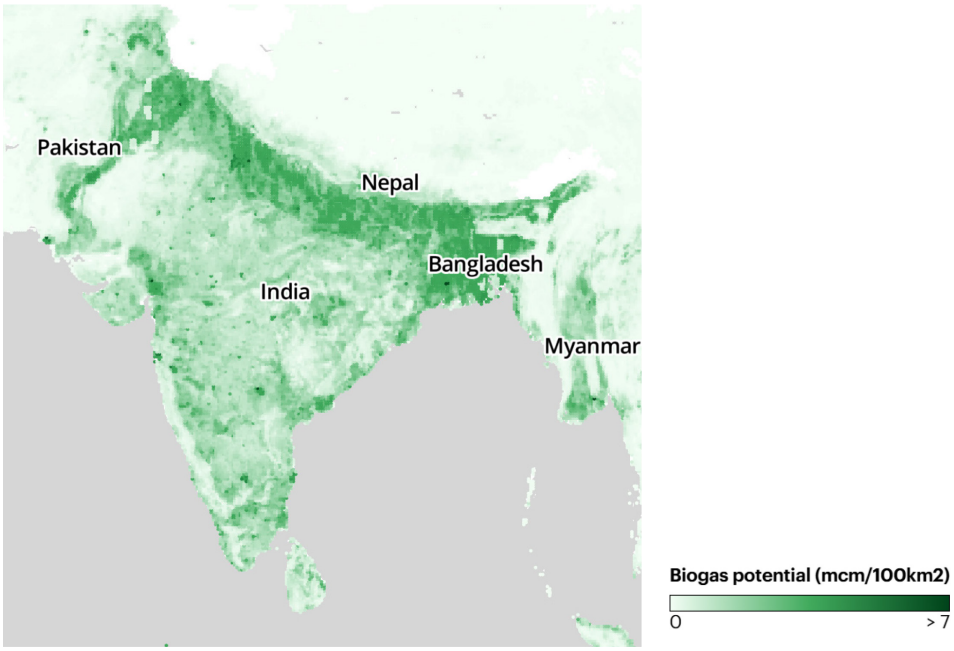
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Biogases include two types of gas stream: biogas and biomethane or compressed biogas (CBG). Biogas, with a typical methane content of around 60%, is the raw gas output from the anaerobic digestion of organic matter. It can be used on site as a fuel for cooking, lighting, industrial heat or power generation. CBG is obtained by purifying biogas to increase its methane concentration to a minimum of 95%, according to the latest quality standard (Indian Standard (IS) 16087:2025). CBG has a similar composition to fossil natural gas and can replace it without further final equipment or infrastructure adaptation.

Feedstock potential

India's resource base for biogases is particularly strong, with a wide range of feedstocks available across the country. Based on the latest IEA assessments[12], India could sustainably produce up to 75 billion cubic metres equivalent[13] of CBG annually, equivalent to 110% of its 2025's natural gas demand. Crop residues account for half of this potential, followed by manure and municipal and industrial organic waste. This creates opportunities for renewable energy production and for addressing environmental challenges such as open-field burning of agricultural residues.

Assessed potential for biogases development in India and surrounding areas, 2025



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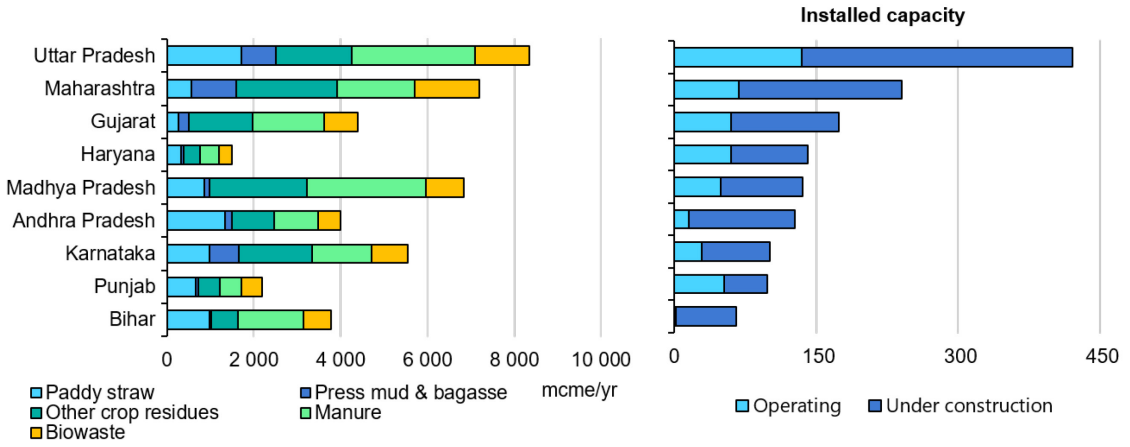
Source: IEA (2026), Interactive Map of Global Biogas and Biomethane Potential, (accessed 23 September 2026).

[12] The IEA has reviewed and refined certain parameters used to estimate feedstock potential for selected crops. The resulting estimates update those presented in the IEA India Bioenergy Market report published in January 2026.
[13] One billion cubic metres equivalent is a measure of energy used in this report as equal to 36 PJ, based on the lower heating value of CBG.

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Feedstock potential is well distributed across the country. The states in the Ganges Valley (Uttar Pradesh, Bihar, West Bengal, Punjab, Haryana, Jharkhand, Uttarakhand and Delhi) account for 29% of the total, and Maharashtra, Madhya Pradesh, Rajasthan and Karnataka contribute an additional 34%. Uttar Pradesh, Maharashtra and Gujarat concentrate the largest installed and announced capacity in the country, broadly aligned with their feedstock potential.

CBG potential by feedstock in selected states in India, 2025



IEA. CC BY 4.0.

Note: mcme = million cubic metres equivalent.
Source: IEA (2026), Interactive Map of Global Biogas and Biomethane Potential, (accessed 23 September 2026).

Current status, policy trends and forecast to 2030

India has a long history of biogas production, with the deployment of small household facilities expanding significantly after the 1980s in rural areas and reaching over 5.2 million installed units, backed by the national Biogas Programme under the Ministry of New and Renewable Energy. These plants mainly use animal manure as feedstock and provide biogas for clean cooking or lighting in households. However, installation of new units has slowed in recent years, and a significant portion of installed small-scale plants are ageing or inactive, reducing their contribution to current production. It is estimated that around 500 000 small plants are currently operative, producing around 313 million cubic metres equivalent per year.

Additionally, community-scale plants for heat and power production in off-grid areas, as well as industrial biogas plants supported through the Ministry of New and Renewable Energy's Waste to Energy financial assistance, contribute approximately another 560 million cubic metres equivalent of biogas per year.

Overall, biogas production is slowly declining, mainly due to the ageing of the small-plant fleet. Programmes supporting the installation of new biogas plants or the upgrading of existing ones to CBG or power production, the Waste to Energy

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Programme and the Biogas Programme, are pending an announcement of extension after FY 2025/26.

The production of biomethane or CBG, however, has recently entered a phase of strong growth, moving towards large-scale deployment. CBG production has increased rapidly in the last 5 years, growing more than eightfold between 2020 and 2025. The new major national policies put in place since 2018 have attracted significant investment interest; there were around 170 functional plants by 2025 and almost 300 more under construction. CBG is typically produced in medium- and large-scale plants, where upgrading technologies can benefit from economies of scale and greater efficiency.

However, operational performance in these new plants remains a concern. Low utilisation rates – often between 20% and 60% – significantly decrease actual output compared with design capacity and contribute to higher production costs.

Policy support has been instrumental in driving early investment in the CBG sector, particularly through guaranteed offtake and fixed prices through the Sustainable Alternative Towards Affordable Transportation (SATAT) scheme and infrastructure support through the CBG–City Gas Distribution (CGD) Synchronisation scheme, both under the Ministry of Petroleum and Natural Gas. The introduction of the CBG blending obligation in 2023 is a critical step forward, mandating a gradual increase in biomethane use in transport (as bio-compressed natural gas) and domestic piped gas starting from 1% in FY 2025/26 to 5% by FY 2028/29. The blending obligation provides a long-term demand signal but would require stronger enforcement mechanisms to ensure compliance and effectiveness. In addition, CBG projects can apply for central financing assistance as well as other subsidies from certain states.

In August 2026, the Ministry of Petroleum and Natural Gas launched the GOBARdhan National Unified Scheme for Compressed Biogas, consolidating previous policy support under a unified framework with a dedicated budget of INR 237 billion. The scheme runs from FY 2026/27 to FY 2035/36 with several components, including CBG offtake assurance, a CBG pricing framework, capital assistance, pipeline infrastructure, support for feedstock aggregation equipment and credit guarantee support.

