Transmission Adequacy and Strength of Interconnection Capacity of States in India for future RE Integration, Market and Decarbonization

Presentation · October 2024

DOI: 10.13140/RG.2.2.30285.65764

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Transmission Adequacy and Strength of Interconnection Capacity of States in India for future RE Integration, Market and Decarbonization

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Indian Context

Climate and Energy Transition Objectives

- India power system - Vast subcontinent-sized power system and diverse mix of intra-state power systems
- Augmentation and strengthening of inter-state and cross-border interconnections within and across the Indian grid under progress
- Bolstering security and resilience in electricity supply, particularly during power plant failures or extreme weather events
- Diminish the necessity for constructing new capital-intensive power plants.
- Seamless integration of renewables into energy markets

Policy and Regulatory Interventions

Institution Building and Transmission Access to Markets

- Independent System Planners
  - Central Transmission Utility of India Ltd. (CTUIL)
  - State Transmission Utilities (STUs)

- Reformed the principles for long-term PPAs and bulk electricity markets
  - Transmission access, transmission pricing, scheduling, and dispatch methods.
  - Point of Connection (PoC) charges and General Network Access (GNA)

Roles and Responsibilities
Transmission Planning

- **Central Electricity Authority (CEA)**
  - National Electricity Plan (NEP)
  - Short Term and Perspective generation & transmission plans
  - Coordinate the activities of planning agencies
- **Central Transmission Utility (CTU)**
  - Network planning and development in accordance with NEP
  - Discharge all functions of planning and co-ordination related to inter-state transmission system (ISTS)
- **State Transmission Utility (STU)**
  - Network planning and development in accordance with NEP
  - Nodal agency for Intra-State Transmission System planning in coordination with distribution licensees and intra-state generators connected/to be connected in the STU grid
- **National Committee on Transmission**
  - To evaluate the functioning of the National grid, consider the recommendations of the Regional Power Committee (Transmission Planning) (RPCTP) & CTU for system expansion

- National Electricity Plan - Generation

https://cea.nic.in/wp-content/uploads/irp/2023/05/NEP_2022_32_FINAL_GAZETTE-1.pdf

- National Electricity Plan - Transmission

https://www.ctuil.in/uploads/cms_documents/NEP-Trans1.pdf

- Indian Electricity Grid Code – Resource Planning Code

https://cercind.gov.in/Regulations/180-Regulations.pdf

- CEA Manual on Transmission Planning Criteria

https://cea.nic.in/wp-content/uploads/psp___a_ii/2023/03/Manual_on_Transmission_Planning_Criteria_2023.pdf

- CERC (Planning, Coordination and Development of Economic and Efficient Inter-State Transmission System by Central Transmission Utility) Regulations, 2018

http://cercind.gov.in/2018/regulation/Transmission.pdf

State-wise interconnection targets
Need for Policy Push

- European Union's (EU) experience
  - Minimum trading capacities (minRAMs) have to be provided to electricity markets.
- Need for Indian policy makers and planners to set interconnection targets
  - To incentivize states to interconnect their electricity production capacity and upcoming load centres with the national grid, including neighbouring states.
- **Setting a minimum interconnection target of 50%**
  - Encourage states to align their transmission systems planning with internal demand and promote the seamless flow of electricity pan India and across regions.
  - Need to expand transmission interconnections in underserved areas of states & regions.
  - Additionally, periodic reviews may warrant revising the target, potentially raising it to 70% by 2030.
- Transmission network reinforcement urgency indicators
  - To address the imbalance between increasing renewable energy capacity and limited interconnection capacities.

