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Green Power Transmission Development in India

Overcoming challenges to build a reliable green grid

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Key Findings

Over 50GW of renewable energy capacity remains stranded nationwide as of June 2025, leading to project delays and increasing per-unit transmission costs. These constraints limit the pace at which new capacity can be brought online.

India's transition to renewables is limited by the mismatch between variable generation and grid consumption. While solar generation aligns with the afternoon peak consumption pattern, it tapers off in the evening when demand is high. This creates a gap that limits renewable integration and leads to the underutilisation of transmission corridors. Energy storage is vital to bridge this gap.

Renewable corridors often operate below their intended capacity; however, some degree of underutilisation is temporary, as it reflects strategic overbuilding to meet future demand growth.

Transmission planning needs to move beyond the traditional five-year static cycle to a more adaptive approach that reflects evolving generation patterns and demand growth.

Executive summary

India's power transmission network, one of the largest in the world, spans over 494,000 circuit kilometres (ckm) of lines and 1.33 million megavolt-amperes of transformation capacity, forming a fully synchronised national grid. However, the network struggles to keep up with renewable energy deployment, leading to a growing gap between clean power generation and the availability of evacuation infrastructure. This imbalance limits renewable integration and increases the risk of stranded assets and higher delivery costs.

The widening gap between planned and actual transmission network expansion is becoming evident. In FY2025, only 8,830ckm of new transmission lines were commissioned against a target of 15,253ckm, reflecting a 42% shortfall, with Inter-State Transmission System (ISTS) additions at their lowest in a decade. Alongside this capacity gap, system inefficiencies are emerging, with analysis by the National Renewable Energy Laboratory indicating that up to 71% of ISTS corridors operate below 30% utilisation, underscoring the mismatch between infrastructure availability and actual power flows.

Market distortions further aggravate the situation. In several high-demand corridors, speculative hoarding of transmission capacity by entities without genuine project intent has driven up connectivity prices and delayed access for viable projects. Structural and procedural bottlenecks, including right-of-way (RoW) disputes, prolonged land acquisition processes, restrictions on equipment procurement, and multi-agency approval requirements, add to the delay. Among these, RoW remains one of the most significant barriers to timely transmission development. Similar land acquisition hurdles in the US have also slowed new transmission build-outs.

In India, the impact is most visible in Rajasthan, where 8 gigawatts (GW) of renewable energy capacity remains stranded, with nearly half curtailed during peak solar hours. Delayed completion of the Associated Transmission System—the dedicated transmission infrastructure linked to new generation projects—along with capacity hoarding and ecological directives mandating underground cabling in Great Indian Bustard habitats, have compounded evacuation challenges, inflated project costs, and reduced operational efficiency.

The implications are significant—over 50GW of renewable energy capacity is currently stranded nationwide, increasing per-unit transmission costs, weakening project viability, and deterring private investment. These constraints limit the pace at which new capacity can be brought online and undermine India's ability to integrate variable renewable energy at scale, risking missed milestones in the country's clean energy transition.

A unified generation-transmission planning framework that aligns timelines and locations for both generation and transmission capacity additions is essential. A single-window clearance system with strict timelines should be implemented to streamline land, RoW, and connectivity approvals. Performance-based incentives and disincentives tied to asset utilisation metrics can encourage timely commissioning and sustained operations. Scaling asset monetisation and public-private partnerships will be essential to unlocking capital for both inter-state and intra-state projects. In parallel, reconductoring of congested corridors and integration of energy storage systems should be prioritised in renewable-rich regions to enhance capacity utilisation and reduce curtailment.

A coordinated approach—combining regulatory reform, operational efficiency measures, and capital mobilisation—will be critical to transforming India's transmission network into a flexible, resilient system capable of supporting high renewable penetration while ensuring cost-effective and reliable power delivery. The recent extension of ISTS charge waivers for storage and the implementation of time block-based General Network Access allocation—which allows power generators to use the transmission network without pre-identifying buyers—are steps in the right direction. Without targeted reforms, misalignment between generation commissioning and evacuation infrastructure is likely to continue driving congestion, curtailment, and systemic inefficiencies, ultimately slowing progress towards achieving India's decarbonisation objectives.

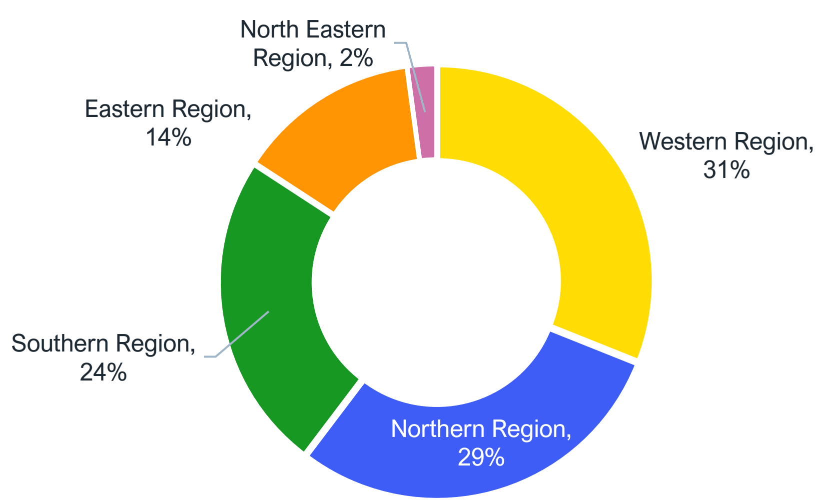
India's power transmission network at a glance

India's electricity transmission system has evolved from fragmented, state-centric grids into one of the world's largest synchronised networks. In the 1960s, state grids began coordinating to enable electricity transfer, moving beyond their earlier focus on localised resource availability. During this period, government entities like the National Thermal Power Corporation Limited and the National Hydroelectric Power Corporation Limited developed most inter-state generating stations and invested in transmission infrastructure. In 1989, the government unbundled the transmission assets of these companies to create a dedicated national transmission utility—the Power Grid Corporation of India Limited (PGCIL).