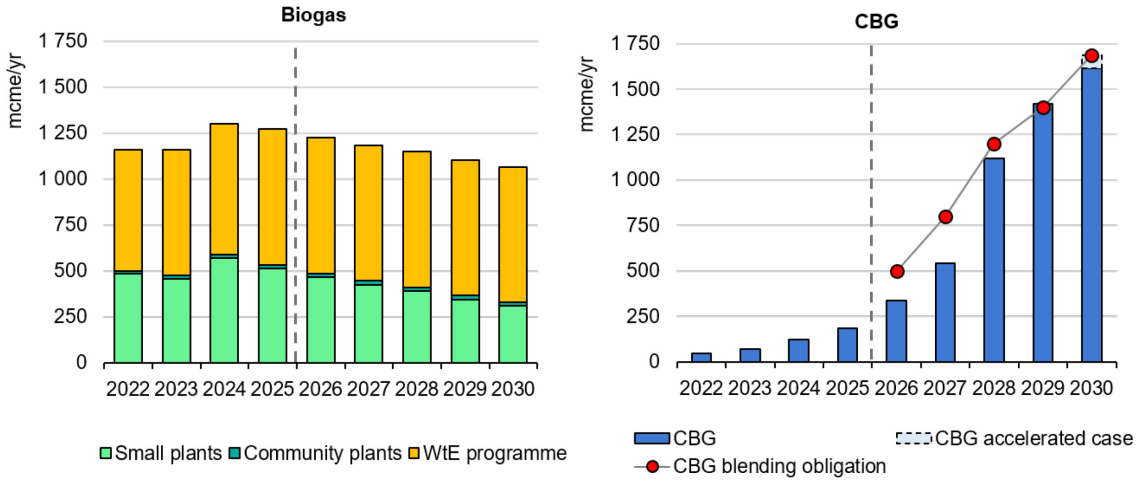
From the demand perspective, CBG's versatility is underscored by its compatibility with existing natural gas infrastructure and equipment, enabling seamless use in transport, industry and households without significant modifications. Furthermore, India's government aims to increase natural gas consumption and expand gas infrastructure, under the One Nation One Gas Grid initiative, targeting a rise in the energy share of natural gas from the current 6-7% to 15% by 2030. The natural gas infrastructure expansion will also drive the demand growth for CBG.

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The transport sector is the most dynamic CBG segment, driven by the rapid growth of compressed natural gas vehicles and service stations and the support of the SATAT programme – now superseded by the GOBARdhan framework – and the CBG-CGD Synchronisation scheme. Industrial use is also gaining attention, particularly in sectors seeking to reduce emissions. Future growth in industrial demand will depend on the development of carbon markets and certification systems and on improved access of CBG to gas grids.

Looking ahead, the sector is poised for rapid expansion. According to planned and under-construction projects registered at the unified GOBARdhan registry, CBG production in India is expected to grow more than sevenfold by 2030. The project pipeline is rapidly increasing, indicating that forecast projections will be close to the blending targets set by the government (considered as an accelerated case in this study). In parallel to attracting investment, optimising plant operability all year round remains key as it reduces the need for additional investment while lowering production costs.

Estimated biogas and CBG production in India, 2022-2025, and forecast to 2030



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Notes: mcme = million cubic metres equivalent; WtE = Waste to Energy programme. CBG planned projects that have not yet begun construction were assigned a 40% success rate. A capacity factor of 35% was applied to all CBG projects. CBG blending obligation volumes are based on the Petroleum Natural Gas Regulatory Board's Good-to-Go projections.

Sources: IEA analysis based on data from India, Ministry of New and Renewable Energy Annual Reports 2017-18 to 2024-25, GOBARdhan Unified Registration Portal, December 2025.

Key challenges for scaling up

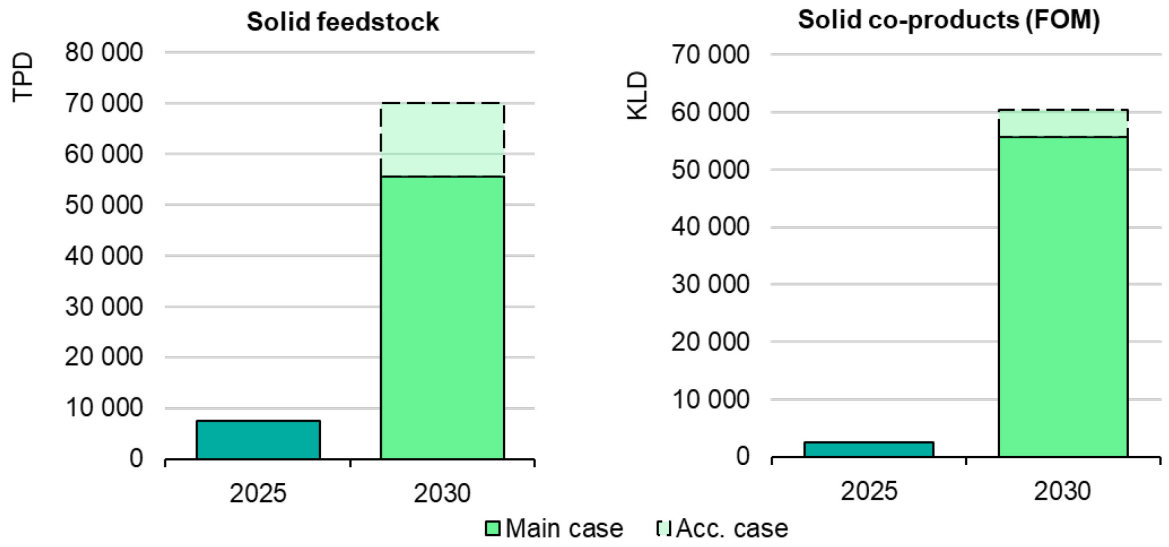
The scale-up of CBG production introduces new complexities, particularly in developing integrated value chains for feedstock supply, processing and distribution.

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Feedstock logistics are one of the most significant challenges. Despite abundant potential, feedstock supply chains are fragmented, seasonal and costly. For instance, agricultural residues are widely dispersed across small farms, paddy straw is available only within a short collection window, and municipal waste streams are generally not segregated. The competing uses and long-distance transport associated with feedstock add further cost and complexity. To address these constraints, aggregation models such as farmer organisations are beginning to emerge, while government initiatives like the Biomass Aggregation Machinery scheme, which subsidises balers, rakers, trolleys and other transport equipment, are helping mechanise crop residue collection at scale. Even so, feedstock aggregation, storage and quality control remain among the most critical bottlenecks to sector expansion.

Co-product management is another key consideration. The digestion process generates large volumes of organic residue that can be converted into fermented organic manure, a valuable soil enhancer. However, the market for fermented organic manure is still developing and presents some logistical issues due to the low value per tonne of the product. Strengthening co-product markets through harmonised standards, quality testing and policy support to develop marketing alternatives is therefore essential to improve project viability and ensure continuous plant operation. Measures such as the Market Development Assistance scheme are intended to accelerate this development.

CBG feedstock needs and digestate co-products in India, 2025 and forecast to 2030



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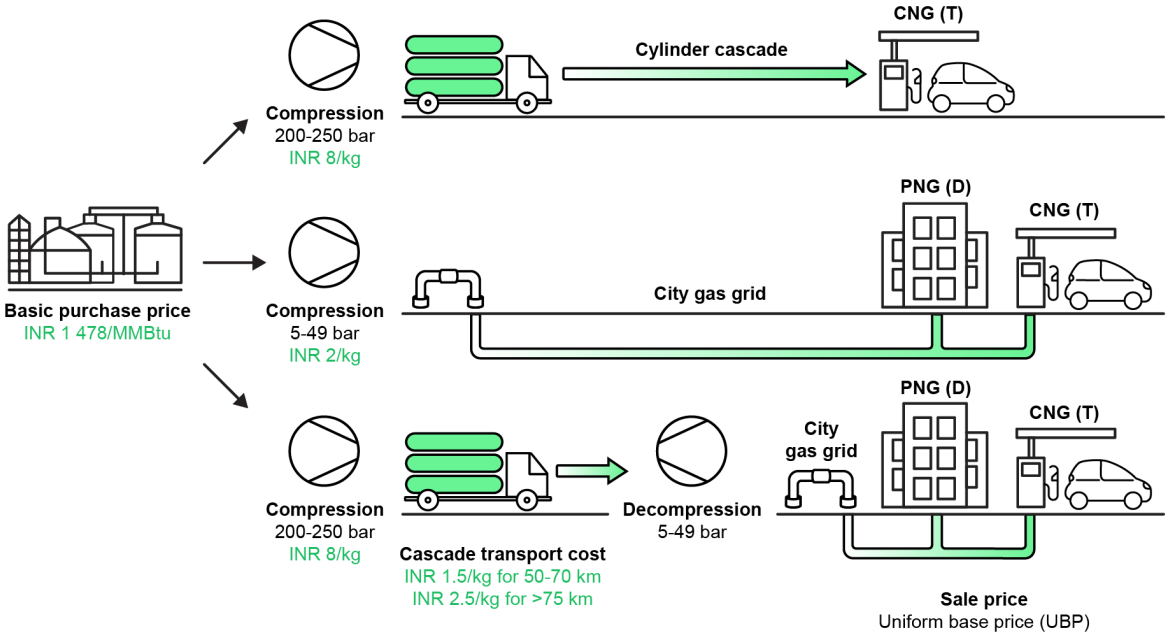
Note: Acc. case = accelerated case; FOM = solid fermented organic manure; KLD = thousand litres per day; TPD = tonnes per day.

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With the current pipeline of projects, feedstock demand and digestate output are expected to increase by an order of magnitude by 2030. To sustain this rapid growth, CBG plant expansion must be matched by a comparable scale-up of feedstock supply chains and the development of robust markets for the fermented organic manure produced by CBG plants.

Gas infrastructure is a key enabler of CBG scale-up. With only 21% of plants connected to city gas grids as of end of 2025, most CBG is still transported via costly mobile cascades with pressurised cylinders. Expanding pipelines and injection points are therefore critical to decrease costs and provide more flexible gas offtake, with government tools such as the CBG-CGD Synchronisation scheme and the Development of Pipeline Infrastructure scheme subsidising transport costs and the construction of connecting infrastructure.

