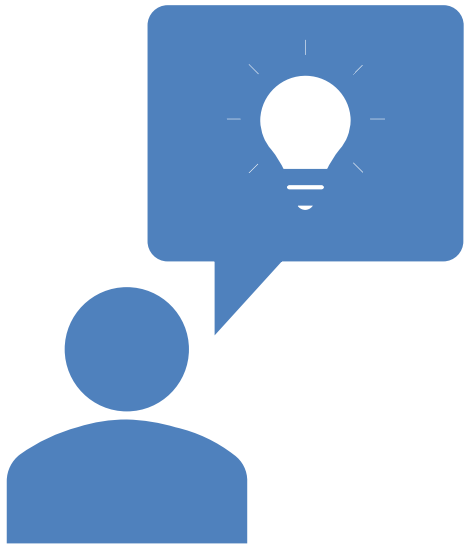


Rethinking Renewable Energy Curtailment- Planning, Regulation and the path ahead



Day-2 4:15-4:30 PM

Mrinal Anand Aggarwal
Manager, Deloitte

Steps to promote Renewable Energy



500 GW of non-fossil fuel installed electricity capacity by 2030
(Panchamrit commitments)



Target revised to 900 GW of non-fossil fuel capacity by 2035
(Updated NDC, 2026)



Govt. of India has taken multiple steps to promote RE, major are

ISTS charges waiver to RE projects

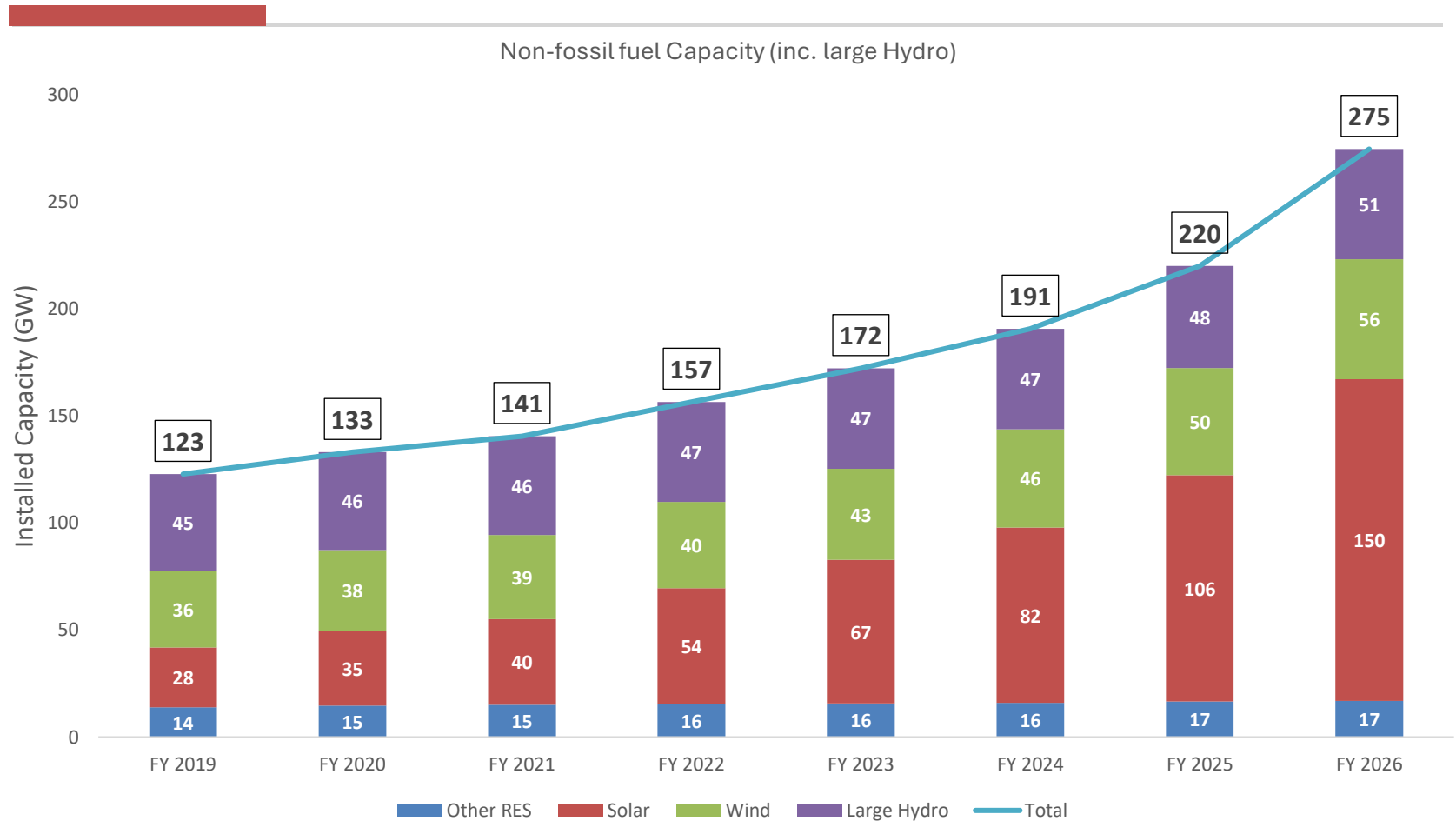
RPO/RCO Targets till FY 2029-30

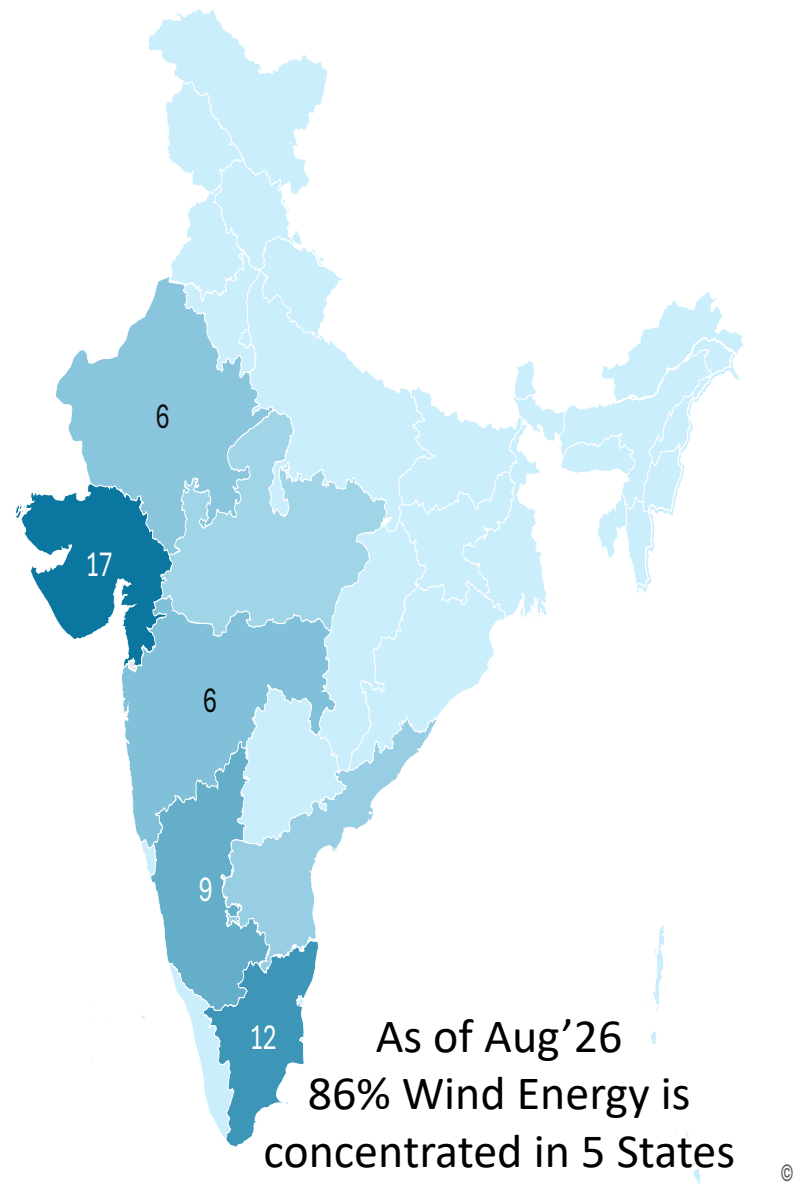
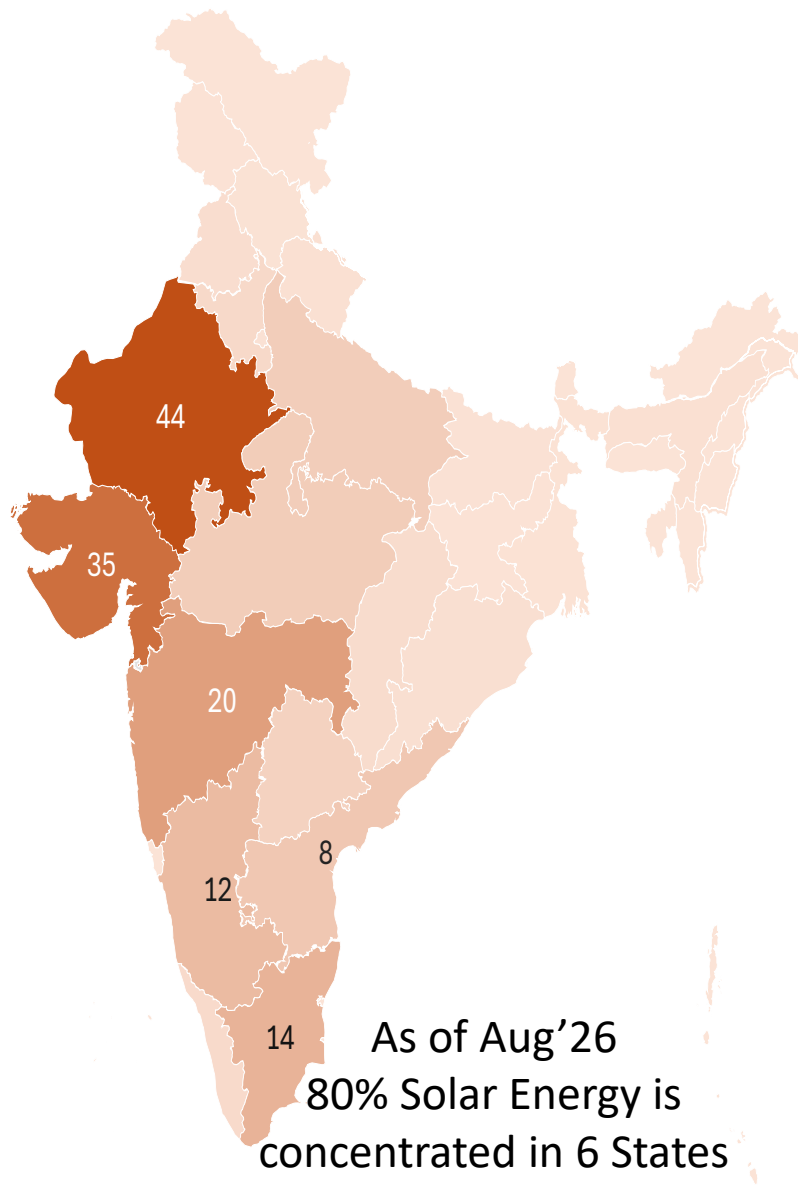
Competitive Bidding Guidelines for RE with Energy Storage