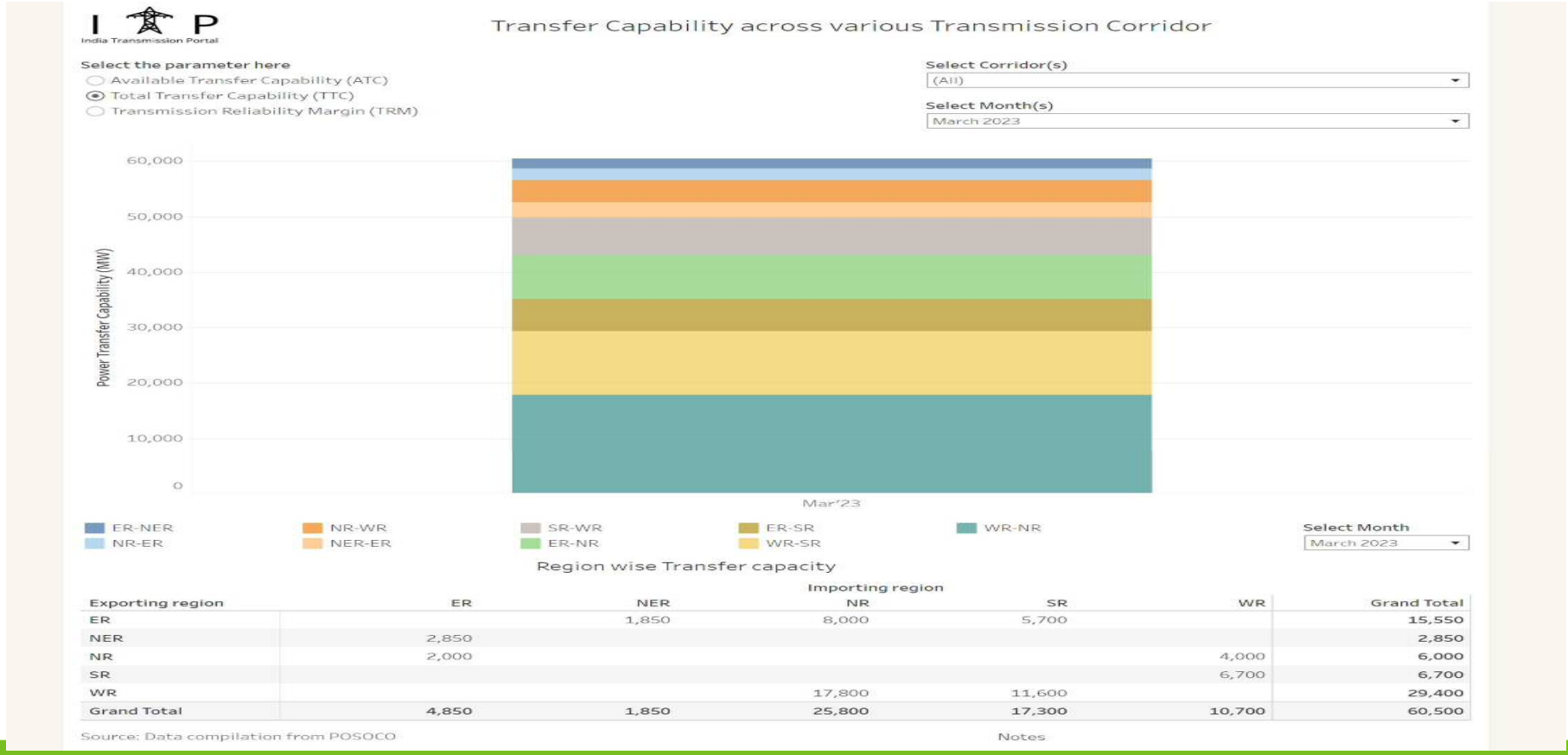
Formulation of Urgency Indicators

Stimulate investments in a timely manner…

- Price differentials in the wholesale market
- Nominal transmission capacity of interconnections relative to peak load and installed renewable generation capacity.
- Various innovative indices and ratios like TTC (Total Transfer Capability) and GNA Network Access with Demand and generation could be devised to quantitatively monitor the performance and achievements

Transfer Capability

Dynamically Varying



Exporting region	Importing region: ER	NER	NR	SR	WR	Grand Total
ER		1,850	8,000	5,700		15,550
NER	2,850					2,850
NR	2,000				4,000	6,000
SR					6,700	6,700
WR			17,800	11,600		29,400
Grand Total	4,850	1,850	25,800	17,300	10,700	60,500