Options for CBG delivery to retail outlets and domestic users under the CBG-CGD Synchronisation scheme



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Notes: MMBtu = million British thermal units; PNG = piped natural gas. Basic purchase price set in June 2025. Transportation and compression charges are from the pricing structure under the CBG-CGD Synchronisation scheme, applicable from 1 November 2025 to 30 April 2026.

Source: IEA (2026), India Bioenergy Market Report.

From a sustainability perspective, biogas and CBG offer significant potential to reduce greenhouse gas emissions, especially from waste-based production. However, their impact depends on the full life cycle, including feedstock sourcing, process efficiency and methane leakage control. Robust sustainability frameworks, monitoring systems and clear carbon accounting are necessary to

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ensure full environmental benefits. Carbon accounting frameworks are also essential to set up certification systems that reward renewable fuel producers.

Hydrogen

Current status

Hydrogen demand in India was just below 10 Mt in 2025. It was concentrated in refining, which accounted for more than 40% of demand; fertiliser production, at more than 30%; and direct reduced iron production in the steel sector, at close to 25%.

Most hydrogen in India is produced from natural gas, which itself is mostly imported and subject to volatile prices and supply disruptions, as observed during 2026, as a consequence of the conflict in the Middle East. Supply shortages led gas deliveries to fertiliser plants to be cut to 70% of normal levels in India, where around one-quarter of ammonia production is based on gas imported from the Middle East.

Renewable hydrogen can therefore support two objectives in India: reducing greenhouse gas emissions and strengthening the resilience of supply chains for hydrogen-based products.

Projects pipeline

India launched the National Green Hydrogen Mission in January 2023. Its objective is to make India a global hub for the production, use and export of renewable hydrogen and its derivatives. The Mission aims to build capacity to produce at least 5 Mt of renewable hydrogen by 2030. This policy signal spurred a rapid increase in project announcements. India moved from almost no projects under development in 2021 to one of the largest announced project pipelines globally.

More than 2 Mt of renewable hydrogen could be produced in 2030 if all announced projects are delivered on time. This volume is around 40% of the Mission's target. Progress towards implementation has nevertheless been slow. Only around 0.1 Mt of potential production has reached a final investment decision, although there are some notable examples of success, such as AM Green's project at Kakinada.

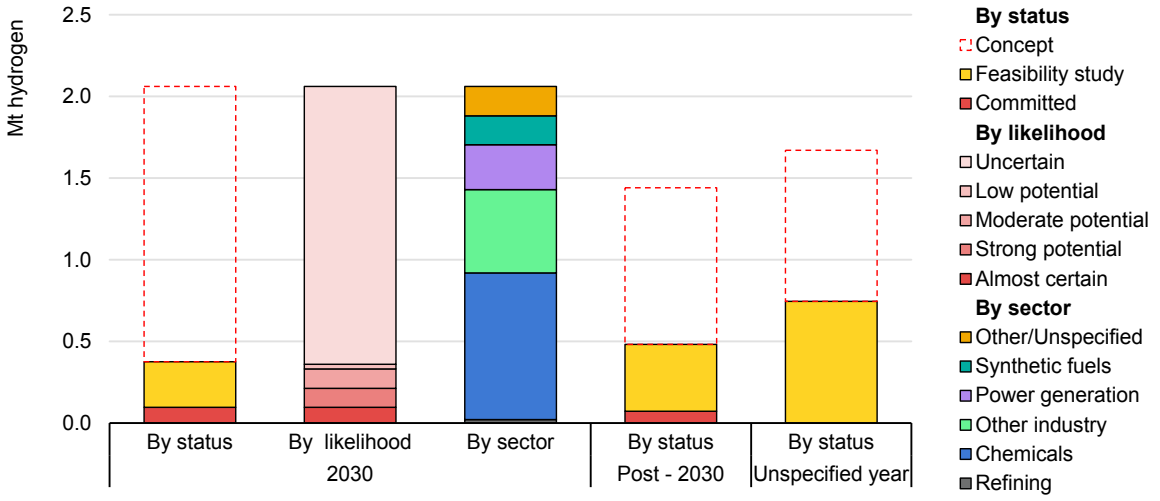
The project is the world's second-largest electrolysis project to have reached final investment decision, after NEOM Green Hydrogen in Saudi Arabia. It plans to have 1.9 GW of electrolysis capacity and aims to produce up to 2 Mt of ammonia. It reached final investment decision in August 2024 for the first million tonnes of ammonia production. It has also signed firm offtake agreements for 750 kt of

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ammonia with Yara and Uniper for exports to Europe, and it was recently named the winner of the Asian lot in the H2Global auction.

IEA analysis indicates that a further 0.25 Mt of potential production has a strong or moderate potential to be operative by 2030, based on project status, size and target end users. The scale of many announced projects and typical development lead times mean that much of the remaining pipeline is better placed to start operation after 2030. A further 1.5 Mt is associated with projects already targeting operation after 2030, while projects representing 1.7 Mt have not yet announced a target start date. Overall, the whole project pipeline would be enough to meet the ambitions of the National Green Hydrogen Mission, although project delivery plans are not aligned with policy ambitions.

Renewable hydrogen production from announced projects in India



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Policy schemes

To meet these ambitions, the government of India has taken decisive steps to establish a comprehensive policy framework that combines standards, supply incentives, demand aggregation, common infrastructure development and support for technology manufacturing.

In August 2023, the Ministry of New and Renewable Energy established the Green Hydrogen Standard. The standard sets an emissions threshold of 2 kg CO_2-eq/kg H_2 for hydrogen produced through electrolysis or biomass conversion. In April 2025, the Ministry implemented a Green Hydrogen Certification Scheme to assess compliance with the standard and, in June 2026, launched a Green Hydrogen Certification Portal to administer the certification scheme and facilitate transparency in compliance processes. In February 2026, the Ministry issued Green Ammonia and Green Methanol Standards. These set thresholds below

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0.38 kg CO_2-eq/kg ammonia and below 0.44 kg CO_2-eq/kg methanol. Carbon dioxide used for methanol may come from biogenic sources, direct air capture or existing industrial sources. The Ministry is to issue separate detailed methods for measurement, reporting, monitoring, on-site verification and certification.

Financial support is channelled through the Strategic Interventions for Green Hydrogen Transition (SIGHT) Programme, which provides support to the private sector via tenders organised in two components: one to support domestic electrolyser manufacturing and another to support production and demand aggregation:

- Component I has launched two tenders to support domestic electrolyser manufacturing. The first tender, launched in 2023, provided payments that declined over 5 years, from INR 4 440/kW (USD 53/kW) in the first year to INR 1 480/kW (USD 18/kW) in the fifth. The second tender, launched in 2024, included eligibility criteria related to the efficiency of the manufactured electrolysers. The two tenders selected 15 companies with targeted manufacturing capacity of up to 3 GW/year.
- Component II, Mode 1, has launched two tenders to support renewable hydrogen production. Producers receive support for up to 3 years, declining from INR 50/kg H_2 (USD 0.36/kg H_2) in the first year to INR 30/kg H_2 (USD 0.60/kg H_2) in the third. The tenders have supported 862 kt H_2 of production.
- Component II, Mode 2, is a demand aggregation programme in which an intermediary aggregates demand from prospective buyers and tenders the required supply at the lowest available cost. Several tenders have been launched to produce renewable ammonia for fertiliser plants and renewable hydrogen for refineries, and additional tenders for renewable methanol are planned.

Component II, Mode 2, of the SIGHT Programme is particularly innovative, and it has been the first one of its kind aiming to help project developers in the country by addressing demand and offtake risk. The tenders that have already been completed show promising results:

- In August 2024, SECI, acting as the intermediary appointment by the government, launched a tender for 724 kt/year of renewable ammonia for 13 fertiliser plants. The winning bids were announced in August 2025, ranging from INR 49.75/kg NH_3 to INR 64.74/kg NH_3 (equivalent to USD 570-750/t NH_3). These bids remain above typical ammonia import prices in India (USD 330-525/t NH_3 in 2025), representing a 10-130% premium. In March 2026, the government announced that 11 fertiliser companies had signed 10-year supply agreements covering more than 90% of the tendered volume, while two companies had withdrawn because they could no longer take the supply. In September 2026, SECI tendered again the corresponding volumes. Uncertainty remains over whether all agreements will proceed. Some low bids relied on regional incentives that may not materialise, and if SECI has to cover the full premium, the tender's original budget would be exceeded.

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- In the case of the tenders for renewable hydrogen for refineries, state-owned oil and gas companies and the Centre for High Technology were named as intermediaries to implement the scheme. Refineries have used build-own-operate procurement for renewable hydrogen plants. Four contracts, covering annual output of 30 kt of renewable hydrogen, have already been awarded at prices of INR 279-397/kg H_2 (around USD 3.0-4.6/kg H_2). This implies a premium of 30-185% compared with hydrogen produced from unabated natural gas in India (USD 1.6-2.3/kg H_2 over the past five years) and abatement costs of USD 65-295/t CO_2.