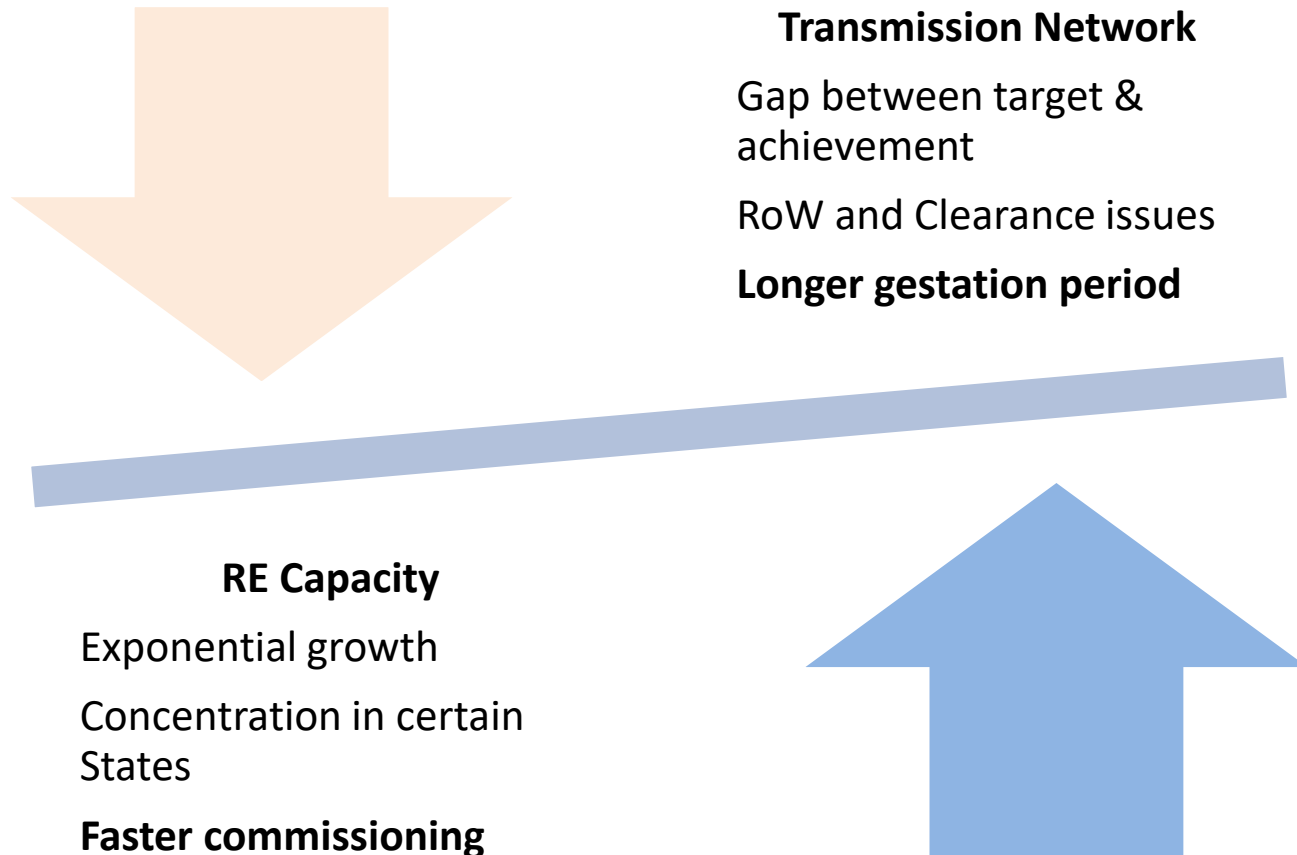
Govt. steps resulted in exponential growth in RE Sector and concentration of Solar & Wind projects in certain States.