PGCIL led the consolidation and expansion of India's inter-state network, building high-capacity corridors that gradually interconnected the five regional grids. In December 2013, the integration of the southern region marked the final milestone, realising the government's vision of "One Nation - One Grid - One Frequency".[1]

As of FY2025, the country operates over 494,000 circuit kilometres (ckm) of transmission lines and more than 1.33 million mega-volt amperes of transformation capacity. The western and northern regions together account for 60% of India's transmission line length, reflecting their pivotal role in grid stability.[2]

Figure 1: Regional distribution of transmission lines in India (FY2025)



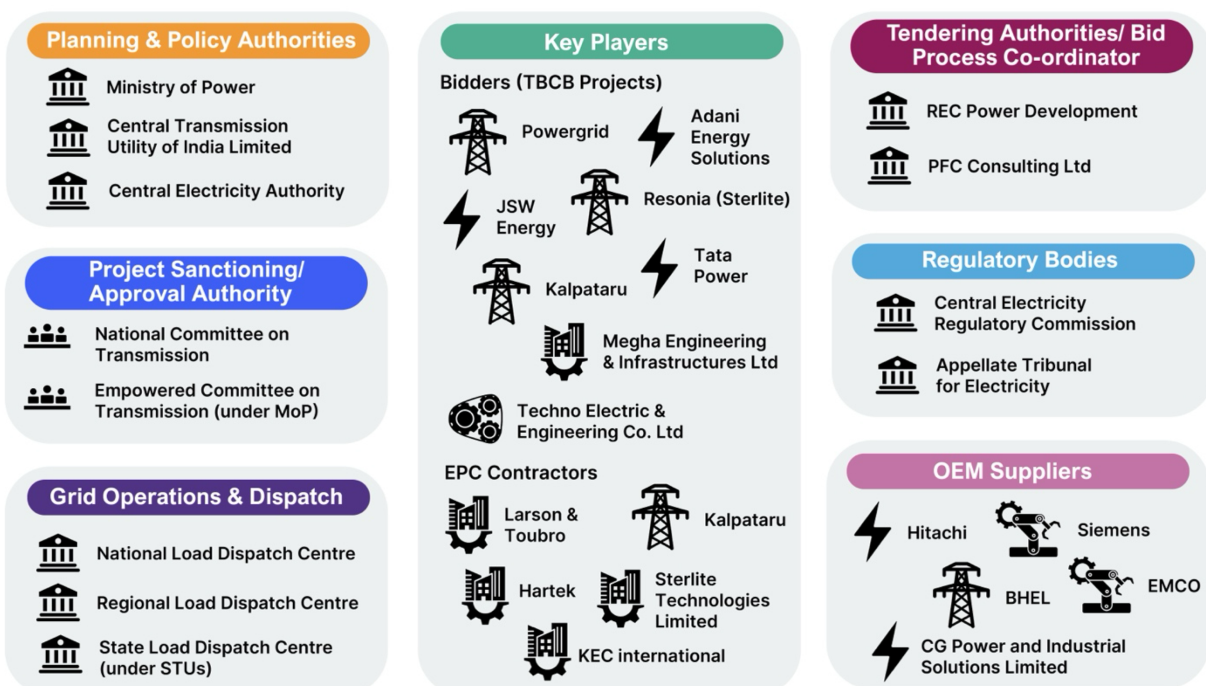
Sources: CEA, JMK Research

[1] Power Line. 25 Events that Shaped the Sector: Change in the making. September 2021
[2] India Climate & Energy Dashboard. Transmission Lines. March 2025

India's transmission sector operates within a well-defined framework. The Central Electricity Authority (CEA) leads long-term system planning through the National Electricity Plan (NEP), which is updated every five years. The NEP for transmission sets ambitious infrastructure targets to support the country's growing energy needs and renewable energy goals. The NEP draws on demand forecasts from the Electric Power Survey, which estimates the country's electricity requirements over the short-, medium-, and long-term. Based on these projections, and inputs from the Central Transmission Utility (CTU) and State Transmission Utilities (STUs), the CEA defines transmission capacity needs using system reliability, contingency preparedness, and grid security criteria.

Private sector participation in transmission has gained momentum, spurred by the shift to Tariff-Based Competitive Bidding (TBCB) for awarding new projects. Major players like Adani Transmission, Sterlite Power (now Resonia) and Tata Power are gradually increasing their share of Inter-State Transmission System (ISTS) assets. This growing diversification has contributed to a more competitive transmission sector. The infographic below illustrates the key institutional stakeholders in India's power transmission sector.

Figure 2: Key institutions in transmission project value chain

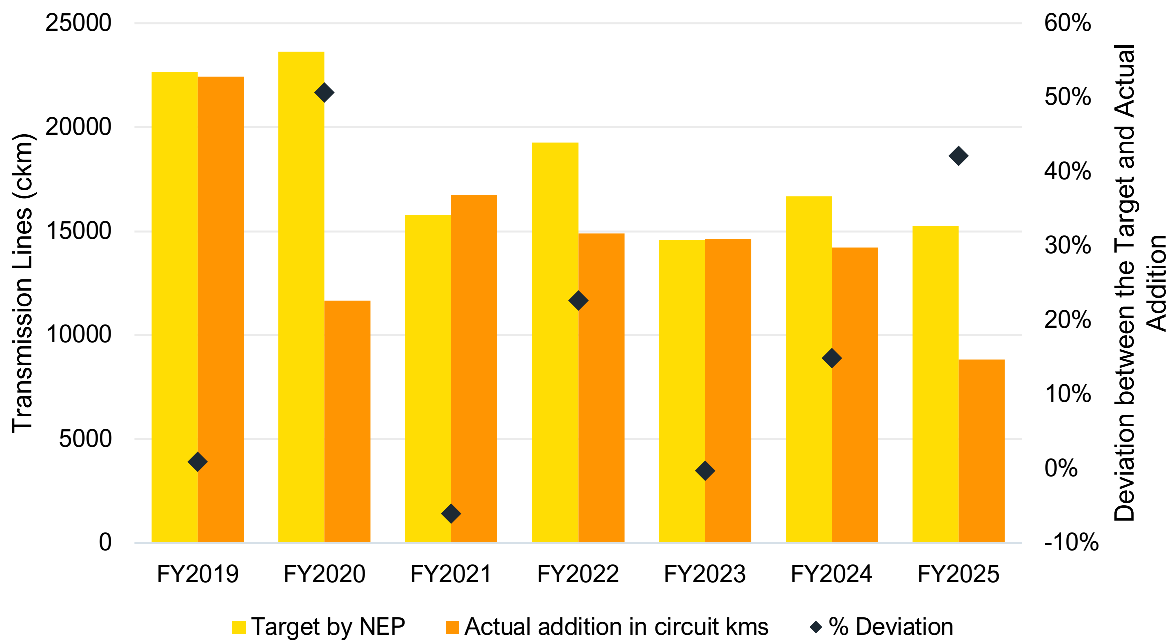


Sources: JMK Research

Note: Key players, EPC contractors, and OEM suppliers are shown only for illustrative purposes. For intra-state projects, respective state authorities are responsible for tendering and approval processes.