Outlook

Taken together, the tender results show why demand creation is central to India's approach. Supply-side support can reduce production costs, but producers still need bankable buyers and commissioning schedules that projects can meet. Demand aggregation gives fertiliser plants access to competitively procured renewable ammonia while providing producers with longer-term purchase commitments. The refinery tenders apply a different model, with suppliers building, owning and operating plants for identified industrial users. Both approaches reveal the remaining cost gap with unabated fossil-based production. They also provide evidence on the level of public support, contractual certainty and project delivery conditions needed to move from announcements to investment and operation.

The SIGHT Programme is complemented by other measures under the National Green Hydrogen Mission, such as a Renewable Hydrogen Hubs programme and several calls to support research and innovation in hydrogen production and its use in steel, heavy-duty transport and shipping. Together, these measures provide a broad foundation for market development. Delivery now depends on converting announced capacity into operating projects, securing viable long-term demand and managing the cost premiums identified through early procurement

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Chapter 3. Energy security implications

Energy consumption in India is rising amid economic and population growth, driven primarily by increasing electricity demand. Since 2019, the country's electricity demand has grown by 5% annually, one of the fastest rates among large economies. In 2025, renewables accounted for nearly all of India's energy demand growth from 2024. Despite renewables' growing role, India remains heavily dependent on fossil fuels for its energy needs. Imports account for over 85% of crude oil requirements and significant volumes of coal and natural gas. This reliance exposes India to energy security risks, particularly amid the current geopolitical situation, which has led to global supply chain disruptions and rising fossil fuel prices. Renewables can play an increasingly critical role in strengthening energy security across the electricity, heat and transport sectors by reducing dependence on imported fuels. This would help India diversify its energy mix, reduce vulnerability to external shocks, and build a more resilient, secure energy system.

Electricity

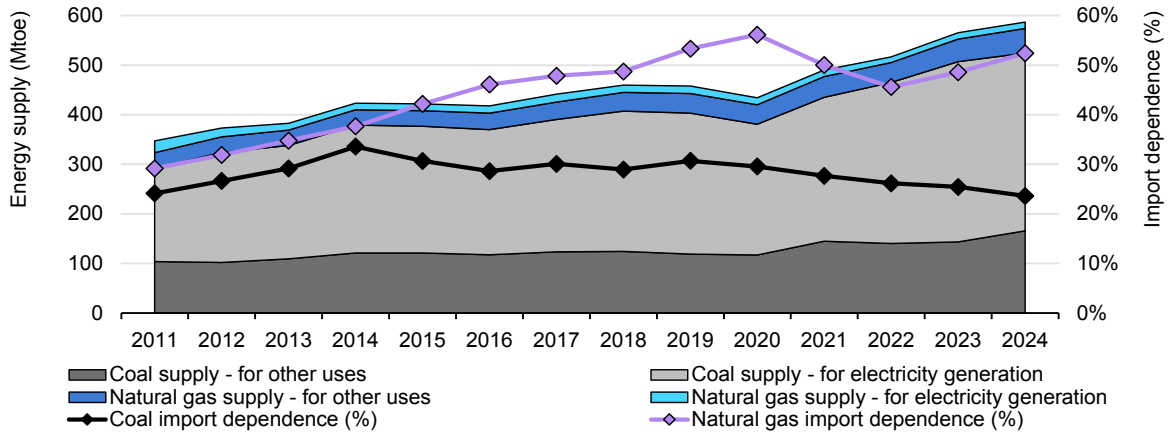
Renewable energy technologies strengthen energy security because they generate electricity without requiring continuous fuel inputs and can utilise domestically produced resources, like biomass. While some critical equipment may need to be imported during construction, renewable power plants can operate for decades with limited external inputs, reducing exposure to fuel supply disruptions and fossil fuel price volatility.

Historical import dependence

These benefits are particularly important in India, where rapidly growing electricity demand has historically increased reliance on imported fossil fuels. Despite being the world's second-largest coal producer, the country has relied on imports to meet a significant share of fossil fuel demand. Before the rapid expansion of solar PV and wind generation and the increase in domestic coal production during the past decade, import dependence for non-coking coal generally ranged between 25% and 30%, with most imports consumed in the power sector. Given that coal accounted for around 70-75% of electricity generation during this period, this created an important vulnerability for the electricity system. Limiting the growth of fossil fuel import dependence associated with rising electricity demand has therefore been one of the key drivers supporting renewable energy deployment.

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Non-coking coal and natural gas supply, consumption for electricity generation, and import dependence of supply, India, 2015-2024



IEA. CC BY 4.0.

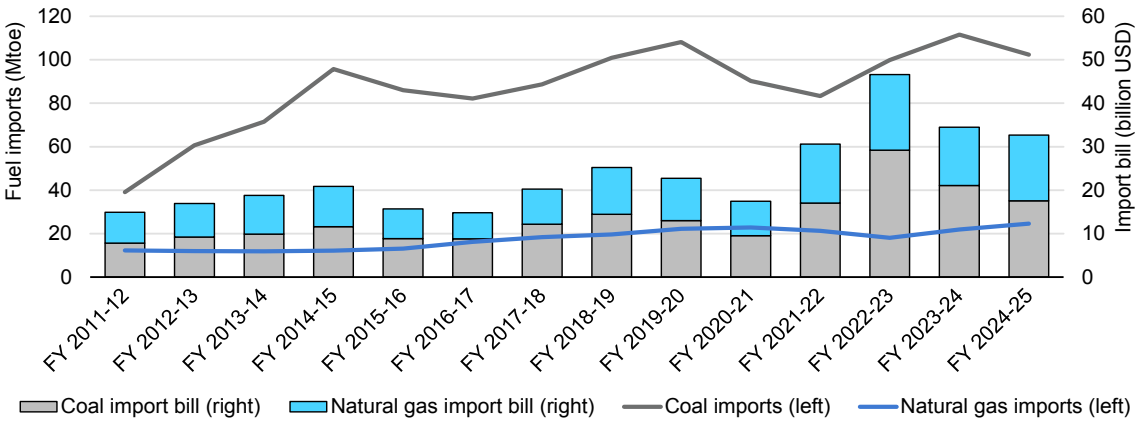
Source: IEA analysis based on data from NITI Aayog.

Natural gas import dependence in India has been even higher, typically ranging between 40% and 55% over the past decade. Although natural gas plays a much smaller role in electricity generation than coal, it remains important in several coastal states, particularly Gujarat, and contributes to overall energy import dependence.

By reducing fossil fuel demand, renewable energy deployment lowers exposure to fossil fuel price shocks and contributes to both energy security and affordability. This became particularly evident during the global energy crisis following the Russian Federation's invasion of Ukraine. Between 2011 and 2021, India's annual import bill for non-coking coal and natural gas averaged approximately USD 19 billion. In FY 2022-23, however, higher fuel prices and growing import volumes increased the combined import bill to USD 46 billion. Although international prices subsequently moderated, import expenditures remained elevated at approximately USD 32-34 billion annually during 2023-2025. These developments highlighted India's continued exposure to international fossil fuel markets and the value of technologies capable of reducing fuel import requirements.

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Non-coking coal and natural gas imports and import bill, India, FY 2015-26 to FY 2024-25



IEA. CC BY 4.0.

Source: IEA analysis based on data from NITI Aayog.

Renewable energy investments also differ fundamentally from fossil fuel imports in their economic impacts. Expenditures on imported fuels largely flow abroad, whereas renewable energy investments are infrastructure intensive and support domestic economic activity through construction, manufacturing, engineering and operations. As domestic renewable manufacturing capabilities expand, an increasing share of investment associated with renewable deployment remains within the national economy.

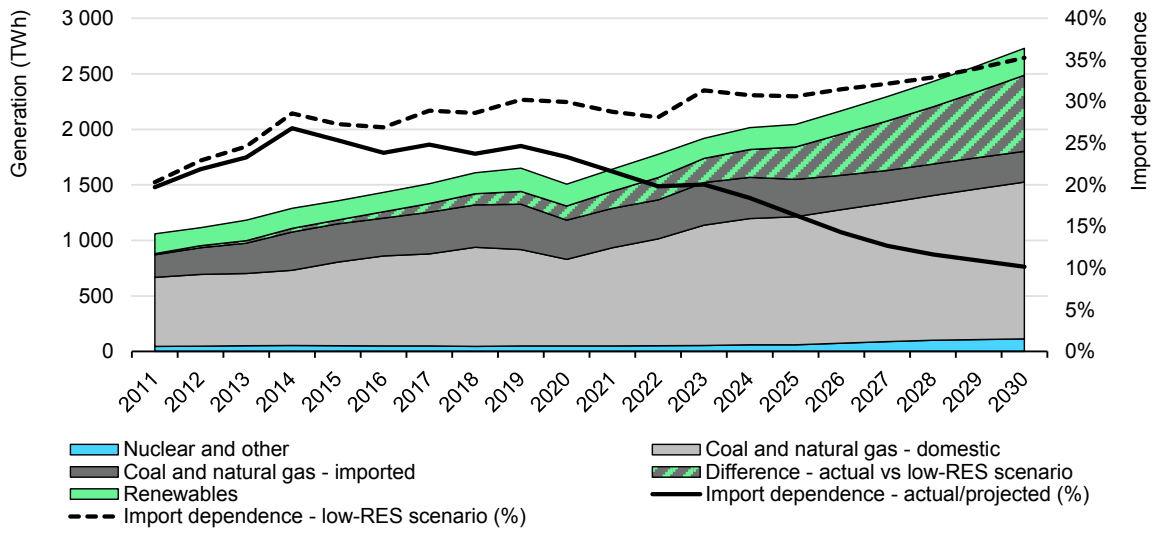
Scenario analysis

To quantify the energy security benefits of renewable energy deployment in India, a counterfactual low renewable energy sources (low-RES) scenario was developed. Under this scenario, no new non-hydro renewable energy capacity is added after 2010. Electricity generated by solar PV, wind and bioenergy in the reference case is instead supplied by coal-fired and gas-fired generation. Hydropower, nuclear and other generation technologies remain unchanged. Additional fossil fuel demand is assumed to be met through imports, reflecting limited scope for expanding domestic production beyond levels achieved historically and projected in current forecasts. The analysis covers historical developments through 2025 and is extended to 2030 using IEA medium-term electricity generation projections.