Growth of Non-fossil fuel Capacity

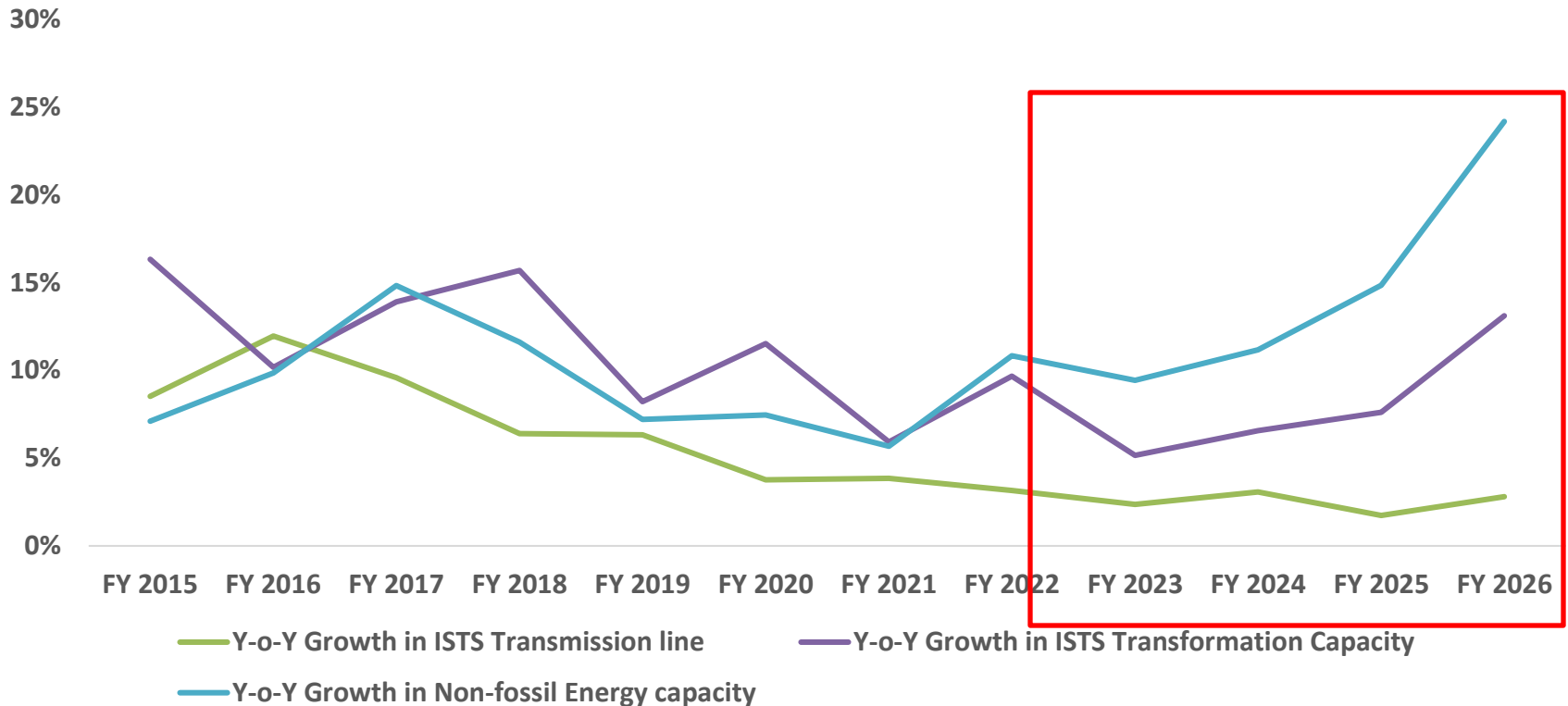




Mismatch resulted delay in connectivity of RE projects, forcibly scheduling power through T-GNA and Curtailment



SCoD-RE $\neq$ SCoD-Tx. Network



In last 5 years, non-fossil fuel based capacity has increased exponentially while the Transmission network fails to keep the pace.