Source: Data compilation from POSOCO

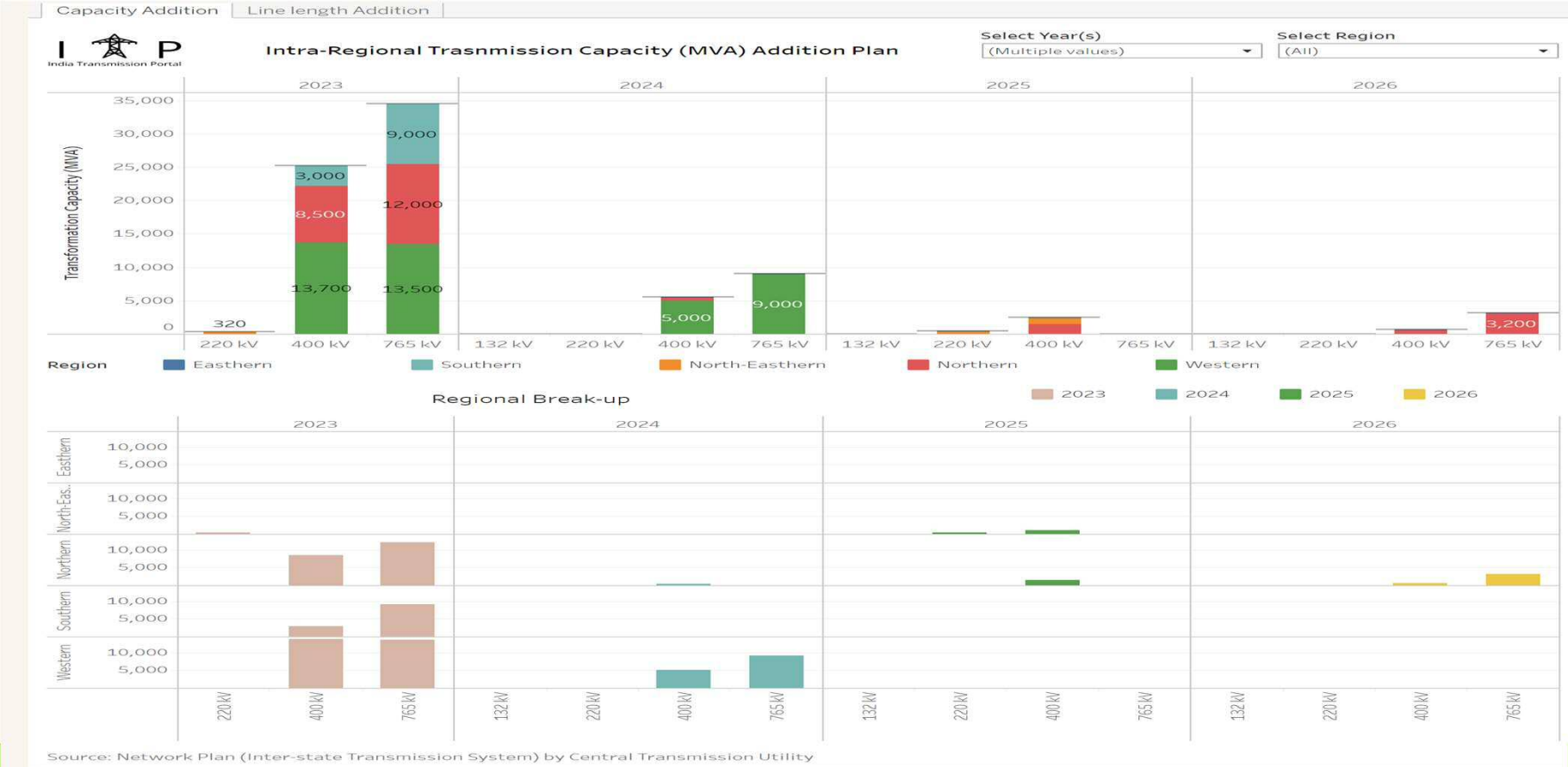
Notes

Transmission Planning

CEA and CTU – Alignment of Perspectives

Capacity Addition Planning

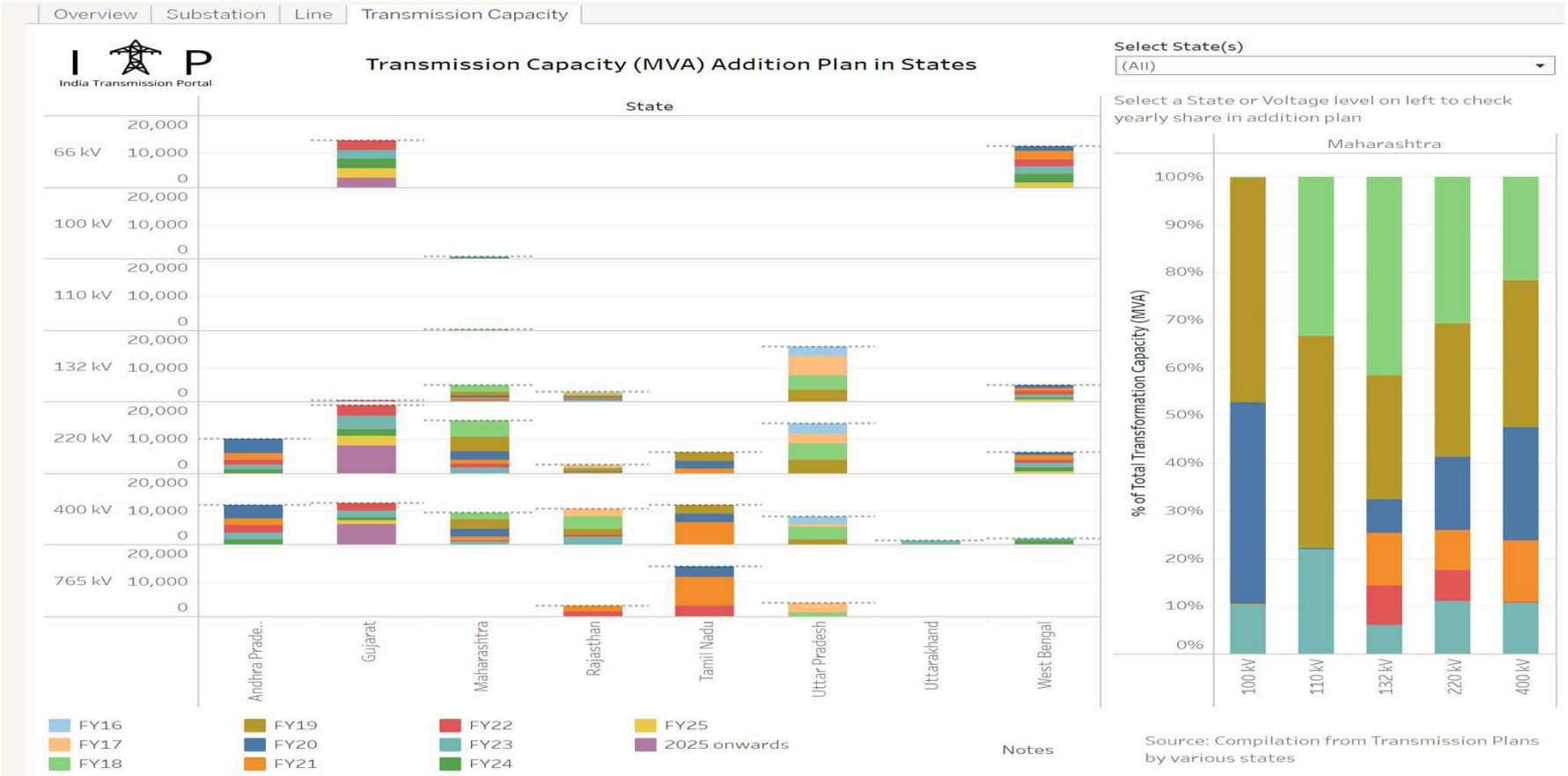
High RE Scenario – 500 GW by 2030



Source: Network Plan (Inter-state Transmission System) by Central Transmission Utility

Capacity Addition by Renewable Rich States

Intra-state Level



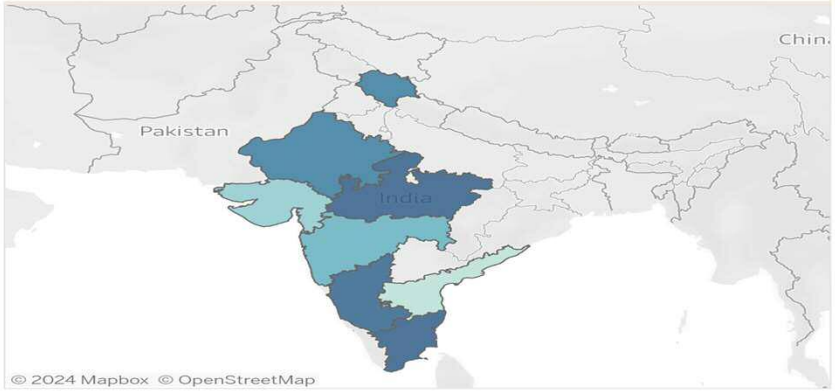
Green Energy Corridors

Transmission of Green Energy across India

I P
India Transmission Portal

Progress of GEC

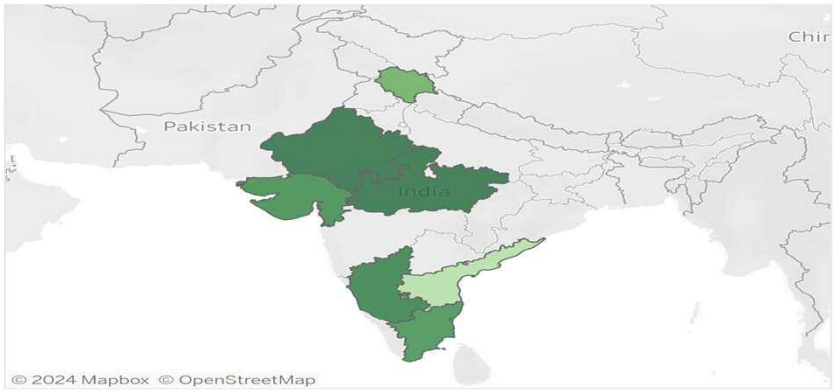
Transmission Length (ckm)



Line 68.87% 100.00%

State	State's Share in ckm target	Target (ckm)	Constructed (ckm)
Madhya Pradesh	28.39%	2,773	2,773
Gujarat	19.54%	1,908	1,429
Andhra Pradesh	10.99%	1,073	739
Tamil Nadu	10.93%	1,068	1,068
Rajasthan	10.79%	1,054	984
Maharashtra	7.89%	771	625
Karnataka	6.33%	618	609
Himachal Pradesh	5.14%	502	470

Transmission capacity (MVA)