The results indicate that renewable energy deployment has already significantly reduced India's dependence on imported fuels. Without investments in solar PV and wind, the import dependence of electricity generation would have exceeded 30% in 2025, approximately twice the actual level.

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Electricity generation by source and import dependence, actual vs low-RES scenario, 2011-2030



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Source: IEA analysis based on IEA data and data from NITI Aayog.

Under the low-RES scenario, import dependence would continue increasing to around 35% by 2030, driven by rapidly growing electricity demand despite strong growth in domestic coal production. This contrasts with current projections, under which rapidly expanding renewable generation offsets a large share of demand growth, allowing electricity sector import dependence to decline to approximately 10% by 2030.

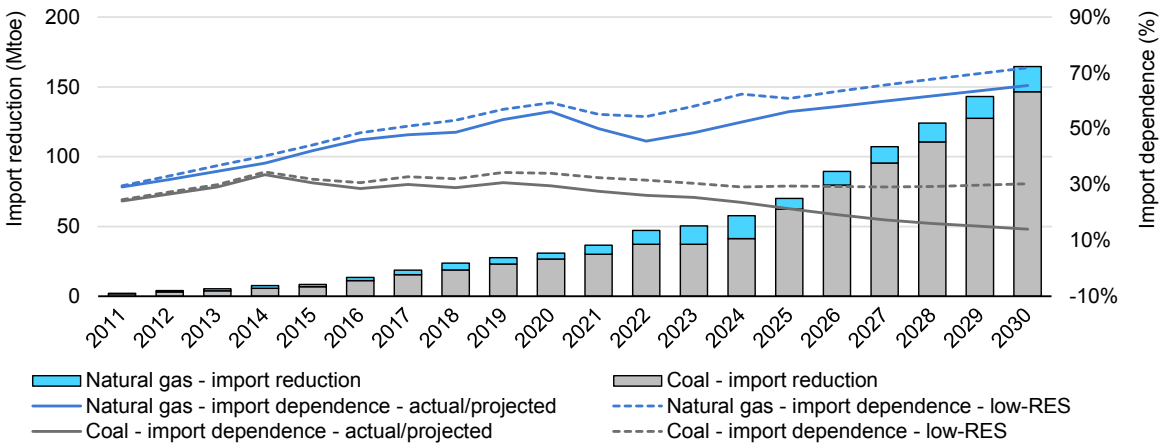
The impact is particularly visible in the coal market. Under the low-RES scenario, coal import dependence remains close to 30% through 2030, compared with less than 15% in the reference case. Annual coal consumption in 2025 would be more than 60 Mtoe higher than observed, equivalent to approximately 110 million tonnes of additional coal demand. This corresponds to around 11% of total coal consumption and more than half of actual coal imports in that year.

The divergence widens further by 2030. Coal demand in the low-RES scenario exceeds the reference case by more than 145 Mtoe, equivalent to approximately 265 million tonnes. This represents around 26% of projected coal consumption and almost four times projected net coal imports in 2030.

Natural gas import dependence is also higher in the absence of renewable deployment, although to a lower extent than with coal. By 2030, gas import dependence exceeds 70% under the low-RES scenario, compared with approximately 66% in the reference case.

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Non-coking coal and natural gas import and import dependence reduction, actual vs low-RES scenario, 2011-2030



IEA. CC BY 4.0.

Source: IEA analysis based on IEA data and data from NITI Aayog.

Estimated savings on fuels import bill

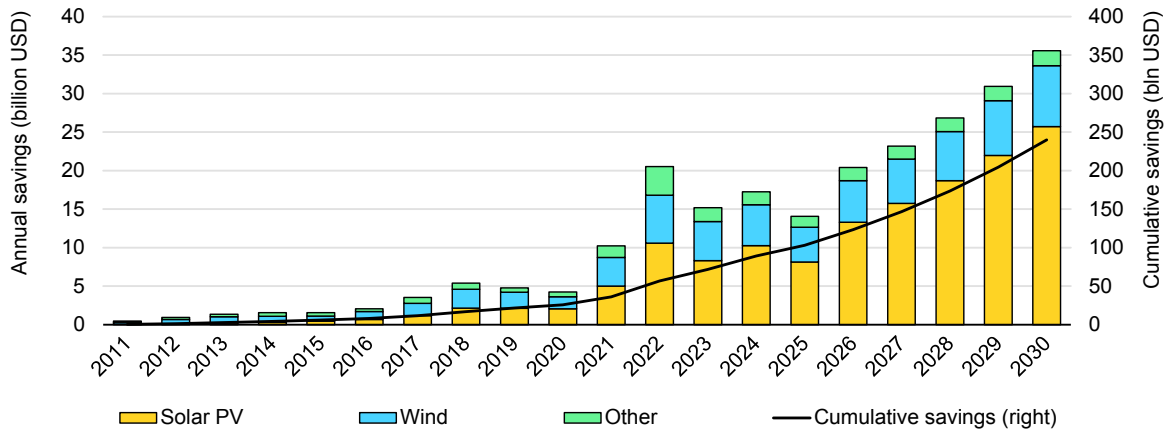
The difference in fossil fuel consumption translates directly into lower import expenditure. Based on historical fuel prices, cumulative savings in coal and natural gas import expenditure attributable to renewable energy deployment exceeded USD 100 billion between 2011 and 2025. Assuming fuel prices remain broadly consistent with average levels observed during 2024-2025, cumulative savings could approach USD 240 billion by 2030.

Solar PV accounts for approximately 60% of these savings, reflecting its dominant contribution to renewable generation growth, while wind power contributes almost 30%. Annual fossil fuel import savings are projected to reach approximately USD 35 billion by 2030, exceeding India's actual non-coking coal and natural gas import bill in FY 2024-25.

Renewable deployment also reduces pressure on fuel supply chains and logistics infrastructure. Lower coal demand reduces the need for imports, port handling capacity and long-distance coal transportation by rail, improving the resilience of the electricity system during periods of high demand, supply disruptions or international market volatility.

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Savings on coal and natural gas import bill by source, actual vs low-RES scenario, 2011-2030



IEA. CC BY 4.0.

Source: IEA analysis based on IEA data and data from NITI Aayog.

Overall, renewable energy deployment has become an increasingly important contributor to India's electricity security. In addition to supporting decarbonisation and improving electricity affordability, solar PV and wind power have significantly reduced fossil fuel import requirements, lowered exposure to international fuel price volatility and strengthened the resilience of India's rapidly growing electricity system. As renewable generation continues to expand towards 2030, these benefits are expected to become increasingly important.

Heat

Given the warm climate in India, the production of heat for industrial processes accounts for the large majority of heat demand in India (60% of total and nearly 70% when excluding traditional use of biomass). Industrial heat also accounts for a big share of India's final energy consumption (34%).

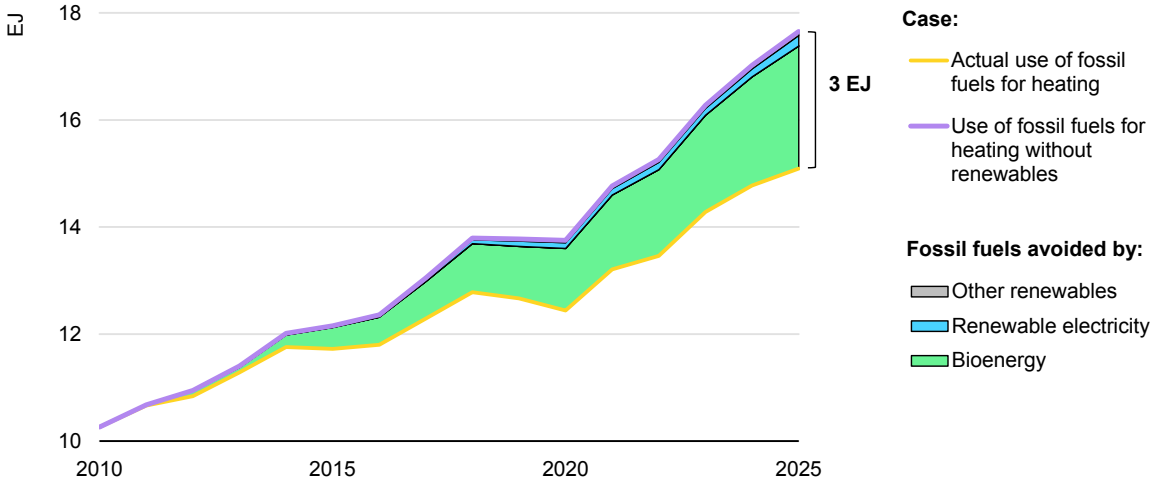
The production of industrial heat in India is highly fossil fuel intensive: modern renewables met just 15% of global heat demand in 2025. The remaining 85% was supplied predominantly by coal, natural gas and oil, leaving industry exposed to fossil fuel price volatility and import dependence.