What is Curtailment

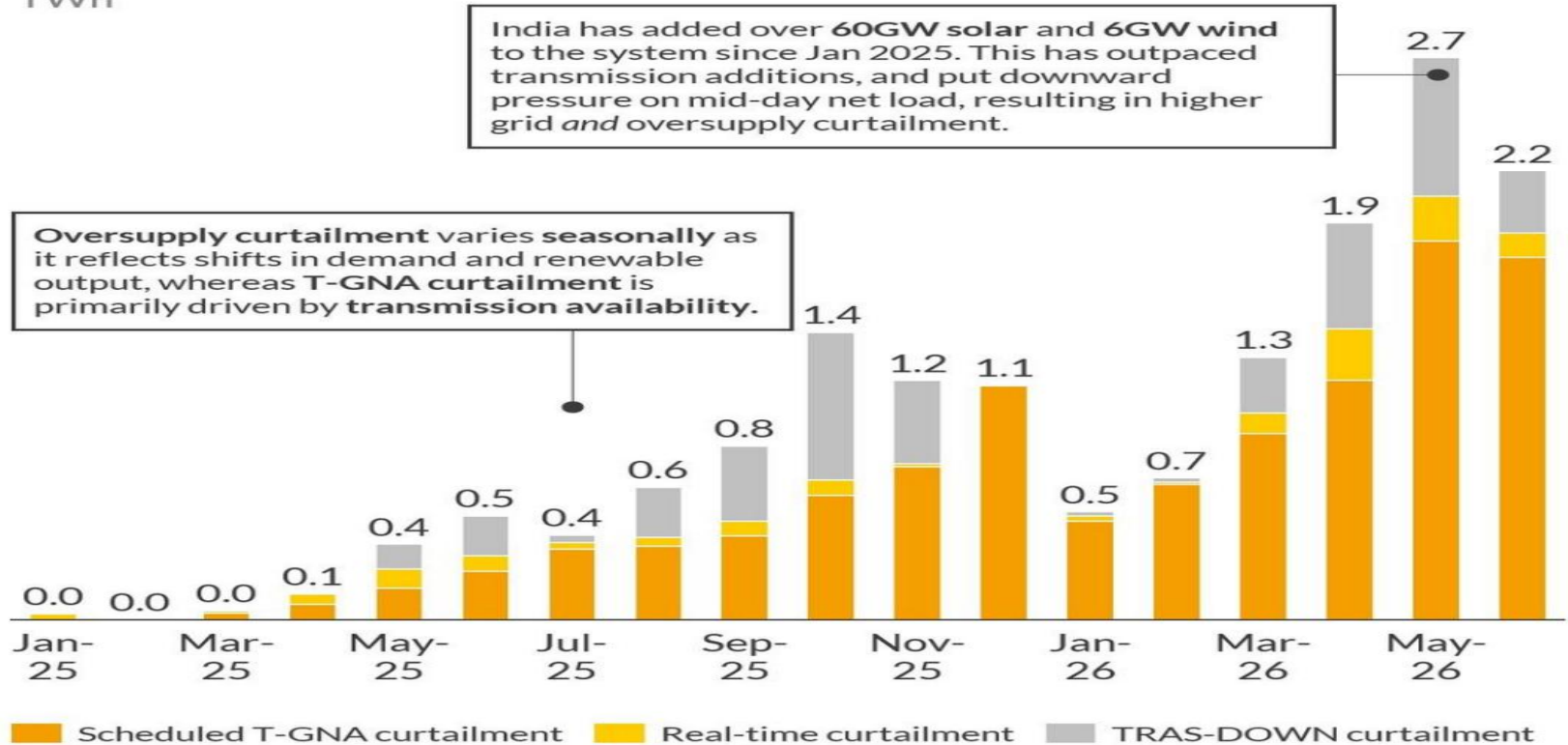
- “***Curtailment***” means a reduction in the output of a generator from what it could otherwise produce given available resources, typically on an involuntary basis.
- The term curtailment is broadly used to refer to the use of less wind or solar power than is potentially available at that time.