However, India's transmission expansion continues to miss NEP targets. As Figure 2 shows, annual transmission line additions have consistently fallen short since FY2019, with only FY2021 surpassing expectations. In FY2025, the sector added just 8,830ckm against a target of 15,253ckm, registering a 42% shortfall. Much of this gap stemmed from the central sector. PGCIL, with a target of 5,281ckm, delivered only 2,534ckm, less than half, pulling overall ISTS additions down to 3,253ckm, the lowest in a decade.[3] These gaps raise concerns about meeting the NEP's ambitions of adding nearly 0.19 million ckm by 2032.[4]

Figure 3: Annual transmission line additions in India (FY2019-25)



Source: ICED, India Transmission Portal, JMK Research

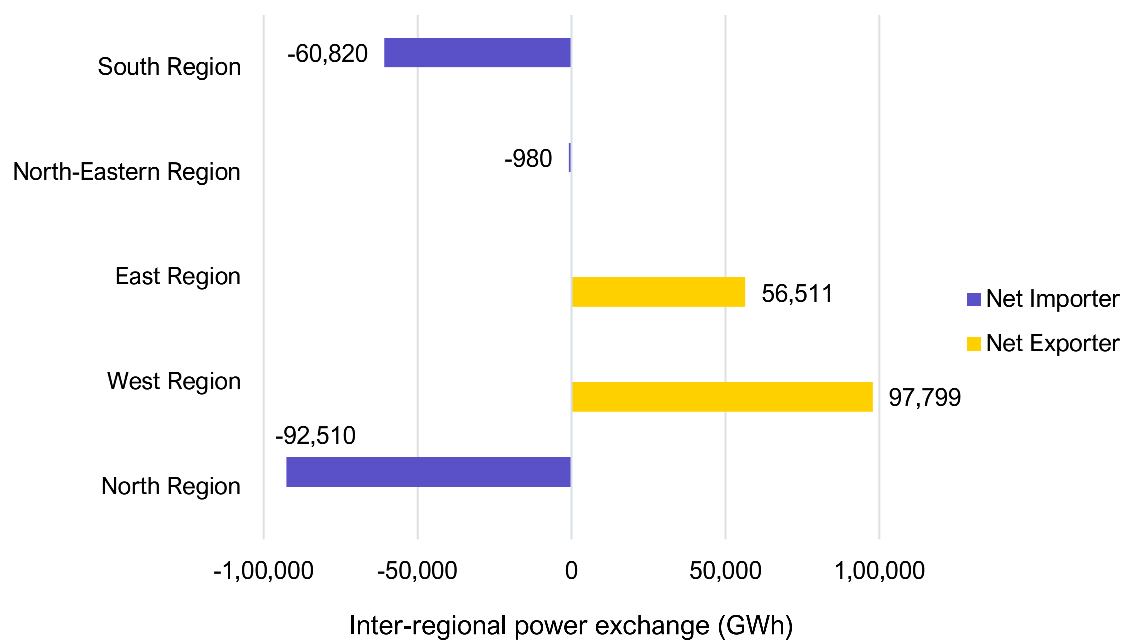
India's transmission network includes a dedicated inter-regional transmission capacity layer, enabling power transfer between its five regional grids. This infrastructure plays a critical role in balancing electricity supply across the country by allowing surplus generation in one region to meet demand in another.

In FY2025, inter-regional power flows reflected a consistent pattern: the western and eastern regions exported electricity across the grid, while the northern and southern regions, which house major consumption hubs, remained net importers. This directional flow underscores persistent regional demand-supply imbalances and highlights the critical role of inter-regional corridors in enabling reliable power transfer. With the growing share of variable renewable energy (VRE), strengthening

[3] T&D India. Transmission line addition fares poorly in May 2025. June 2025
[4] PIB. National Electricity Plan (Transmission) launched by Cabinet Minister for Power and Housing & Urban Affairs. 14th October 2024

these corridors is essential to minimise curtailment, manage fluctuations, and ensure clean energy reaches high-demand zones efficiently.

Figure 4: Inter-regional power imports and exports (FY2025)



Source: Grid India, JMK Research

Note: A negative (-) value indicates a net importer of electricity, while a positive (+) value denotes a net exporter.

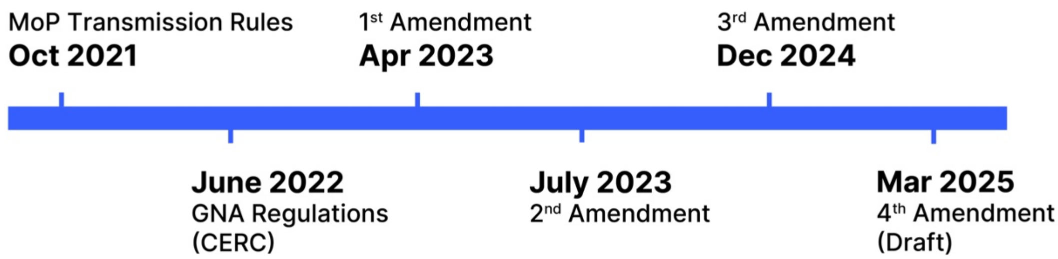
Government initiatives for green power transmission development

The government has launched key initiatives to integrate renewable energy into the grid. While the Green Energy Corridor builds dedicated transmission infrastructure across renewable-rich states, the introduction of the General Network Access (GNA) framework streamlines connectivity for renewable generators. Other initiatives, such as ISTS charge waivers, indirectly support the expansion of ISTS transmission infrastructure.

General Network Access

GNA, introduced by the Central Electricity Regulatory Commission (CERC) in 2022, allows power generators to use the transmission network without identifying buyers in advance. It replaces the old system where access was tied to specific buyers, which often delayed renewable energy projects and limited market flexibility. GNA makes grid use fairer and more efficient, supports open market trading, and helps connect more renewable energy to the national grid.

Figure 5: Progression of India's GNA policy



Source: Ministry of Power, CERC

A key benefit of GNA is its role in improving transmission system planning. Under the earlier framework, medium-term and short-term contracts were excluded from network strengthening assessments, leading to fragmented planning and underprepared infrastructure.[5] GNA addresses this by considering all contracted capacities, including medium- and short-term, during planning. This enables more accurate demand forecasting and timely development of transmission assets aligned with actual market needs. This shift enhances grid reliability and ensures that transmission growth keeps pace with the evolving generation landscape.

The GNA framework has undergone significant reforms, with the third amendment (2025)[6] introducing a more dynamic allocation model. Previously, transmission capacity was allocated on a 24×7 basis, regardless of actual generation patterns, which often left corridors underutilised in solar-heavy regions. GNA for renewable energy projects is now divided into solar and non-solar hours, ensuring transmission capacity is better aligned with generation windows. This reform unlocks capacity that would have otherwise remained idle and allows other ready-to-inject resources, such as wind or storage, to access corridors.

GNA has been allocated to a wide range of entities across states and regions. Rajasthan, Gujarat, and Tamil Nadu—key renewable generation hubs—have received high GNA volumes to facilitate solar and wind evacuation. Similarly, demand centres such as Maharashtra and Uttar Pradesh have been allocated GNA based on projected consumption and system strengthening needs. As per CTU