Renewable heat production has nevertheless made a measurable contribution to energy security since 2010. The use of bioenergy in industry – which in many cases is already cost-competitive, given that it is often a by-product of certain industrial processes (e.g. black liquor) – accounts for a large portion of renewables in industry, even though renewable electricity is now growing fast as some industrial processes become increasingly electrified and some solar thermal projects for industry get installed.

Had renewable heat consumption remained at the 2010 level, fossil fuel use for heating would have been some 3.3 EJ (17%) higher in 2025, equivalent to around India's total energy supply of natural gas.

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Avoided use of fossil fuels for heating by renewable energy source, India, 2010-2025



IEA. CC BY 4.0

Notes: Avoided fossil fuel use is estimated relative to a counterfactual scenario in which renewable heat consumption stays at the 2010 level for each region and sector, with the shortfall met by coal, oil and natural gas in proportion to the fossil fuel heat mix for each region and sector. Renewable heat covers modern bioenergy (including biogas), solar thermal and geothermal energy, ambient heat captured by heat pumps, renewable district heat, and the renewable share of electricity used for heat. Industrial bioenergy is counted as displacing fossil fuels.

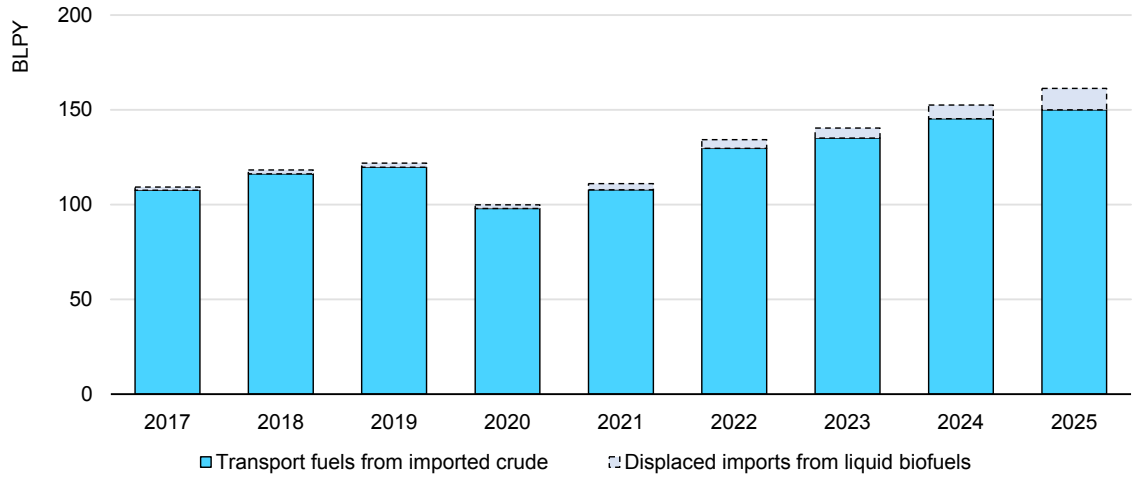
Source: IEA analysis based on IEA data only.

Transport

India relies on imports for 85-90% of the crude oil refined domestically to produce a suite of transport fuels (e.g. gasoline, diesel, jet fuel), despite being a net exporter of refined oil products. Amid increasing transport fuel demand, the rapid expansion of liquid biofuels has resulted in small but increasing reductions in transport fuel import dependence. In 2017, liquid biofuels reduced transport fuel import dependence by less than 1 percentage point, compared to a counterfactual scenario in which no biofuels were consumed. In 2025, the reduction in import dependence grew to nearly 4 percentage points.

IEA. CC BY 4.0.

Liquid biofuel displacement of crude oil imports in India, 2017-2025



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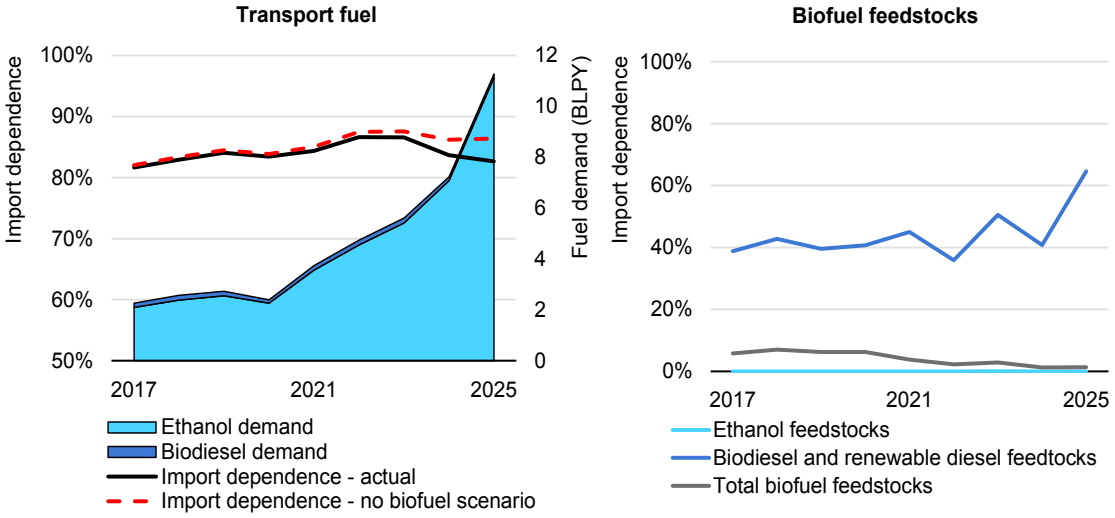
Notes: BLPY = billion litres per year. This figure uses total Indian crude oil imports as the country primarily imports crude oil to refine into different oil products (e.g. gasoline, diesel and jet fuel) to meet transport sector demand.
Source: IEA analysis based on IEA data only.

For some transport fuels, the role of liquid biofuels in displacing crude oil imports has been more pronounced. For example, domestic production of more than 11 billion litres (235 PJ) of ethanol in 2025, supported by a suite of supply and demand policies since 2018, has helped reduce gasoline import dependence by 12 percentage points. In India, domestic biodiesel production remains relatively small, at 155 million litres (5 PJ) in 2025, reducing diesel import dependence by less than 1 percentage point, with feedstock availability being the binding constraint to further expansion.

Feedstock import dependence for total biofuel production remains low in India, at roughly 1%; however, this masks the diverging trends between ethanol and biodiesel production. India has rapidly developed its ethanol industry, accounting for 9% of global ethanol production in 2025, up from only 1% in 2017. This rapid scale-up has been made possible in large part due to an abundance of domestic feedstock and a history of biofuel policies rooted in agricultural development and energy security. As a result, India has historically been a net exporter of ethanol feedstocks. For biodiesel, on the other hand, India is becoming increasingly reliant on feedstock imports to serve domestic production, importing 65% of all biodiesel feedstock used in 2025.

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Transport fuel import dependence and biofuel demand in India, main case, 2017-2025 (left), biofuel feedstock import dependence in India, main case, 2017-2025 (right)



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Notes: Import dependence is calculated as total net imports of oil products (gasoline and diesel), net imports of crude oil for domestically refined oil products, net imports of biofuels (ethanol, biodiesel and renewable diesel), and net imports of biofuel feedstocks for domestically produced biofuels, divided by total consumption of oil products and biofuels. The counterfactual scenario assumes that all biofuel consumption in the given year is directly replaced with imported oil products. Feedstock import dependence is calculated as net imports divided by total domestic feedstock use for biofuel
production based on the energy value of the fuels produced. Values for net imports of agricultural products are from the OECD, values for net imports of waste and residue oils are from Kpler and values for domestic demand are from the IEA.

Source: IEA (2025), Oil 2025; OECD/FAO (2026), OECD-FAO Agricultural Outlook 2026-2035; Kpler (2026), World Annual Net Exports, Biofuels.

Renewable electricity use is beginning to reduce transport sector fossil fuel dependence, though its contribution remains small relative to biofuels. Electricity demand in road transport reached nearly 11 PJ globally in 2025, almost 40% above the 2024 level, of which an estimated 3 PJ (25%) was supplied by renewable energy sources, displacing electricity demand that would have otherwise been met with coal- and gas-fired generation. As the shares of both renewable power generation and electrified transport demand rise, renewable electricity will further reduce reliance on imported fossil fuels for transport in India.

With more than 450 million vehicles expected to be on the road by 2030, demand for transport fuel is expected to increase. While electrification of the sector will continue, further production of liquid biofuels will continue to reduce India's dependence on crude oil imports. Continued development of policies and programmes such as the Ethanol Blended Petrol Programme, setting guaranteed pricing for ethanol based on the feedstock costs that oil marketing companies pay to purchase ethanol, and the Scheme to Enhance Ethanol Distillation Capacity, covering a portion of the loans for capital expenditure on new facilities, could further support supply increases.