(as per FoR Model Guidelines)

RE Curtailment in India - Issue

Solar power curtailment and restriction are being carried out to maintain grid security and due to mismatch between commissioning of transmission lines and RE projects (as per MNRE)

Monthly curtailment by regulatory mechanism
TWh



Prevailing in other countries too with huge RE penetration

Key reason of curtailment

Limited availability of RE curtailment, only available in daily VRE Report of Grid-India. Major reasons of curtailments are as follows:

TRAS-down related
T-GNA related
System Stability • Control under drawal • Due to high frequency and heavy under drawal • In view of system requirement • Overloading or outage of Transmission element • System requirement and grid security & stability

Legal & Regulatory aspects w.r.t. RE curtailment in India

APTEL
Judgement 2021



FoR Model
Guidelines 2022



TNERC –
Procedure 2024

Summary

APTEL judgment dated 2/08/2021 (NSEFI vs TNERC, TANGEDCO, TNSLDC, etc.)	Key observations are: • Back down of Renewable Energy only after exhausting all other possible means of achieving & ensuring grid stability • Compensation for PAST curtailment @ 75% of PPA Tariff and @ Tariff in future • Summarized criteria of grid security
FoR - Model Guidelines for management of RE Curtailment for Wind & Solar generation in Nov 2022 (in line Hon'ble APTEL)	• Defined "<i>Curtailment</i>" • Events considered for RE curtailment • Compensation • No compensation in case of grid operation safety/security • Compensation @ Tariff in case of grid unavailability upto 50 hrs or as mentioned in PPA • In case of other reason @ tariff for Solar & Hybrid Project & @ 50% of tariff for Wind Project
TNERC Procedure for Management of RE Curtailment	TNERC issued Detailed Procedure for Management of RE Curtailment for Wind and Solar Generation in June 2024, in line with FoR Model Guidelines
Standard PPA clause	As per clause 4.10.1 Standard PPA, SPD are compensated due to offtake constraints due to Grid Unavailability beyond 175 hrs in a contract year against 50 hrs



Impact of Curtailment

- **Revenue Loss:** Every unit curtailed translates to direct, unrecoverable top-line cash flow losses for project developers.
 - As per our estimate, annual curtailment by 1% results annual generation loss per MW will be around 0.018 MU and revenue loss of Rs. 0.46 Lakh/ MW annually (at Rs. 2.50/kWh).
- **Reduced Returns (IRR):** Unanticipated backdowns, turning profitable projections into marginal or non-viable assets. Lower generation means lower cash available for debt service.
- **Lender Hesitation:** Financial institutions penalize high-curtailment zones with higher interest rates or stricter debt-to-equity prerequisites.

