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Built and Blocked: How Transmission Bottlenecks Are Curtailing India's Renewable Energy

 **INDIAN EXPRESS**

31 July 2026

ENVIRONMENT**ECONOMY****GS3**

CURATED & WRITTEN BY

**Bharat Choudhary**

UPSC Educator & Content Creator

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Built and Blocked: How Transmission Bottlenecks Are Curtailing India's Renewable Energy

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GS3



INTERVIEW ANGLE

"If transmission takes three to five times longer to build than generation, should India require transmission-capacity guarantees before approving new renewable capacity auctions, even if that slows headline renewable-addition numbers in the short term?"

✓ Every fact web-verified against primary sources

THE LIFT LINE

Building a solar farm and then discovering there is no road wide enough to carry its power to market is not a technology failure; it is a planning failure, and the meter is still running on every curtailed unit of clean electricity while the argument about whose job the road was continues.

WHY THIS EDITORIAL MATTERS FOR YOUR EXAM

Transmission-generation sequencing is a precise, quantifiable GS3 problem that goes beyond the generic “India needs more renewable energy” framing UPSC candidates often default to, rewarding those who can identify infrastructure-timeline mismatches as a distinct category of policy failure.

GS Paper 3: Infrastructure: energy; conservation, environmental pollution and degradation; achievements of Indians in science and technology (grid-scale storage, dynamic line rating).

For **Prelims**, fix the generation-versus-transmission commissioning timeline gap (12-18 months versus 36-60 months) and the curtailment figures as precise, testable facts.

CONCEPT	MEANING	WHY UPSC TESTS IT
Curtailment	Deliberately reducing generation output below available capacity, usually because transmission or grid capacity cannot absorb it	The direct, quantifiable symptom of the transmission-generation mismatch
Dynamic line rating (DLR)	Technology allowing a transmission line's safe carrying capacity to be adjusted in real time based on weather and loading conditions, rather than a fixed static rating	A near-term technical mitigation, increasingly relevant to renewable-heavy grids
Pooling station	A grid node where multiple generation sources connect before power is transmitted onward	The proposed location for grid-scale battery storage to absorb curtailed generation
Synchronised generation-transmission planning	Approving new generation capacity auctions only where matching transmission capacity is confirmed on a compatible timeline	The core structural-reform proposal this editorial advances

BACKGROUND AND CONTEXT

India's renewable energy capacity has expanded rapidly in recent years, driven by falling technology costs and aggressive capacity-addition targets. This generation-side success has outpaced the country's transmission infrastructure build-out, which faces inherently slower construction timelines due to land acquisition, multi-state right-of-way clearances, and the coordination complexity of connecting geographically dispersed renewable projects, often sited in resource-rich but grid-peripheral regions like Rajasthan, to demand centres elsewhere in the country.

METRIC	FIGURE
Generation commissioning timeline	12 to 18 months
Transmission commissioning timeline	36 to 60 months
Curtailment in parts of Rajasthan	Up to 70 to 95 per cent
Solar curtailment, Q1 FY27 (national)	8,133 GWh

THE CORE ARGUMENT / ISSUE

The arithmetic of the mismatch

A three-to-five-times gap between generation and transmission commissioning timelines is not a marginal planning inefficiency; it is a structural guarantee that transmission will lag unless planning for it begins well before, not concurrent with, generation capacity approval. Every renewable project commissioned under the

current sequencing effectively starts a multi-year wait for adequate evacuation infrastructure, during which curtailment is the default outcome rather than an occasional exception.

Why Rajasthan is the sharpest example

Rajasthan's status as one of India's premier renewable-resource states, with abundant solar irradiance and wind potential, has made it a magnet for generation-capacity investment, but its relative geographic peripherality to major demand centres means the transmission build-out required to fully utilise that generation is correspondingly larger and slower, producing the extreme 70 to 95 per cent curtailment figures cited in some areas, an outcome that represents both wasted clean-energy potential and stranded investor capital.

Near-term mitigation versus long-term fix

Grid-scale battery storage at congested pooling stations offers a genuine near-term mitigation: it allows excess generation, which would otherwise be curtailed, to be stored and released later when transmission capacity frees up or demand rises, effectively **decoupling** the moment of generation from the moment of transmission. Dynamic line rating offers a complementary near-term fix, extracting additional safe capacity from existing lines under favourable conditions without requiring new construction. Neither, however, addresses the underlying sequencing problem; they treat the symptom of curtailment rather than the cause of mismatched planning timelines.

The harder structural fix

Synchronised generation-transmission planning, requiring new renewable capacity auctions to be matched with confirmed, timeline-compatible transmission capacity before approval, addresses the root cause but is harder to implement because it may slow the headline pace of renewable capacity addition in the near term, a politically and internationally visible metric that policymakers have strong incentives to keep maximising even at the cost of downstream curtailment inefficiency.

HOW TO THINK ABOUT THIS (ANALYTICAL FRAME)

When two interdependent infrastructure components have different natural build timescales, sequencing them incorrectly guarantees a bottleneck regardless of either component's individual quality. This is a general infrastructure-planning principle, not specific to power: any system with a fast-build component (generation) and a slow-build component (transmission) that are approved independently rather than jointly will produce a bottleneck at the slow component, and the fix is planning synchronisation, not just building more of the fast component faster.

THE DIAGRAM IN WORDS

Picture a factory (renewable generation capacity) that can be built and start producing goods within a year, sitting at the end of a single-lane road (the transmission line) that takes four years to widen into a highway. If the factory is approved and built the moment land is available, without waiting for the road-widening project to also begin, the factory sits producing goods faster than the road can carry them away for roughly three years, the exact gap between the two construction timelines, and those goods, in this case electricity, are simply not produced during that window, which is what curtailment means in practice.