Capacity 44.04% 100.00%

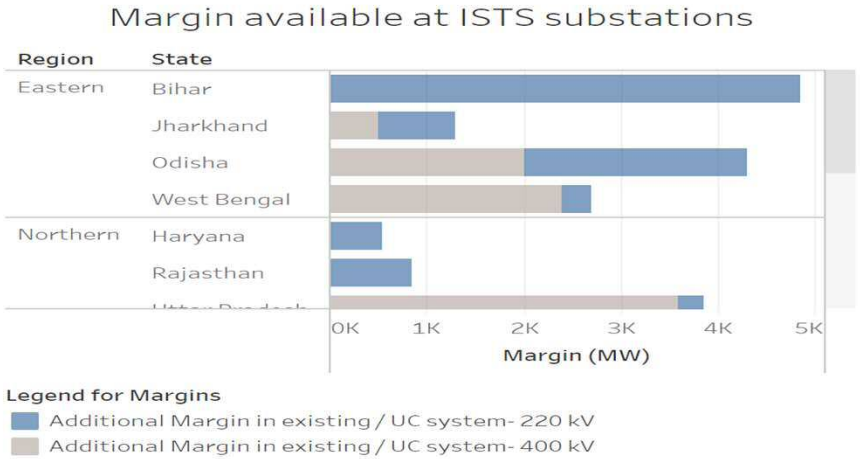
State	State's share in MVA Target	Target (MVA)	MVA Charged
Gujarat	35.17%	7,980	6,980
Madhya Pradesh	20.93%	4,748	4,748
Karnataka	11.91%	2,702	2,490
Tamil Nadu	9.92%	2,250	1,910
Andhra Pradesh	9.51%	2,157	950
Rajasthan	8.44%	1,915	1,915
Himachal Pradesh	4.13%	937	653

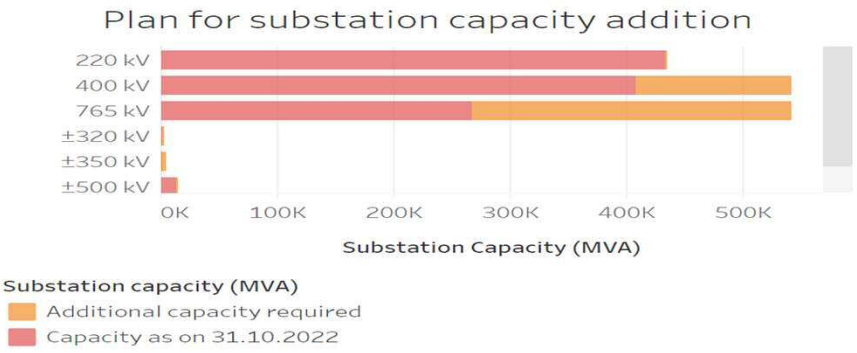
Source: Ministry of New and Renewable Energy