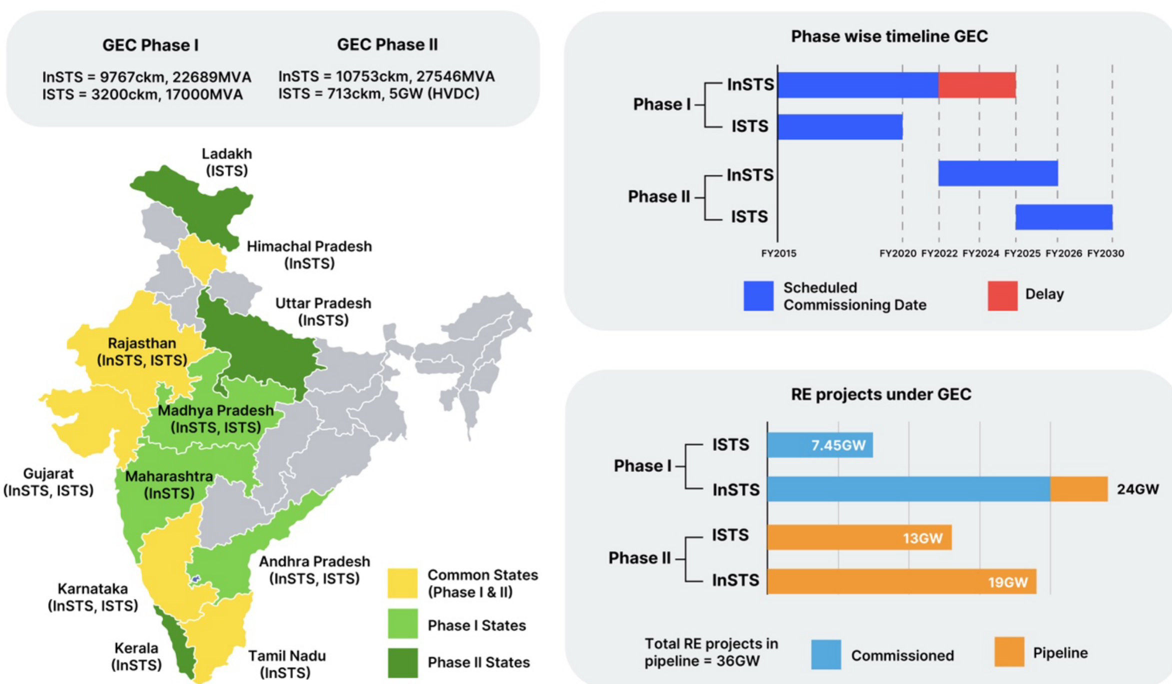
[5] Powerline. Transmission Reform: General network access marks a new paradigm in system planning. Nov. 2021
[6] CERC. GNA 3rd Amendment. 31st August 2025

data for March 2025, India has seen a total deemed GNA[7] allocation of 108,651MW and an additional GNA allocation of 19,319MW[8].

Green Energy Corridor

The Green Energy Corridor (GEC) was conceptualised in 2015 to address the widening mismatch between India's rapidly growing renewable energy capacity and the limited availability of corresponding transmission infrastructure. It targets inter- and intra-state transmission development as a phased programme. PGCIL is implementing the ISTS, while STUs are developing intra-state transmission (InSTS) networks in key renewable-rich states.

Figure 6: Overview of the GEC initiative (Phases I & II) and associated RE capacity



Source: Ministry of Power, India Transmission Portal, MNRE, JMK Research

The ISTS component of Phase I was completed in March 2020, enabling the evacuation of around 7.45GW of renewable energy. In contrast, progress on InSTS infrastructure has lagged. Andhra Pradesh, Gujarat, Maharashtra, and Himachal Pradesh had to seek extensions beyond the expected commissioning timeline (FY2024) due to persistent execution challenges. As of FY2025, four out of

[7] Deemed GNA is transmission capacity allocated based on past allocations mainly to central generating stations and generating stations connected to the ISTS network. Additional GNA refers to any new capacity sought beyond the deemed allocation.
[8] India Transmission Portal. GNA Allocation by CTU. June 2025

the eight participating states have completed 100% of their assigned work, while the remaining four have achieved 90-94% progress.[9]

As of June 2025, the GEC has enabled the commissioning of 27.45GW of renewable energy capacity, including 7.45GW of ISTS and 20GW of InSTS, with an additional 36GW in the pipeline across ISTS and InSTS Phases I and II. While Phase I is nearing completion, the timely execution of Phase II, especially the 19GW InSTS component, is crucial for the evacuation and utilisation of renewable energy.[10] With renewable capacity accelerating, the risk of a mismatch between generation and evacuation readiness is high, raising concerns about whether transmission infrastructure will be operational before upcoming renewable energy projects go live.[11]

Transmission development challenges

India's green power transmission build-out faces multiple bottlenecks that delay infrastructure deployment. Key challenges include execution delays driven by land acquisition and right of way (RoW) issues, complex institutional procedures requiring multi-agency approvals, and equipment procurement constraints that delay the commissioning of transmission infrastructure. These factors collectively hinder last-mile connectivity and create systemic risks for renewable energy integration.

Execution challenges

Execution-related challenges continue to impede the timely development of green power transmission infrastructure, particularly at the intra-state level.

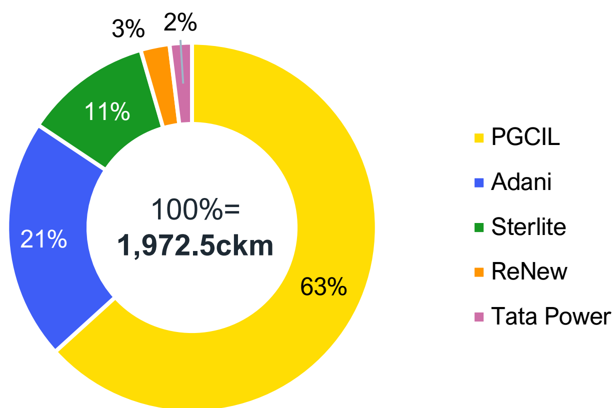
Unlike ISTS projects that benefit from centralised planning and secure cost-recovery frameworks, intra-state lines are typically built by financially constrained STUs. These entities struggle with limited access to concessional finance and low creditworthiness. In GEC Phase I, only 40% of capital expenditure was covered through central grants,[12] while Phase II offers an even lower support share (~33%)[13]. As a result, states often rely on high-cost commercial borrowing, but the elevated interest rates and associated repayment risks make lenders more cautious and prolong financial closure, ultimately delaying project execution.

Execution delays are exacerbated by RoW constraints. At least 14 ISTS projects have experienced significant delays in recent years, with most of these linked to unresolved RoW issues. Land acquisition disputes, driven by compensation demands exceeding state-notified rates, have stalled construction and led to significant cost overruns. These challenges have affected transmission

[9] Financial Express. Green energy corridor Phase-I makes major headway, 20 GW on stream. Jul 2025
[10] Powerline. Green Energy Superhighways: GEC progress, challenges and the road ahead. Mar 2025
[11] Ministry of Power, India. Waiver of Inter-State Transmission Charges for Energy Storage Systems (ESS). June 2025
[12] MNRE. Intra-State GEC Phase-I. 2017
[13] MNRE. Intra-State GEC Phase-II. 2022

players like PGCIL and private players like Adani and Sterlite.[14] To address these risks, tendering agencies should formalise RoW clearances within their scope. By securing approvals or achieving partial RoW readiness, tendering agencies can provide developers greater certainty, reduce execution risks and accelerate project delivery.