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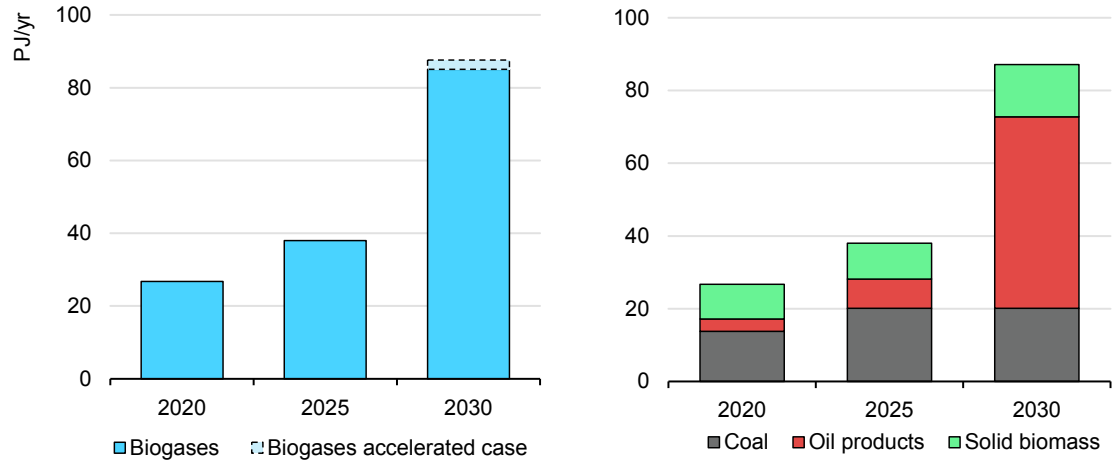
Similar trends are also expected in aviation. Domestic passengers are expected to reach 300 million by 2030; this volume of travel will remain difficult to electrify in the short and medium term, creating an opportunity for liquid biofuels to reduce crude oil imports for jet kerosene production. Further support would be required for SAF production and innovation, given that many fuel production pathways remain much more expensive than their fossil fuel counterparts.

Biogases

Biogas and biomethane provide energy for clean cooking, residential heat and power, industrial heat, and transport, displacing the consumption of coal, crude oil fuels, liquefied petroleum gas, natural gas and traditional solid biomass. The main displaced fuels are coal (used primarily in power generation), oil products in transport and traditional solid biomass for residential uses, mainly cooking.

However, India has one of the fastest-growing energy demands in the world, propelled by increasing economic activity. Part of this growth is expected to be supplied in the form of natural gas, following the Indian government's plans to move from the current 6% natural gas share in the energy mix to 15% by 2030. This growth is expected to come from liquified natural gas imports, although biogas and CBG can contribute to reducing these import needs. In 2024, the natural gas import share was 52% of total supply, and it is expected to rise to around 71% by 2030, when biogases could contribute to reducing it by 2 percentage points, down to 69%.

Biogas production and accelerated case forecast (left) and related fuel savings (right), India, 2020, 2025 and 2030



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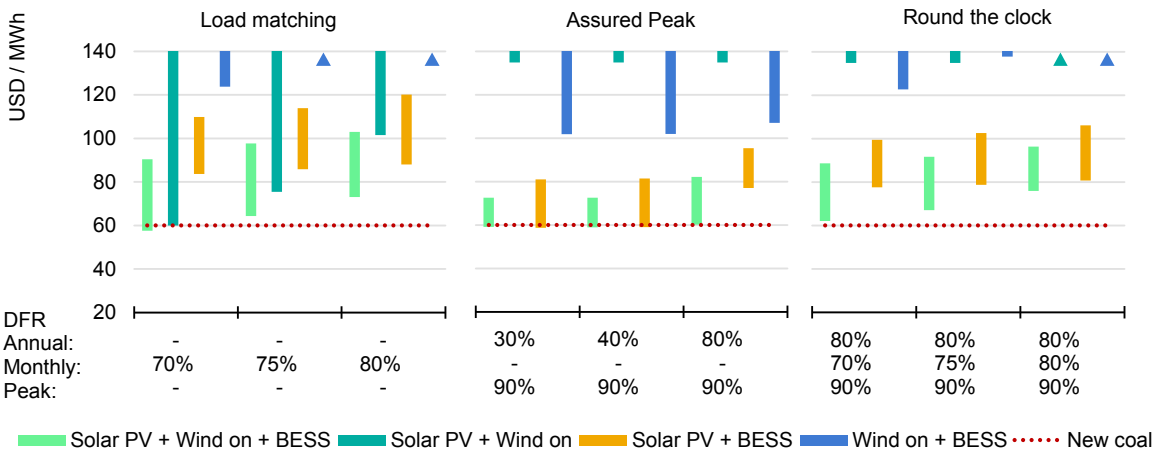
Source: IEA analysis based on IEA data only.

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Annex – Hybrid projects regional sensitivity analysis

Northern region

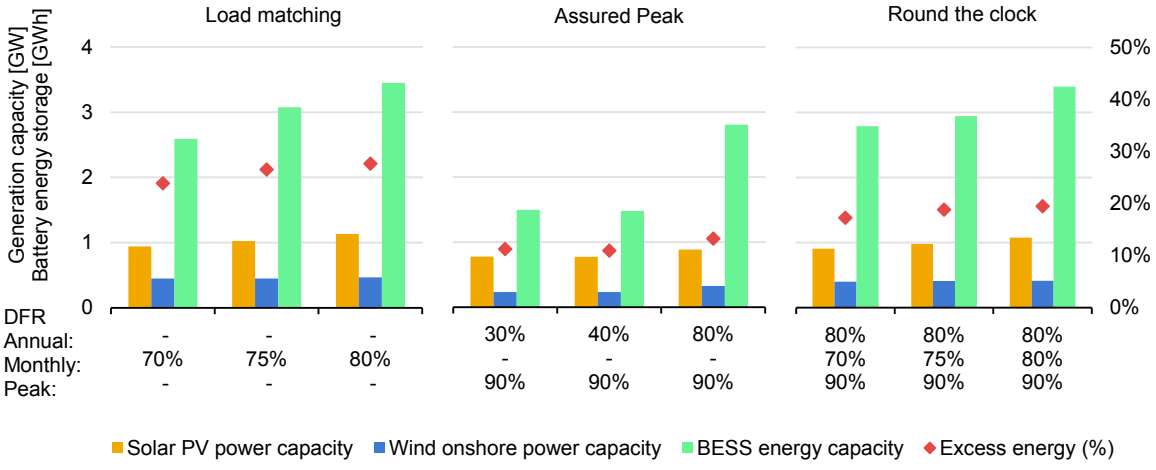
Estimated LCOE to fulfil various hybrid auction requirements to cover 300 MW nominal load, northern grid zone of India, 2025



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Notes: BESS = battery energy storage system; DFR = demand fulfilment requirement; LCOE = levelised cost of electricity; wind on = onshore wind. *New coal* refers to the estimated LCOE of a newly built coal power plant. All monetary values are expressed in real terms, using 2025 as the base year.

Technology split required and excess generation to be considered to fulfil various hybrid auction requirements to cover 300 MW nominal load, northern grid zone of India, 2025



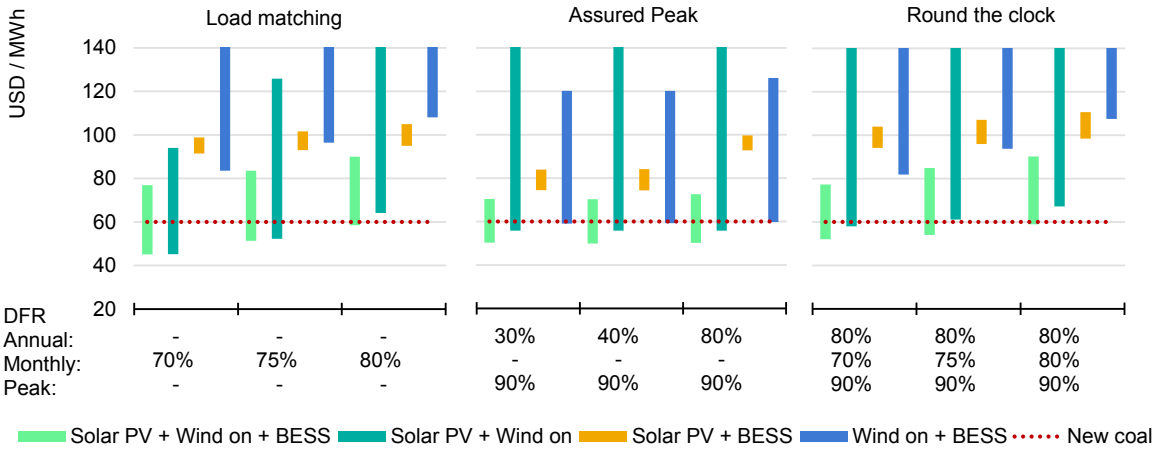
IEA. CC BY 4.0.