Data as on 30th November, 2022

Inter-regional Capacity Addition

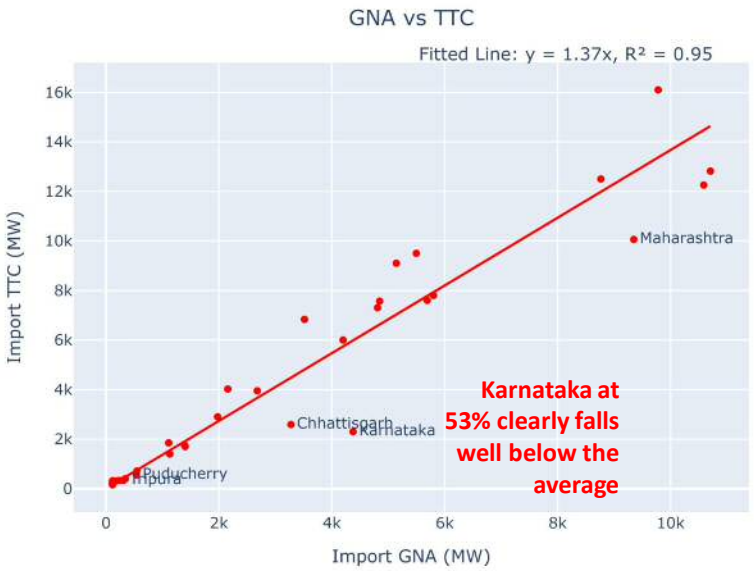
Margins available

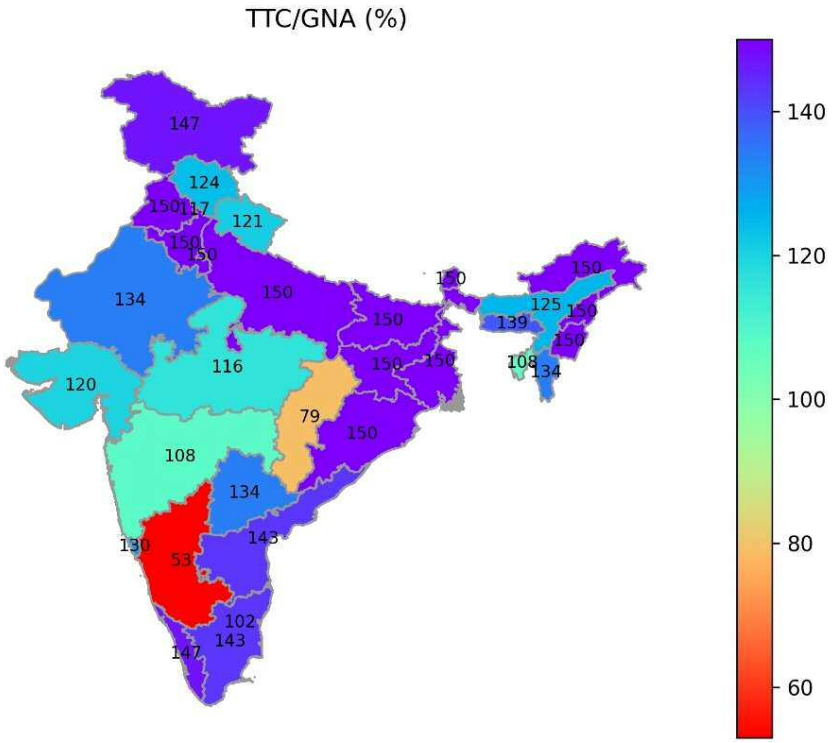




Indicator -1

TTC/GNA

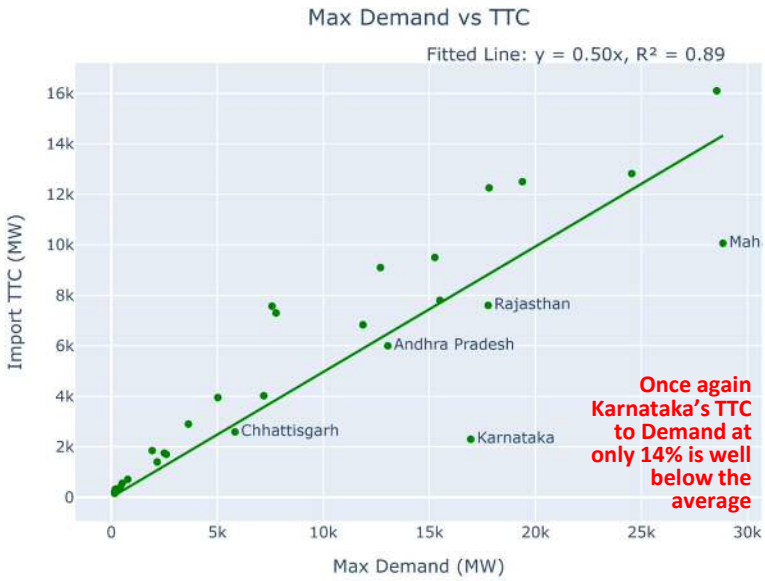


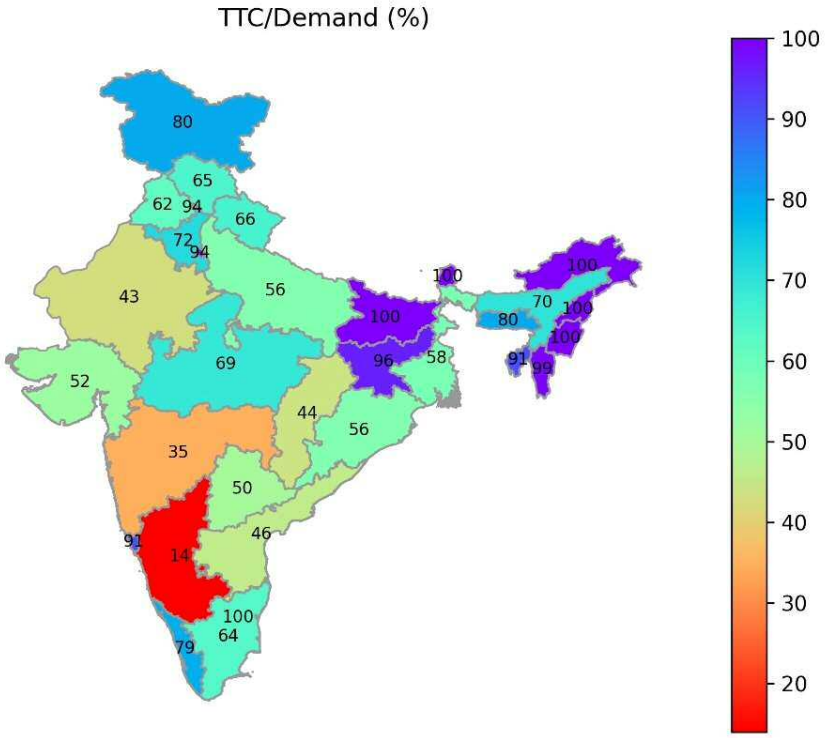


It is evident that states should prioritize enhancing their transmission networks immediately to ensure that their transfer capability exceeds GNA requirements.