Issues and Steps taken

Issues and Status as of now	Steps taken
Limited Transmission capacity 12 GW of RE faced evacuation restrictions 21 GW of RE evacuated through T-GNA	NEP (Volume-II) expansion of TL to 6.48 lakh ckm & TC to 2345 GVA by 2032 GEC-I & II for evacuation of 44 GW, GEC-III- 135 GW HVDC, Capex by STU for InSTS network
Limited storage 3 GW/9GWh- BESS capacity against 227 GW Intermittent RE	CEA in Feb'25 advised min. 2Hr BESS equivalent to 10% CEA in Sept'26 proposed mandating 2Hr BESS for 10% of WS with SCoD after July'27 and 4Hr BESS for 10% after July'29
Inflexible thermal generation Intra-state level Thermal plants fails to meet MTL @ 55% - CEA	CEA published Flexibilization of coal-based power plants- a roadmap for achieving 40% MTL CEA also identified 34.5 GW capacity and aged 35 years or older— for two-shift operations by 2030
Limited system monitoring and forecasting DSM relaxed to WS sellers	CERC announced to treat WS seller as General seller by 2031
Aging Grid infrastructure	Industry request CEA to issue National Reconductoring Plan to upgrade transmission infrastructure efficiently
Demand Response - Limited impact due to ToD (Assam) - Lack of Demand Response Regulations	CEA is working to modify ToD slabs and its awareness SERCs issued Demand Response Regulations (RERC, AERC, KERC & MERC) Use surplus energy to GH2, E-mobility, Data centers, etc.

Key questions to be deliberated

- **Investment in Transmission Network:** What is the least-cost combination of transmission, storage and demand flexibility required to accommodate the next 50 GW of renewable energy?
- **Deployment of ESS:** Where does storage provide greater system value than the next transmission investment?

*Thank
you!*

Summary of Legal & Regulatory Aspects



1. APTEL Judgment:

Identifying reasons for RE Curtailment and compensation

- NSEFI on behalf of RE developers challenged [TNERC Order dated 25/03/2019](#), wherein Commission didn't not grant compensation to RE developers as no provision in the agreement signed with the Utility for payment of deemed generation charges.
- After analyzing submission and detailed report by [Grid-India](#), APTEL vide judgment dated [2/08/2021](#), directed Respondent to pay **compensation at the rate of 75% of PPA tariff** per unit along with carrying cost.



1. APTEL Judgment:

Identifying reasons for RE Curtailment and compensation

1. Conditions wherein RE curtailment does not fall under Grid security:
 - a) Frequency in the band of 49.90Hz-50.05Hz;
 - b) Voltages level within range
 - c) No network loading issues or transmission constraints;
 - d) Margins available for backing down from conventional energy sources;
 - e) State is overdrawing from the central grid or State is drawing from grid on short-term basis from Power Exchange or other sources simultaneously backing down power from intra-state conventional or non-conventional sources.
2. Any RE curtailment for the reasons other than grid security shall be **compensated at PPA tariff in future** and compensation shall be based on the methodology adopted by POSOCO
3. Forum of Regulators or the Central Government to formulate guidelines in relation to curtailment of renewable energy



2. FoR - Model Guidelines for RE Curtailment (1/3)

- Following the Hon'ble APTEL directions, Forum of Regulators issued "[Model Guidelines for Management of RE Curtailment for Wind and Solar Generation](#)" in November 2022.
- Key points from the Guidelines are:
 - Defined curtailment as
"Curtailment" means a reduction in the output of a generator from what it could otherwise produce given available resources, typically on an involuntary basis. The term curtailment is broadly used to refer to the use of less wind or solar power than is potentially available at that time"
 - *Reiterated conditions of Grid security parameters: Freq. band, voltage range, under drawal volume limit for states, Tech. min for thermal plants, limits for Transmission lines and ICT, etc.*