Figure 7: Player-wise share of delayed ISTS transmission lines (ckm) due to RoW issues (as of March 2025)



Source: Ministry of Power, JMK Research

Although the Ministry of Power revised its RoW compensation policy in June 2024 to align with market rates, state-level adoption appears challenging.[15] The guidelines clearly define RoW-related costs and allow them to be passed through in some instances, reducing financial risks for bidders. However, the success of these measures will depend heavily on practical implementation and state-level cooperation. The GEC initiative has faced similar setbacks. The InSTS component was delayed due to RoW disputes, delays in land acquisition for substations, and repeated re-tendering.[9]

Internationally, the US illustrates how RoW acquisition has become a barrier even in a country with a long-established transmission network. Over 70% of US transmission infrastructure is over 25 years old,[16] much of it built in an era when securing easements was straightforward and faced limited opposition. Today, acquiring RoW has become far slower and costlier, with developers confronting landowners, rising compensation demands, and frequent legal or community challenges. As a result, build-out rates have declined sharply. High-voltage transmission additions have fallen from ~1,700 miles (2,736 ckm) per year in the early 2010s to just 350 miles (563ckm) annually between 2020 and

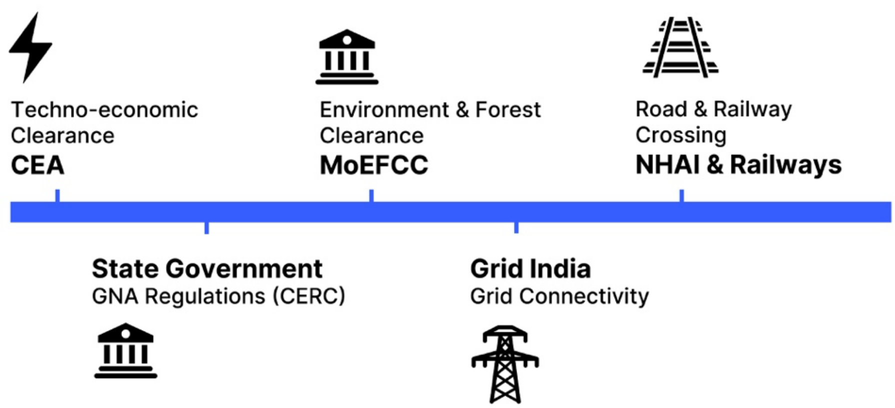
[14] MoP. RoW challenges delaying critical transmission projects. 2025
[15] Economic Times. Centre rolls out new payout rules for transmission line land use, states told to comply. March 2025
[16] U.S. Department of Energy. What does it take to modernize the U.S. electric grid. October 2023

2023,[17] underscoring how RoW issues are likely to become an even more prominent execution bottleneck in India as transmission expansion accelerates, and land pressures mount.

Complex institutional processes

Complex institutional procedures delay the operationalisation of green power transmission infrastructure, contributing to underutilisation risks. Since electricity is a concurrent subject, the central and state governments exercise jurisdiction over planning and regulation. The CEA leads long-term transmission planning, the CTU manages inter-state implementation and connectivity approvals, STUs handle intra-state networks, and Regional Load Dispatch Centres / State Load Dispatch Centres (RLDC/SLDC) coordinate real-time scheduling. While this structure enables decentralised decision-making and brings in role clarity across agencies, its multiple layers create high entry barriers for new players, lengthen approval timelines, and add uncertainty across project stages, from planning to final grid integration.

Figure 8: Key procedural approvals and authorities responsible for final connectivity



Source: JMK Research

Setting up a transmission line requires coordination with multiple authorities across different government levels. Key approvals include techno-economic clearance from the CEA, grid connectivity from dispatch centres, and transmission licences from regulatory commissions. State and local agencies must obtain additional approvals, such as land acquisition and route alignments. These layered approvals often follow independent timelines and involve overlapping jurisdictions, contributing to procedural delays. These delays pose a risk to the timely deployment and full utilisation of green power transmission assets.

[17] Clean Energy Grid. Declining Large-Scale Transmission Construction in the U.S. July 30, 2025

Equipment procurement constraints

A key challenge facing transmission players is the restriction imposed by the amended General Financial Rules introduced in 2023, which limits equipment procurement from neighbouring countries.[18] This regulation creates supply-side bottlenecks, particularly in sourcing transmission infrastructure goods (transformers, circuit breakers, tower parts and accessories), especially for High Voltage Direct Current systems.[19] Unlike renewable energy developers, transmission players are not exempt from this provision, leading to procurement delays that derail timely project execution. The Electric Power Transmission Association has flagged this as a major execution hurdle and has urged the government to grant temporary exemption until 2030 to address these constraints and accelerate the rollout of grid infrastructure.[20]

Underutilisation of transmission infrastructure

India's renewable energy transition faces a growing challenge of underutilised transmission assets. Underutilisation occurs when transmission corridors, designed to carry renewable energy, operate significantly below their intended capacity for prolonged periods. Although some underutilisation may result from overbuilding to anticipate future demand, a temporary surplus of transmission capacity is preferable to a critical shortage that could disrupt essential services. However, prolonged inefficiencies increase costs and strain project economics.

Hoarding of transmission capacity creating artificial scarcity

In key corridors like Fatehgarh and Bikaner, smaller players exploit the time lag between renewable project readiness and transmission availability by pre-booking large chunks of transmission capacity without the intent to develop projects, creating artificial scarcity. This compels genuine developers to pay premiums as high as Rs40 lakh per MW (US$45,578) to secure connectivity.[21] This grey market practice drives up costs, delays project execution, and leaves transmission infrastructure underutilised, even as viable projects remain stranded.

Energy storage at the transmission level

India's transition to renewable energy is limited by the mismatch between variable generation and grid consumption. While solar generation aligns with the afternoon peak consumption pattern, it tapers off in the evening when demand is high. This creates a gap that limits renewable integration and leads to the underutilisation of transmission corridors. Energy storage in India is essential for aligning renewable generation with demand and plays a critical role in delivering ancillary services

[18] General Finance Rules (GFRs), 2017, Amendment to Rule 144(xi) of the General Financial Rules (GFRs), 2017. Feb 2023
[19] Ministry of Finance, Department of Expenditure, Procurement Policy Division. Order (Public Procurement No. 4). Feb 2023
[20] T&D India. EPTA seeks exemption to Rule 144 (xi) to overcome HVDC supply-side constraints. May 2025
[21] The Times of India. Solar players make a fast buck by blocking plug points to the grid. June 2025

that support grid reliability. At key transmission nodes, storage systems can provide valuable ancillary services such as frequency regulation, voltage stability, congestion management, and black start capabilities. This is especially crucial in a high-renewable energy system where variability can destabilise real-time operations.