Indicator -2

TTC/Demand

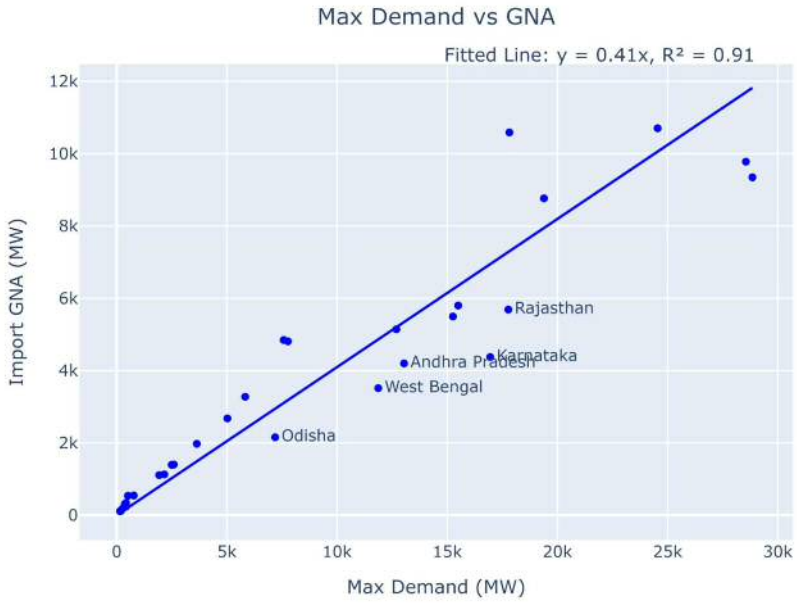


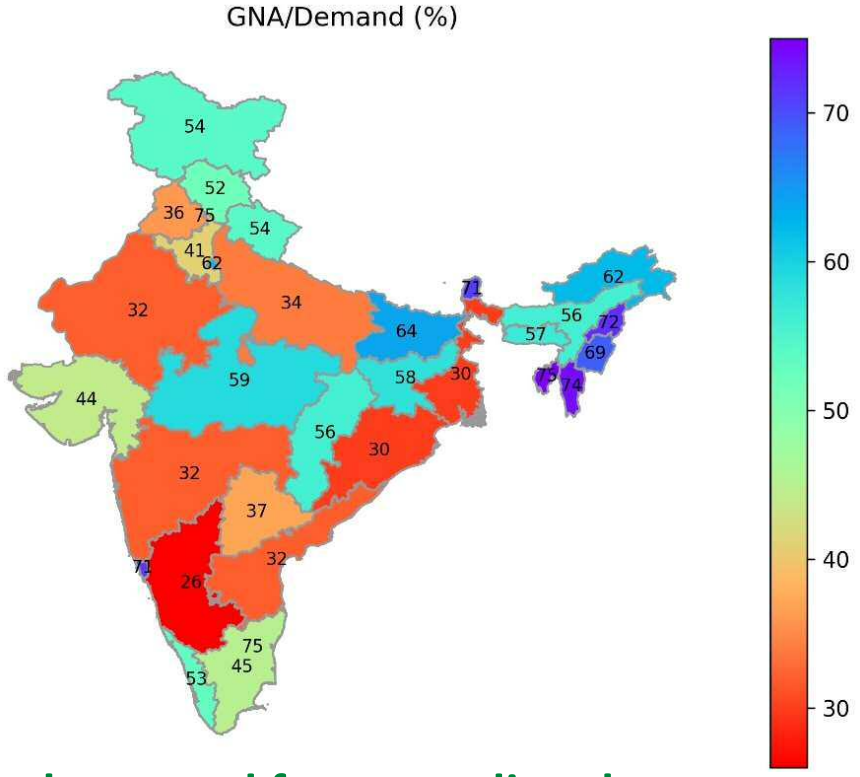


states should aim to augment their transmission system to have 50% of their demand as their import transfer capability to have more flexibility to meet their demand

Indicator -3

GNA/Demand

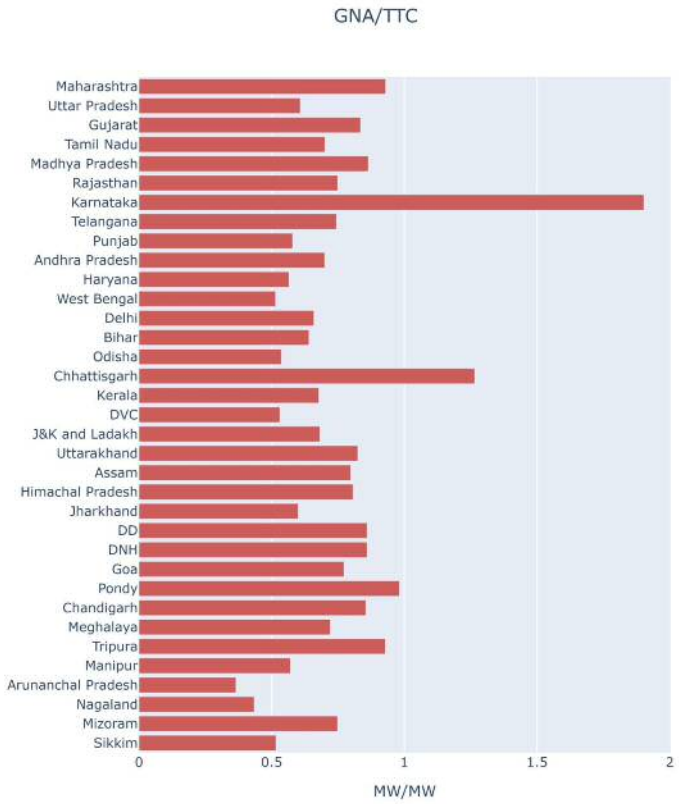


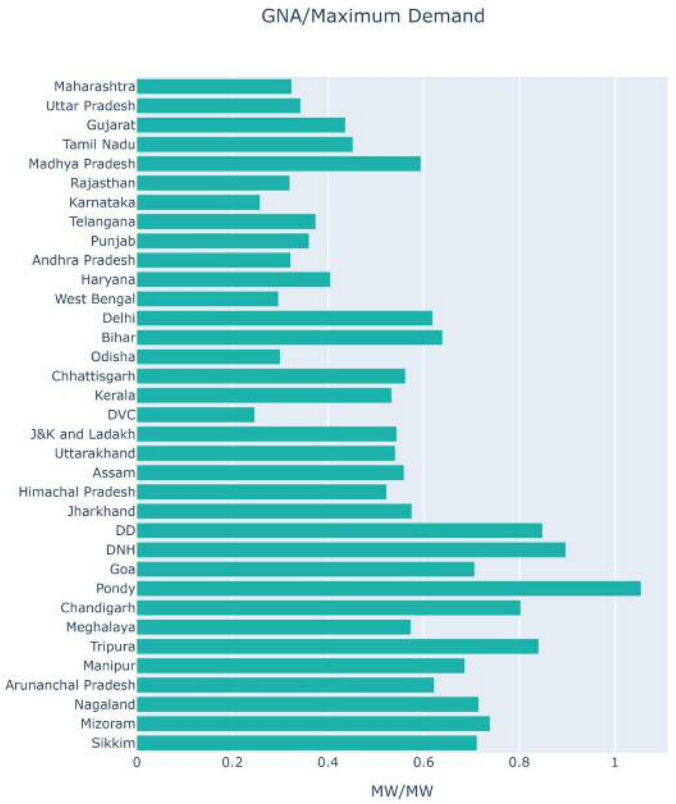


States with lower ratio suggests that there may be a need for expanding the transmission network to improve access and reliability of electricity supply.