Conditions of Grid Security Parameters

Parameter	Specific Conditions																
Operating Frequency band	Average frequency for two or more successive time-blocks exceeds 50.05 Hz																
State Volume Limits ² as per CERC Regulations	Under-drawal by State at state periphery outside the range of 250 MW for two or more successive time blocks.																
Technical Minimum Margin for TPS % of MCR or Installed Capacity	In case all intra-state thermal generating stations are operating at technical minimum of 55% (or as per State Grid code subject to conditions for specific generating units, as approved by State Commission) and no further limit for backing down any thermal generation unit exits.																
Thermal limit of Transmission lines	Permissible maximum Loading limit on transmission line shall be its thermal loading limit as stipulated under CEA (Manual of transmission planning criteria), 2022																
Transformer/ICT loading limits	Loading limit for Inter-connecting transformer (ICT) shall be its Nameplate Rating as stipulated under CEA (Manual of transmission planning criteria), 2022																
Operational voltage limits	The steady state operating voltage limits under Normal conditions shall be within operating range as specified under Table-1, Clause (b) of Regulation 3 of CEA (Grid Standards) Regulations, 2010 and amendments Thereof <table> <tr> <th>Operating Voltages</th><th>IEGC/CEA limits</th></tr> <tr> <td>765kV</td><td>728-800 kV</td></tr> <tr> <td>400kV</td><td>380-420 kV</td></tr> <tr> <td>220kV/ 230kV</td><td>198-245 kV</td></tr> <tr> <td>132kV</td><td>122-145 kV</td></tr> <tr> <td>110kV</td><td>99-121 kV</td></tr> <tr> <td>66kV</td><td>60-72 kV</td></tr> <tr> <td>33kV</td><td>30-36 kV</td></tr> </table>	Operating Voltages	IEGC/CEA limits	765kV	728-800 kV	400kV	380-420 kV	220kV/ 230kV	198-245 kV	132kV	122-145 kV	110kV	99-121 kV	66kV	60-72 kV	33kV	30-36 kV
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2. FoR - Model Guidelines for RE Curtailment (1/3)

Events considered for RE curtailment

- i. Planned/forced outages on the evacuation infrastructure
- ii. Over-voltages on transmission line/ evacuation infrastructure
- iii. Over-loading of transmission line and/or associated evacuation infrastructure (incl. ICT)
- iv. Demand crash in the State with heavy under-drawal from ISTS & all the thermal generators are running at technical minimum with grid frequency crossing beyond higher permissible limits ($>50.05\text{Hz}$).
- v. State's under-drawal is far below the volume limits specified by the CERC DSM Regulations and there are limitations/constraints to minimise the schedule of generation from Interstate Generating Stations.



2. FoR - Model Guidelines for RE Curtailment (1/3)

Compensation Clause

- **Curtailment for grid operational safety/security:** No compensation shall be payable to the RE generators
- **Loss of generation due to grid unavailability:** Compensation (as specified in PPA/ EPA) for a duration more than the minimum period (50 hours a year, in case no details available)
- **Curtailment for reasons other than grid security:**
 - For Wind Energy projects: $50\% \times (\text{Average Generation during the month corresponding to the capacity backed down}) \times \text{PPA Tariff}$
 - For Solar Energy projects: $100\% \text{ of } [(\text{Average Solar Generation per hour during the month}) \times (\text{number of backdown hours during the month})] \times \text{PPA tariff}$
 - For RE Hybrid (Wind-Solar) projects: $100\% \text{ of } [(\text{Average Generation per hour during the month}) \times (\text{number of back down hours during the month}) \times \text{PPA Tariff}]$

The compensation in the event of RE curtailment for reasons other than grid security, shall be borne by the distribution companies/ buyers and that such compensation paid shall not be allowed as a pass-through in tariff.



Other

- TNERC adopted the FoR “Model Guidelines for Management of RE Curtailment for Wind and Solar Generation” and issued “[Detailed Procedure for Management of RE Curtailment for Wind and Solar Generation](#)”
- **Amendment in Standard PPA clauses:**
 - As per [clause 4.10.1 Standard PPA](#), SPD are compensated due to offtake constraints due to Grid Unavailability beyond 175 hours in a contract year as
$$\text{Generation Compensation} = ((\text{Tariff} \times \text{Solar Power (MW) offered but not scheduled by the Buying Entity})) \times 1000 \times \text{No. of hours of grid unavailability}.$$
 - However, in the case of third-party sale or sale in the power exchange, as price taker, the 95% of the amount realized, after deducting expenses, shall be adjusted against the Generation compensation payable, on monthly basis.