While thermal plants operate at plant load factors of 56-75%, solar and wind assets average just around 15% and 23%[22] capacity utilisation, respectively, which limits the efficient use of transmission infrastructure. A National Renewable Energy Laboratory analysis suggests that up to 71% of India's ISTS transmission corridors may run at less than 30% utilisation, with 9% potentially unused for over 25% of the year, due to the variable output of renewable sources. These figures advocate energy storage as a strategic tool to unlock transmission capacity, enhance grid reliability, and reduce renewable energy curtailment.[23]

The CEA projects a need for 73.9GW / 411GWh of storage by 2031-32, but the current capacities are just 0.50GW[24] of battery and 6.20GW[25] of pumped hydro, which fall significantly short of this requirement. However, with an operational life of only 8-12 years[26]compared to 50-60 years for transmission infrastructure, battery energy storage systems (BESS) remain a temporary solution. Repeated replacements further escalate overall system costs,[27] unlike long-lasting grid assets.

Technical issues leading to underutilisation

Renewable-rich states like Rajasthan face technical challenges that can affect the optimal utilisation of transmission infrastructure. Frequent line outages, severe voltage fluctuations, and non-compliance with grid standards disrupt power evacuation, causing renewable capacity to remain stranded during peak generation periods.

- **Frequent outages of EHV lines**: Rajasthan faces repeated outages of extra-high voltage (EHV) corridors. In May 2025, multiple 400kV lines, including Jaisalmer-Barmer and Bhinmal-Barmer, suffered outages due to tower collapses, stranding significant renewable capacity during peak generation hours.
- **Severe voltage instability**: System voltage fluctuates sharply between 750kV and 800kV within a single day. Voltage dips sharply during solar hours because of high reactive power injections and spikes at night under low-load conditions. This leads to grid instability, forcing the grid operator to implement emergency measures, including line outages.
- **Inadequate compliance with grid standards**: Non-compliance with CEA Grid Connectivity Standards by some renewable developers is compromising grid stability. Since 2022, over 59 incidents of generation loss exceeding 1,000MW have been linked to inadequate Low Voltage

[22] NITI Aayog. Renewable Energy Resource Adequacy Planning to meet RPO by the States in India. February 2024
[23] NREL. Policy and Regulatory Environment for Utility-Scale Energy Storage: India. Dec 2020
[24] Rajya Sabha. Solar energy storage systems (Unstarred question no. 302). July 2025
[25] CEA, Status of pumped storage development in India. June 2025
[26] KSERC. Renewable Energy and Related Matters, Regulations 2025. May 2025
[27] SBICAPS. Report on energy storage systems. Nov 2024

Ride Through (LVRT), High Voltage Ride Through (HVRT), and reactive power support capabilities.[28]

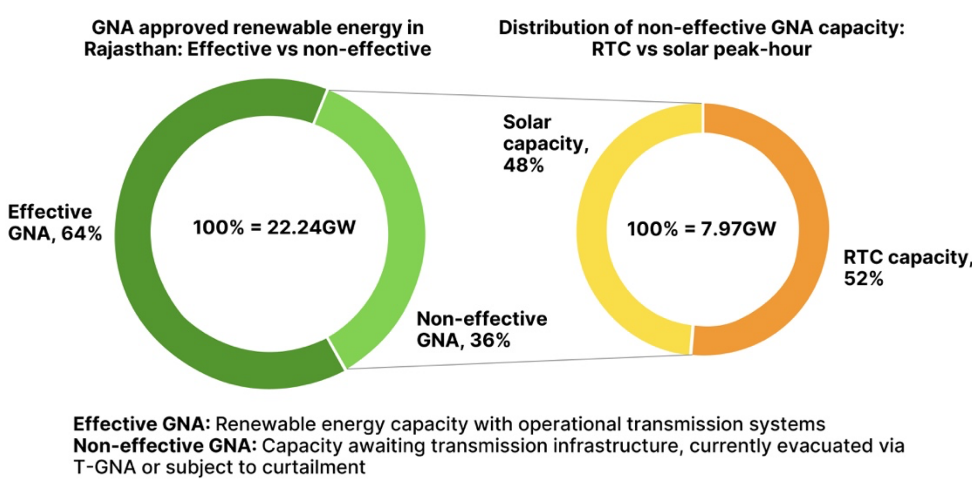
The impact of these technical faults has been particularly pronounced in Rajasthan, where aggressive renewable energy capacity additions in recent years have outpaced transmission build-out. The case study below highlights how these bottlenecks have led to stranded assets, delayed commissioning, and increased costs for developers.

State spotlight: Rajasthan

Rajasthan, where more than 70% of installed capacity comes from renewable energy, is a frontrunner in advancing India's green energy ambitions. However, it is also a hotspot for stranded assets due to delayed commissioning of transmission infrastructure, ecological hurdles, and speculative grid access.

As of July 2025, 22GW of ISTS-connected renewable energy projects were operational in Rajasthan. However, only about 14GW (64%) had access to dedicated transmission infrastructure. The remaining 8GW lacked an Associated Transmission System (ATS)—the dedicated transmission infrastructure linked to new generation projects—and were relying on Temporary GNA (T-GNA).

Figure 9: Rajasthan's GNA-approved ISTS renewable energy projects (July 2025)



Source: Northern Regional Power Committee, JMK Research

Nearly half of this stranded capacity (around 3.8GW of solar) is curtailed during peak solar hours due to corridor unavailability. Most of the stranded capacity (two-thirds) is linked to Phase-II transmission

[28] National Regional Power Committee. Operation Co-ordination sub-committee meeting. May 2025

projects planned for Rajasthan's Renewable Energy Zones, where the development of transmission infrastructure is delayed. The remaining (one-third) pertains to Phase-III REZ plans, where no transmission infrastructure is ready, even though about 2.7GW of renewable energy generation is already online. This mismatch exposes developers to financial strain, operational uncertainty, and additional T-GNA charges.

The situation is further aggravated by real-time operational constraints during peak solar hours:

- Heavy loading on corridors like Bhadla-Ajmer (765kV) and Bhadla-Bikaner (400kV)
- Voltage dips and oscillations in high-wind areas caused by reactive-power draw

Hoarding of transmission capacity by developers is worsening underutilisation. This practice inflates project costs and blocks timely access for genuine generators. Additionally, the ecological directive mandating underground cabling in Great Indian Bustard habitats has exacerbated power evacuation challenges and driven up costs, affecting an estimated 5-6GW of renewable energy capacity in the region.

With 19.1GW of utility-scale renewable energy capacity still in the pipeline, Rajasthan's transmission bottlenecks risk compounding unless:

- ATS completion is expedited,
- Speculative GNA misuse is curbed, and
- Real-time planning and approval coordination between CTU, STU, and regulatory bodies is strengthened.