Comparison of States

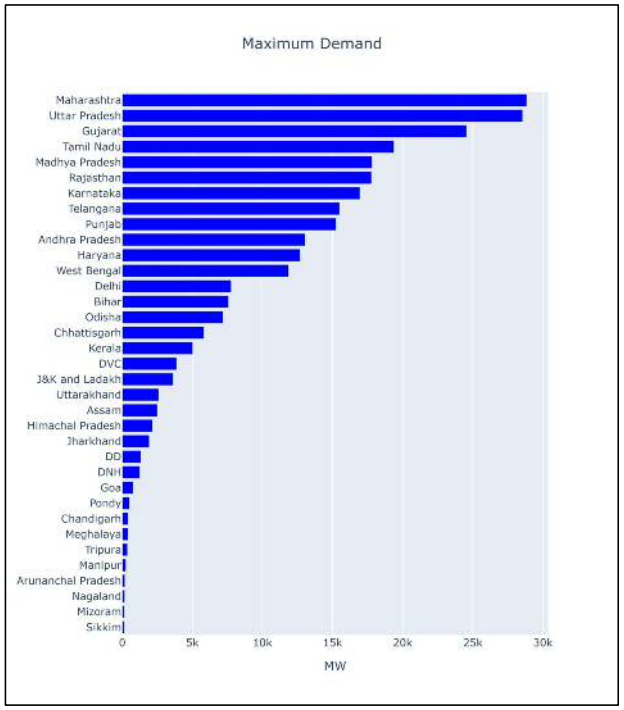
Indicators

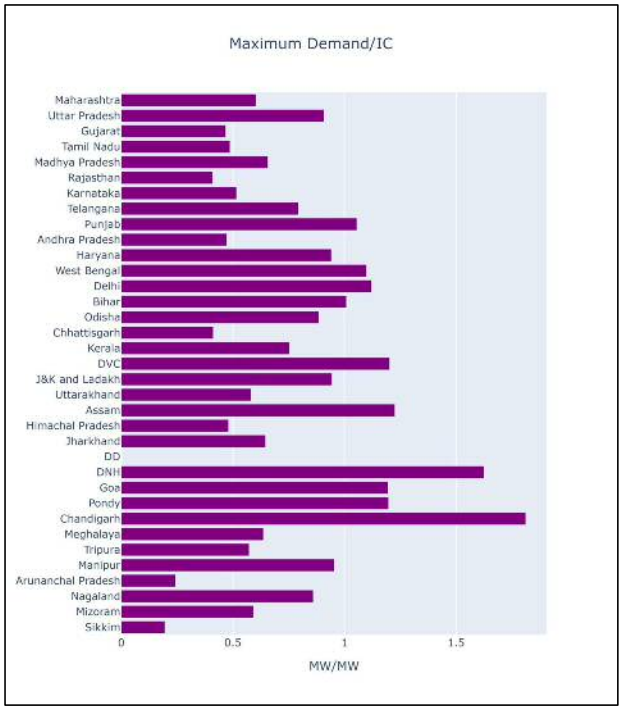


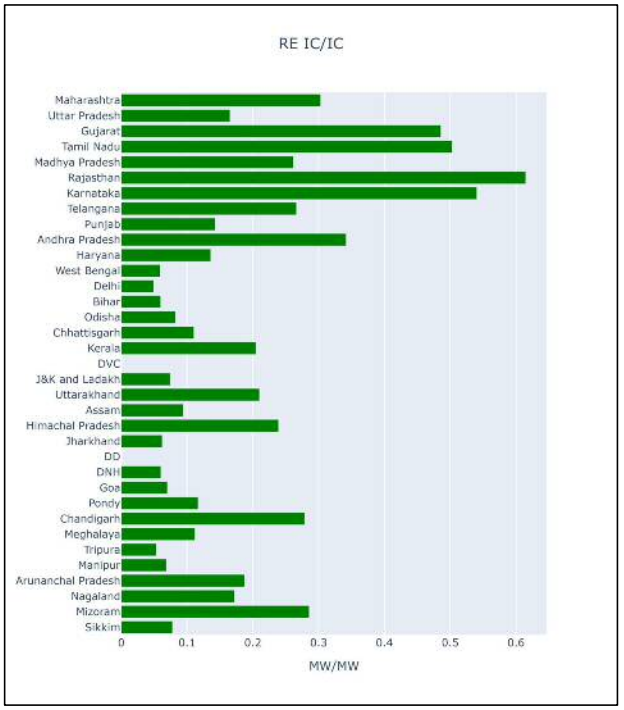


Comparison of States

Maximum Demand and Installed Capacity

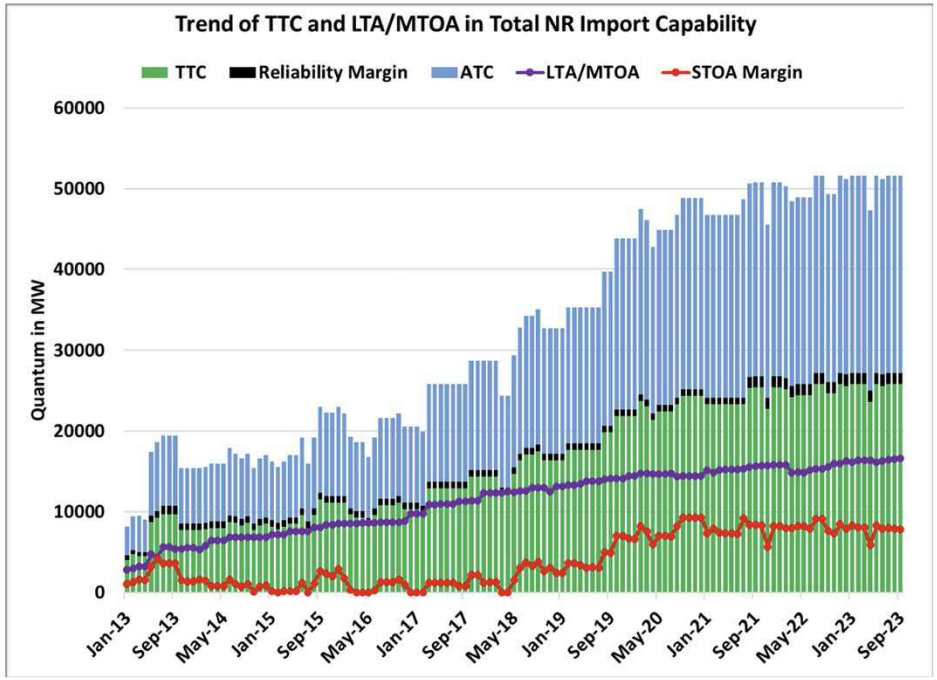