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Western region

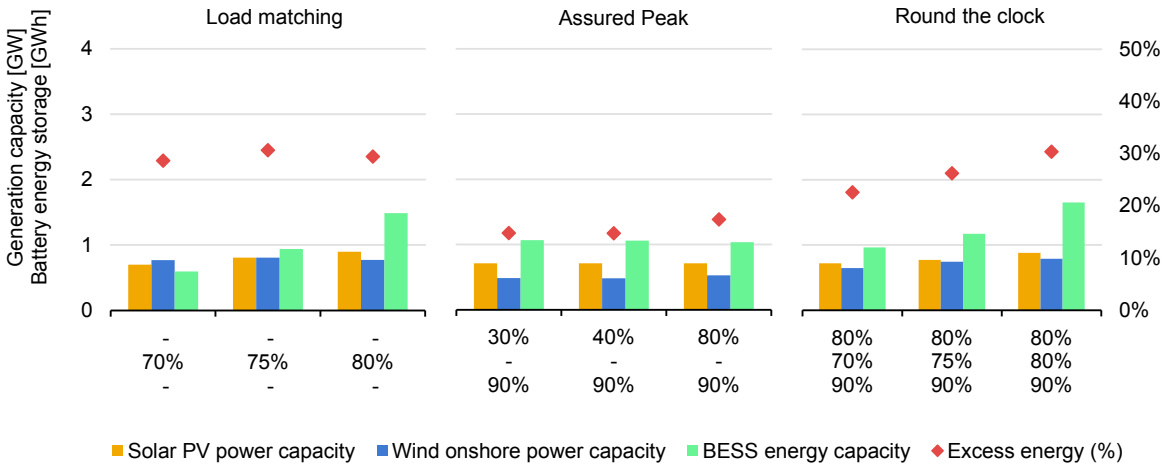
Estimated LCOE to fulfil various hybrid auction requirements to cover 300 MW nominal load, western grid zone of India, 2025



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Technology split required and excess generation to be considered to fulfil various hybrid auction requirements to cover 300 MW nominal load, western grid zone of India, 2025



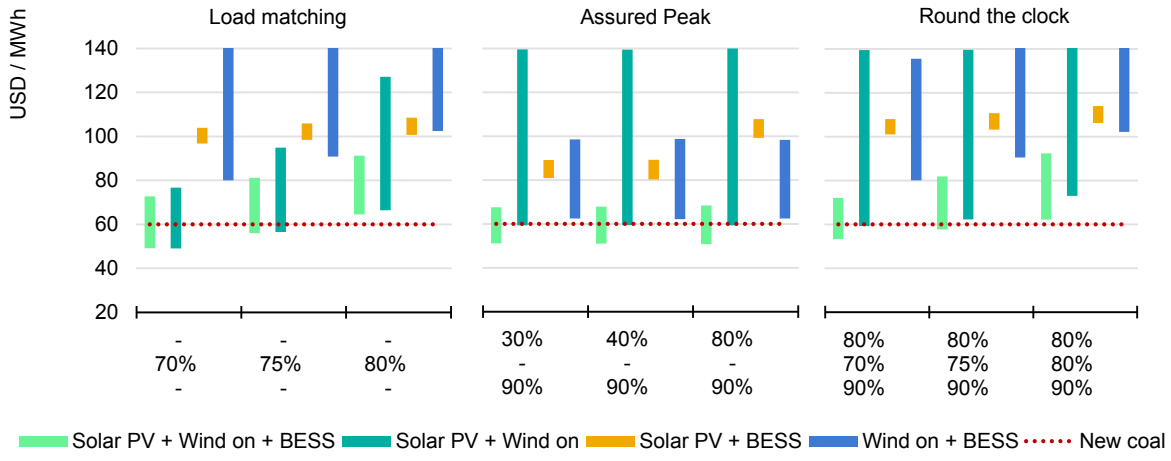
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Note: BESS = battery energy storage system; DFR = demand fulfilment requirement.

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Southern region

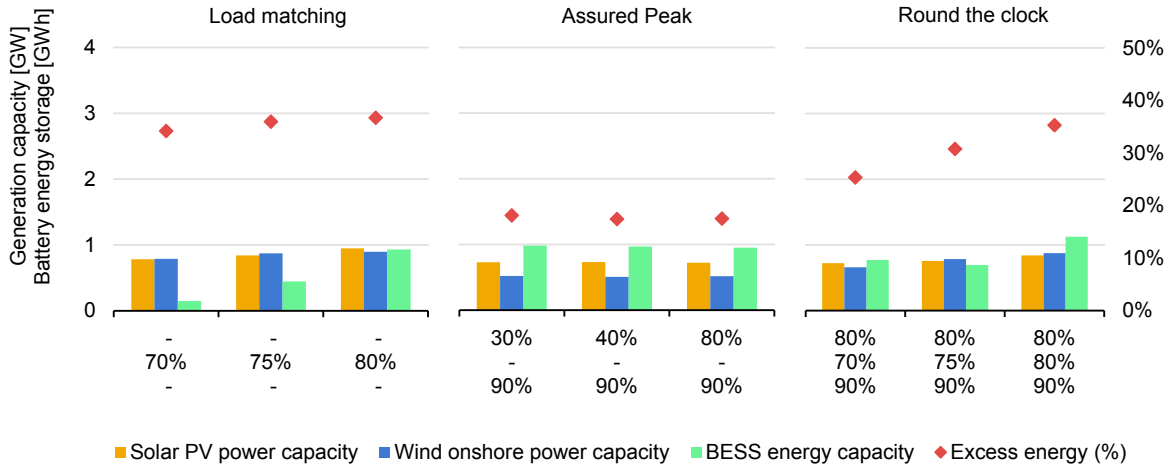
Estimated LCOE to fulfil various hybrid auction requirements to cover 300 MW nominal load, southern grid zone of India, 2025



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Notes: BESS = battery energy storage system; DFR = demand fulfilment requirement; LCOE = levelised cost of electricity; wind on = onshore wind. *New coal* refers to the estimated LCOE of a newly built coal power plant. All monetary values are expressed in real terms, using 2025 as the base year.

Technology split required and excess generation to be considered to fulfil various hybrid auction requirements to cover 300 MW nominal load, southern grid zone of India, 2025



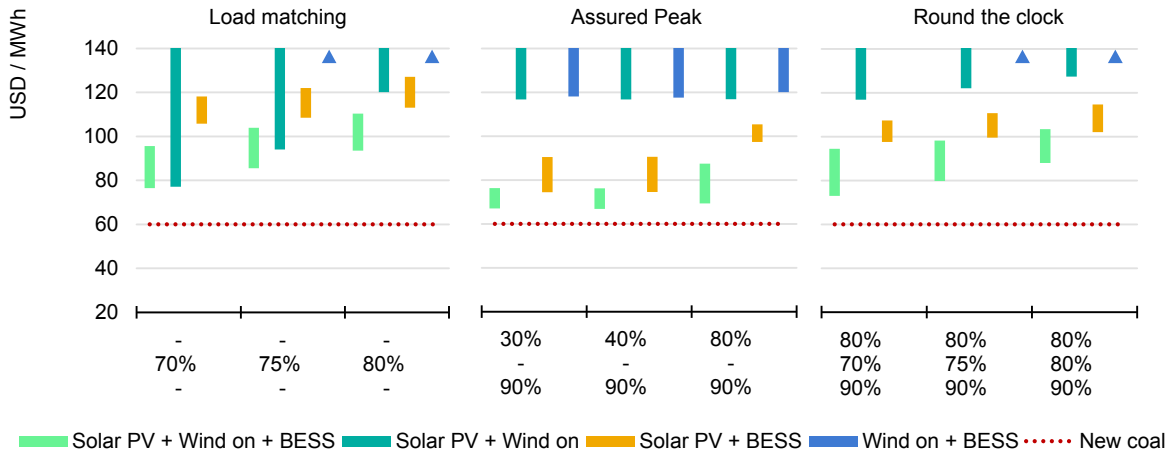
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Note: BESS = battery energy storage system; DFR = demand fulfilment requirement.

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Eastern region

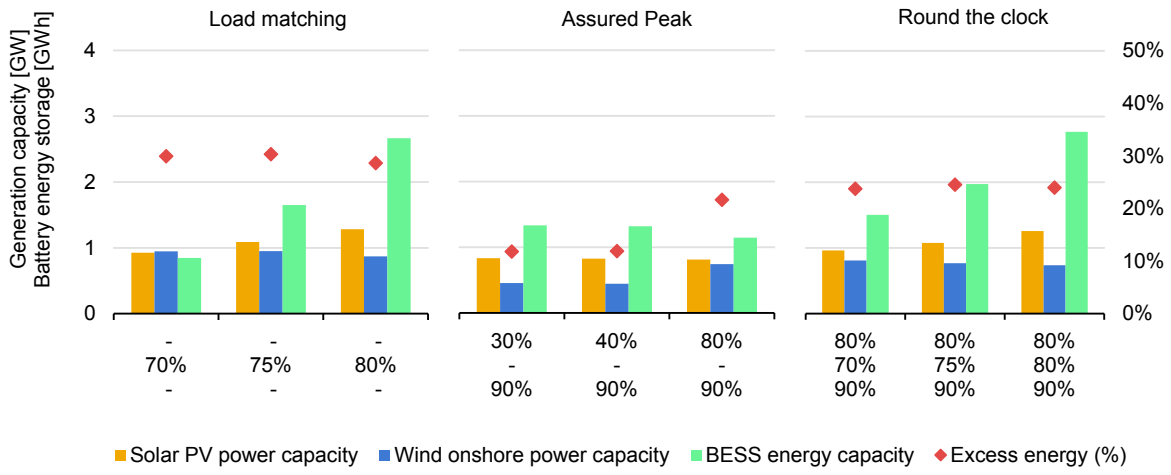
Estimated LCOE to fulfil various hybrid auction requirements to cover 300 MW nominal load, eastern grid zone of India, 2025



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Notes: BESS = battery energy storage system; DFR = demand fulfilment requirement; LCOE = levelised cost of electricity; wind on = onshore wind. *New coal* refers to the estimated LCOE of a newly built coal power plant. All monetary values are expressed in real terms, using 2025 as the base year.

Technology split required and excess generation to be considered to fulfil various hybrid auction requirements to cover 300 MW nominal load, eastern grid zone of India, 2025



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