Impact on the renewable energy sector

This section explores the multidimensional impact of transmission bottlenecks on various segments of the renewable energy value chain, primarily utility-scale renewable energy, consisting of two segments—DISCOM PPAs and open access for commercial and industrial (C&I) consumers. While impact intensity varies across segments, common effects include stranded capacity, commissioning delays, cost escalations, and wavering investor confidence.[29]

Utility-scale DISCOM PPAs

Transmission constraints undermine the viability of utility-scale renewable energy projects in India, particularly those dependent on long-term power purchase agreements with DISCOMs.[30] Coupled

[29] Indian Express. Grid infra, HVDC transmission major bottlenecks to meet renewable target: Vineet Mittal. May 2024
[30] International Energy Agency. Renewables Integration in India. 2021

with DISCOM financial stress, estimated at Rs7.5 lakh crore (US$88 billion)[31] as of FY2024, this has eroded trust in the sector. These resulting consequences have led to several tangible impacts:

- Delays in PPA and PSA signing, with multiple gigawatts of awarded capacity awaiting transmission infrastructure readiness. There is reluctance among DISCOMs to sign new PPAs, even for competitively priced projects, due to concerns over grid congestion and the risk of non-availability of contracted power during curtailment events.
- Wavering investor and lender confidence, resulting in higher financing costs and slower capital inflow.
- Reduced transmission player participation in competitive bidding, especially for projects in weakly connected zones.
- Stranded or underutilised commissioned renewable energy capacity, awaiting interconnection or facing limited grid access.

Open access

Open access projects face issues like stranded capacity and transmission delays, similar to those discussed in the previous sub-section on utility-scale renewable energy DISCOM PPAs, alongside some additional constraints.

Transmission access delayed by regulatory and DISCOM-level barriers: Open access projects often receive lower operational priority in transmission planning and corridor allocation than utility-scale projects tied to DISCOM PPAs. Infrastructure accessibility remains constrained as open access developers must navigate overlapping and uncoordinated approvals from SLDCs, RLDCs, DISCOMs, and state regulators. In several states, DISCOMs impede C&I migration through procedural delays, surcharge imposition, and contractual hurdles, creating sustained barriers despite technical readiness.

Inconsistent regulatory enforcement and the low prioritisation of transmission planning continue to hinder the growth of renewable energy under open access. Without targeted reforms and DISCOM-neutral grid access, the segment risks falling short of its potential to drive C&I open access at scale.

Stranded capacity from inadequate transmission infrastructure

India's renewable energy expansion is increasingly limited by a mismatch between generation readiness and transmission availability. Commissioned renewable projects often remain stranded while awaiting grid connectivity. Key issues include voltage/frequency instability, tower failures, and re-tendering delays caused by tardy responses from contractors responsible for engineering, procurement and construction, and land acquisition bottlenecks.

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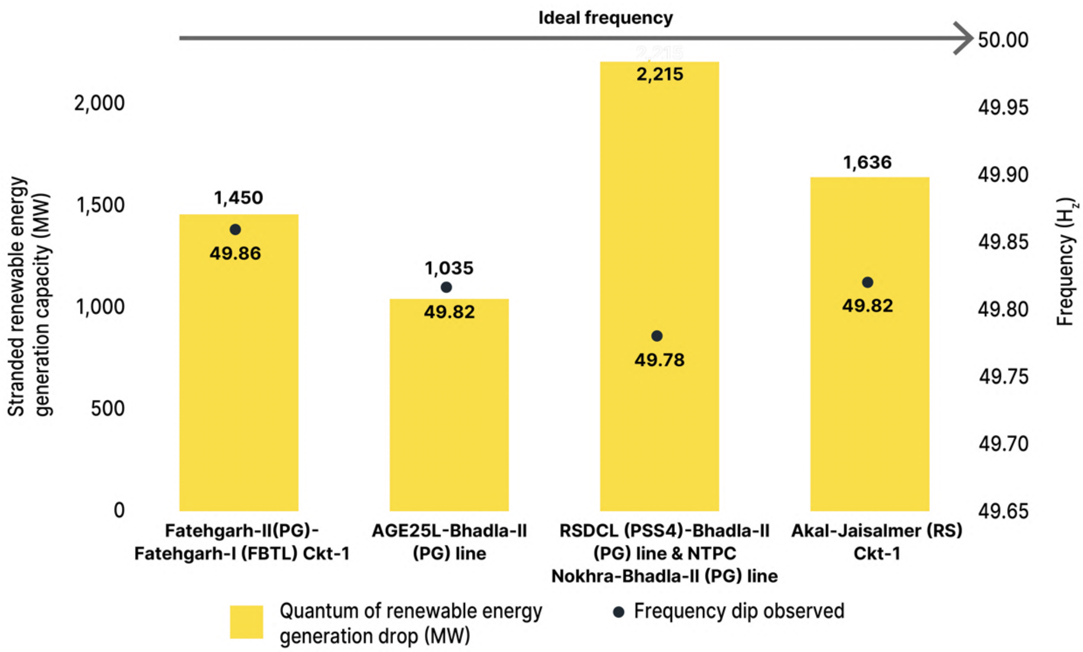
[31] PFC. 13th annual integrated rating and ranking (page no. 357). April 2025

From January to June 2025, the northern region alone reported over 6,300MW of generation loss linked to LVRT/HVRT non-compliance and grid faults.[32]

Figure 10: Renewable energy output loss linked to transmission faults and system frequency disturbances (Jan-June 2025)



Source: Northern Regional Power Committee, JMK Research

In the absence of long-term GNA or evacuation infrastructure, developers resort to T-GNA or absorb losses, which can affect project viability. Around 50GW of renewable energy capacity is currently stranded across India, leading to cost overruns, delayed returns, and wavering investor confidence.[33]

Recommendations

Addressing the underutilisation of green power transmission infrastructure requires a comprehensive strategy encompassing regulatory reform, targeted investment, and grid modernisation.

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[32] Northern Region Power Committee. Renewable Energy Sub Committee meeting. June 2025

[33] Reuters. India's renewable projects without supply deals double in nine months, documents show. 2nd August 2025

Coordination among policy stakeholders

Policy reforms should aim to enhance institutional coordination, mandate transparency, and enforce performance-based accountability.

- **Integrate generation and transmission planning:** Policymakers should establish a unified planning framework that aligns generation timelines and locations with corresponding evacuation infrastructure. Aligning the efforts of CTUs, STUs, and private players will minimise stranded assets, reduce delays, and improve transmission utilisation.
- **Establish a single-window clearance:** Set up a unified, single-window clearance system that consolidates key approvals like land acquisition, forest clearance, RoW, and grid connectivity, under one interface with strict adherence to timelines. This will enable faster project approvals and facilitate the timely resolution of RoW issues, ensuring the prompt execution of transmission lines.
- **Performance-based incentives:** Policymakers should embed performance-linked mechanisms to improve asset utilisation. They must impose disincentives for prolonged underutilisation and offer incentives for timely commissioning and sustained use. Linking financial support and regulatory approvals to post-commissioning utilisation metrics will ensure that investments translate into operational efficiency.

Modernise transmission planning

Annual studies should be conducted to evaluate whether transmission development is progressing as planned and to identify the reasons behind deviations. Transmission planning needs to move beyond the traditional five-year static cycle to a more adaptive approach that reflects evolving generation patterns and demand growth. These plans should integrate cluster-level demand forecasting by coordinating with state IT, industry, and urban development agencies to identify emerging high-intensity loads like data centres, electric vehicle charging hubs, etc. Since individual facilities can add significant load and develop far faster than traditional urban or industrial loads, embedding this insight into planning will enable policymakers and utilities to anticipate risks of stranded or inadequate transmission capacity and build a more resilient grid.