WAY FORWARD

- ❶ **Mandate synchronised generation-transmission planning at the auction stage**, approving new renewable capacity only where matching transmission capacity is confirmed on a compatible timeline.
- ❷ **Deploy grid-scale battery storage at the most congested pooling stations** as a near-term mitigation for existing curtailment, prioritised by curtailment severity data.
- ❸ **Accelerate dynamic line rating adoption** on existing high-curtailment transmission corridors to extract additional safe capacity without new construction.
- ❹ **Streamline land acquisition and right-of-way clearance processes** specifically for transmission projects, addressing the structural source of the timeline gap.
- ❺ **Publish standardised, transparent curtailment-compensation mechanisms** for generators affected by transmission bottlenecks, ensuring the financial risk of planning mismatches does not fall entirely on renewable-energy investors.

PYQ LINKAGE AND PRACTICE

UPSC has tested renewable energy expansion, grid infrastructure, and energy-storage technology as recurring GS3 themes; this editorial's specific focus on the generation-transmission timeline mismatch offers a sharper, more precisely testable angle than a general renewable-capacity-growth narrative.

Practice question: "India's renewable energy transition is now constrained less by generation capacity than by transmission infrastructure." Examine this claim with reference to the generation-transmission commissioning timeline gap and curtailment data from Rajasthan. (250 words, 15 marks)

Interview angle: If transmission takes three to five times longer to build than generation, should India require transmission-capacity guarantees before approving new renewable capacity auctions, even if that slows headline renewable-addition numbers in the short term?

Sources: The Indian Express, Central Electricity Authority, Ministry of New and Renewable Energy

Source: Built and Blocked: How Transmission Bottlenecks Are Curtailing India's Renewable Energy — Ujjiyari.com

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• KEY ARGUMENTS AT A GLANCE

India's renewable energy capacity build-out has outpaced its transmission infrastructure so severely that generation is now being curtailed, in some parts of Rajasthan by up to 70 to 95 per cent, because solar and wind projects can be commissioned in 12 to 18 months while the transmission lines needed to evacuate their power take 36 to 60 months to build, a structural mismatch that squanders both generation investment and clean-energy potential.



SUPPORTING

- The commissioning-time gap between generation (12-18 months) and transmission (36-60 months) means transmission planning that begins only after generation capacity is auctioned is almost mechanically guaranteed to lag behind, since transmission cannot catch up within a renewable project's own construction timeline.
- 8,133 GWh of solar generation curtailed in a single quarter (Q1 FY27) represents a direct, quantifiable loss of clean-energy output and generator revenue, imposing real economic cost on top of the climate cost of underutilised clean capacity.
- Grid-scale battery storage at congested transmission pooling stations and dynamic line rating technology, which allows existing lines to safely carry more power under favourable conditions, both offer ways to extract more capacity from existing transmission infrastructure without waiting for new line construction.



COUNTER

Transmission infrastructure involves land acquisition, right-of-way clearances and multi-state coordination that are inherently harder to compress than generation-project timelines, meaning some structural lag between generation and transmission build-out may be unavoidable regardless of planning improvements, and the realistic policy goal may be narrowing the gap rather than eliminating it.



WAY FORWARD

Mandate synchronised generation-transmission planning at the auction stage, so that new renewable capacity is only approved where transmission capacity is either already available or

contractually guaranteed on a matching timeline, shifting the sequencing risk away from already-built generation assets.


MAINS ANSWER FRAMEWORK
QUESTION

India's renewable energy build-out is increasingly constrained by transmission infrastructure rather than generation capacity. Examine the causes of this mismatch and evaluate potential solutions, including synchronised planning and grid-scale storage. (250 words)

INTRODUCTION

India's renewable energy transition faces a structural bottleneck that has shifted from generation capacity to transmission infrastructure: solar and wind projects can be commissioned in 12 to 18 months, while the transmission lines needed to evacuate their power take 36 to 60 months to build, a mismatch now causing severe curtailment, up to 70 to 95 per cent in parts of Rajasthan, and 8,133 GWh of solar curtailed in a single quarter (Q1 FY27) nationally.

BODY

The root cause of the mismatch is sequencing: transmission planning has historically followed generation capacity auctions rather than preceding or accompanying them, meaning by the time a transmission line's land acquisition, right-of-way clearance and construction process is complete, the generation capacity it was meant to serve has often already been built and sitting partially idle for years. This is compounded by the inherently harder logistics of transmission-line construction compared to solar or wind project construction: transmission requires multi-state coordination, extensive land acquisition often across diverse ownership, and right-of-way clearances that generation projects, typically sited on more consolidated land parcels, do not face to the same degree.

Proposed solutions operate on two timescales: near-term mitigation through grid-scale battery storage at congested pooling stations, which can absorb excess generation when transmission capacity is the binding constraint, and dynamic line rating technology, which allows existing transmission lines to safely carry more power under favourable weather conditions than their static rated capacity assumes; and longer-term structural reform through synchronised generation-transmission planning, ensuring new renewable capacity auctions are matched to guaranteed, timeline-committed transmission capacity rather than being approved independently and left to compete for scarce evacuation infrastructure after the fact.

CONCLUSION

Given that transmission construction timelines are unlikely to compress to match generation timelines even with improved planning, the more realistic and immediately actionable policy priority is synchronising future capacity auctions with confirmed transmission availability, while deploying storage and dynamic line rating as near-term mitigants for the curtailment already occurring on the existing, under-evacuated generation base.

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