Additionally, there is a need to move beyond conventional PPA or merit-order-based dispatch and adopt Security Constrained Economic Dispatch (SCED). SCED optimises real-time generation schedules by accounting for constraints such as transmission limits, generator ramp rates, and reserve requirements. SCED was launched as a pilot in April 2019 for select inter-state thermal generating stations, resulting in substantial cost savings. The pilot reduced variable generation costs by approximately Rs2,070 crore (Rs20.7 billion) between April 2019 and February 2022.[34] The CERC has since formalised SCED, issuing regulatory procedures for its implementation across all inter-

[34] Grid India. Detailed Feedback Report on Pilot SCED. March 2022

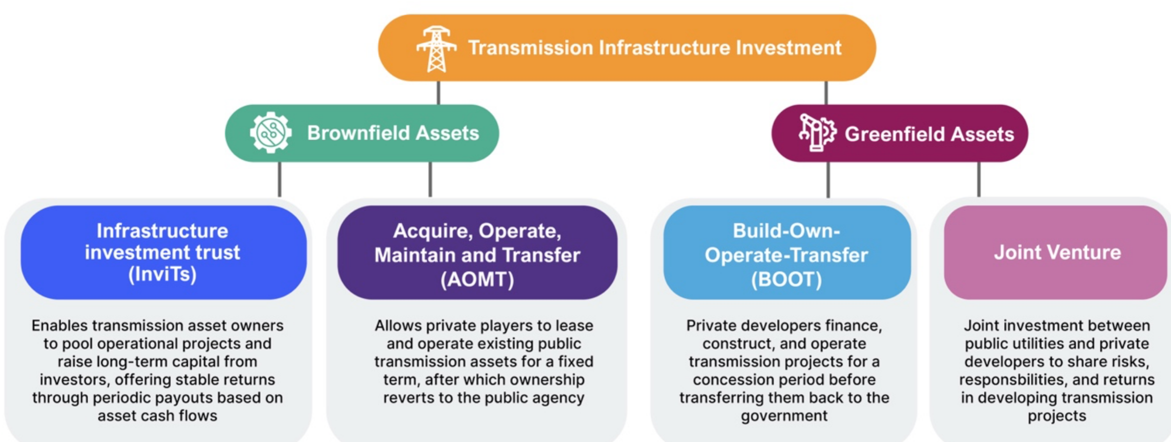
state thermal generating stations.[35] Expanding SCED into the intra-state domain would lower procurement costs, enhance reliability, and support the smoother integration of renewables, creating an efficient and resilient dispatch framework.

Asset monetisation strategies

Scaling India's transmission infrastructure requires unlocking capital through institutionalised asset monetisation and greater public-private participation. Central and state utilities should adopt standardised monetisation frameworks to recycle capital from brownfield assets. In parallel, policymakers must accelerate greenfield development by promoting structured Public-Private Partnership (PPP) models that enable efficient risk-sharing and faster execution. The figure below illustrates key investment pathways in the transmission sector, categorised by asset type.

While the TBCB model has improved private sector participation, there is scope to broaden the pool of transmission developers. Lessons from the renewable energy sector—where bids are capped at a percentage of project capacity per player to diversify participation—suggest that transmission issuing authorities can adopt similar measures to prevent market concentration and encourage new entrants. Additionally, introducing targeted construction grants or viability gap funding dedicated to transmission projects can help offset entry barriers, accelerate project execution, and attract fresh capital to the sector.

Figure 11: Asset monetisation strategies for transmission infrastructure



Source: Industry reports, JMK Research

[35] CERC. Detailed Procedure for Security Constrained Unit Commitment, Unit Shut Down (USD) and Security Constrained Economic Dispatch (SCED) at Regional Level. 16th April 2024

Operational efficiency measures

- **Prioritise reconductoring:** Reconductoring replaces existing power lines with advanced, higher-capacity conductors using the same RoW and transmission structures. Despite its benefits, utilities neglect reconductoring. The current rate-of-return model guarantees profits based on the total capital expenditure, incentivising new construction over upgrades. This drives overall costs, which are ultimately passed on to consumers through higher tariffs. Regulators must realign incentives to make reconductoring the preferred option, especially in congested, renewable-rich corridors.
- **Deploying energy storage to enhance grid flexibility and reduce curtailment:** Integrating storage as a core component of transmission infrastructure requires policymakers to complement viability gap funding with targeted regulatory and planning reforms. They should mandate CTUs/STUs to evaluate storage as a standard option in transmission planning, especially in renewable-rich, congested regions. Regulatory commissions must establish clear cost-recovery frameworks that allow transmission licences to treat storage as part of regulated capital expenditure, enabling viable deployment and ensuring long-term bankability.

Conclusion

India's ambition of achieving 500GW of non-fossil capacity by 2030 hinges on developing a robust, future-ready transmission network. As VRE penetration accelerates, the role of transmission will evolve beyond simply evacuating power. The infrastructure must accommodate rapid demand growth, storage integration, and emerging technologies such as green hydrogen and electric mobility, while maintaining reliability and flexibility.

The extension of ISTS charge waivers for BESS until 2028 will sustain strong interest in renewable projects that incorporate energy storage. By reducing transmission costs, these waivers enhance the economic viability of solar-plus-storage projects. Additionally, the introduction of time block-wise GNA will alleviate congestion during non-solar hours, creating opportunities to discharge energy when it is most valuable.

Concurrently, grid upgradation and asset monetisation strategies will be crucial for strengthening InSTS infrastructure. ISTS-connected projects often depend on InSTS for their final connectivity, making these state networks indispensable for reliable power delivery. Without targeted investments from STUs and private transmission players in higher-capacity lines, advanced protection systems, and digital monitoring, bottlenecks at the state level could offset the benefits of ISTS expansion. Prioritising InSTS upgrades alongside inter-state development will ensure seamless power flow and optimise asset utilisation.

Accelerating this transformation will require capital at scale and new forms of collaboration. Strengthening PPP frameworks and the TBCB model are vital to attract private investment, drive cost efficiency, and accelerate project execution. The recent entry of players such as Reliance Industries and Dineshchandra Infracon into the ISTS-TBCB space signals the sector's growing attractiveness to diversified conglomerates and infrastructure specialists. Building on this momentum will require a competitive secondary market for transmission assets and strategic joint ventures between domestic and global transmission players to bring in technology and execution excellence.

As renewable integration deepens, transmission planning must evolve into a more coordinated, data-driven process. Learning from past planning gaps is critical to avoid congestion, stranded assets, and cost overruns. Aligning central and state-level plans, supported by institutionalised real-time curtailment reporting, will enable synchronised execution. Simultaneously, leveraging advanced forecasting, load flow modelling, and real-time monitoring will enhance predictability and operational efficiency. Greater grid operations and decision-making transparency will reduce uncertainty for players and financiers, ensuring India's transmission system remains flexible, resilient, and fully aligned with its long-term decarbonisation goals.

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The Institute for Energy Economics and Financial Analysis (IEEFA) examines issues related to energy markets, trends and policies. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy. www.ieefa.org

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