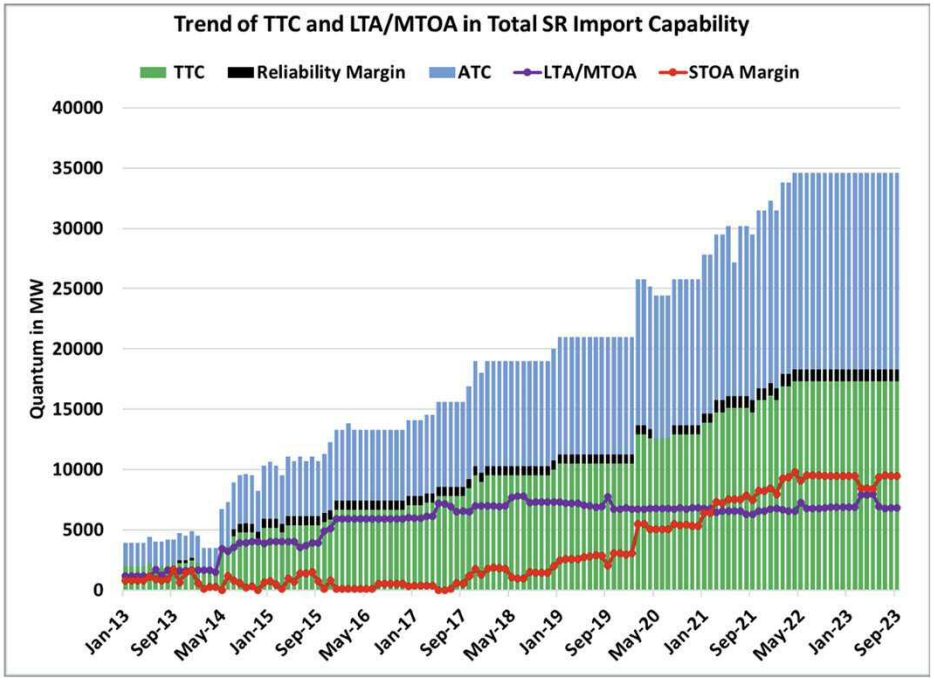




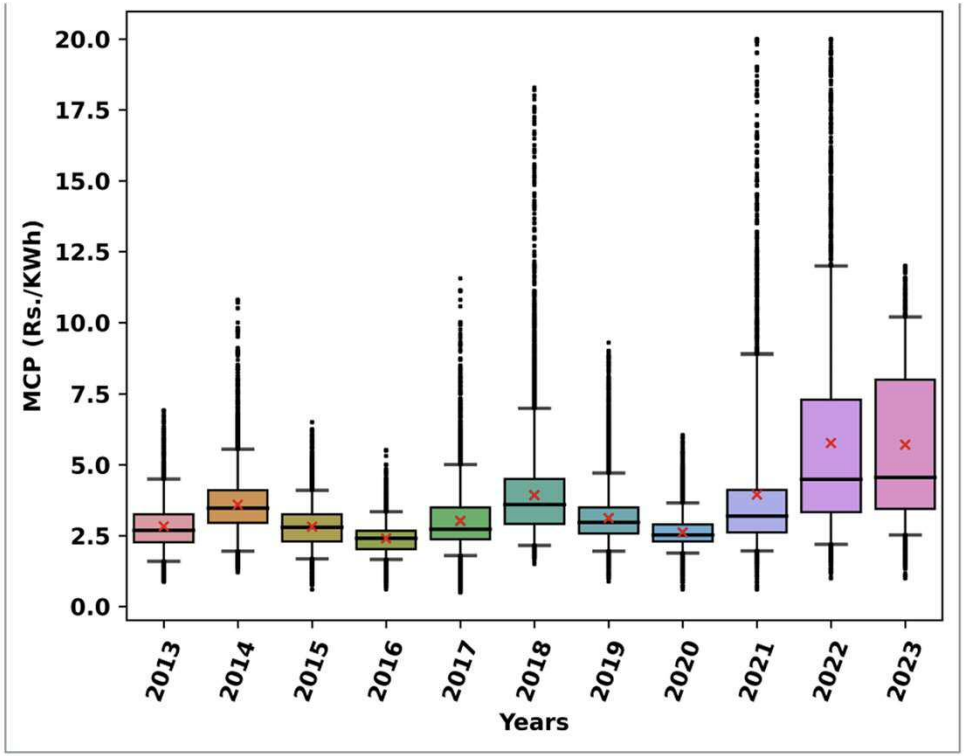
TTC and Transmission Access

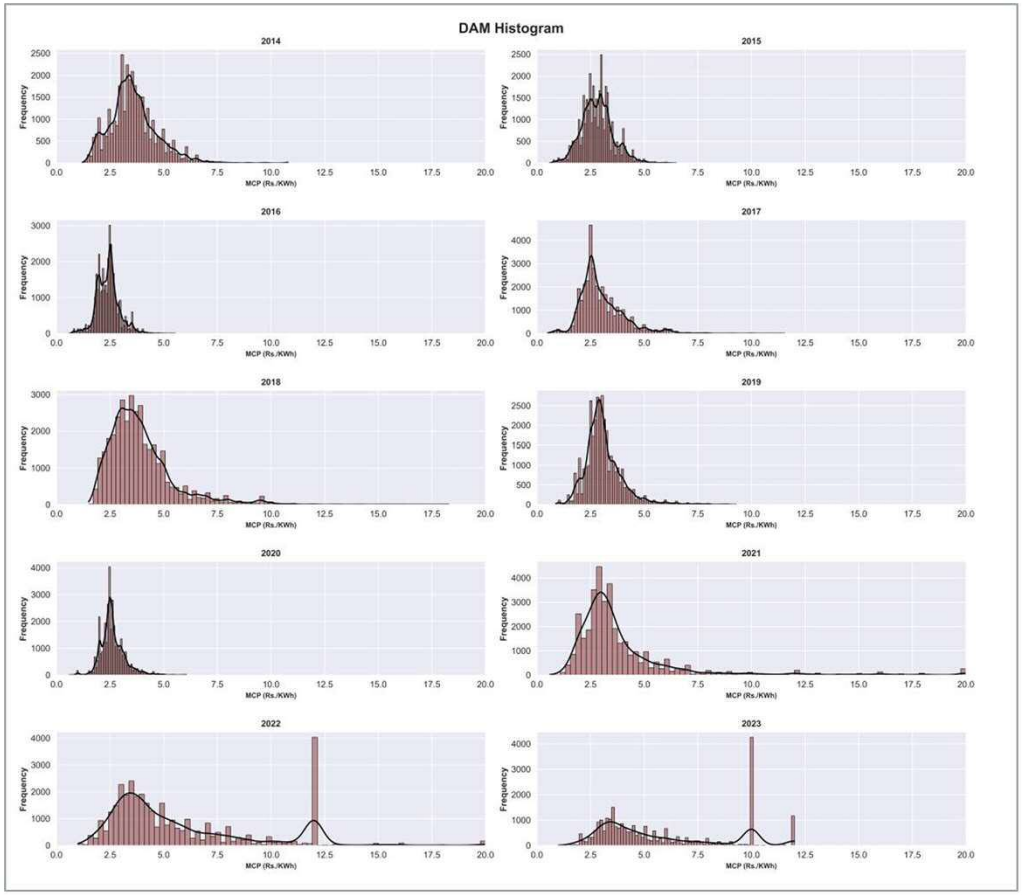
Effect of Transmission Addition





DAM Prices over the years





Value of transmission expansion

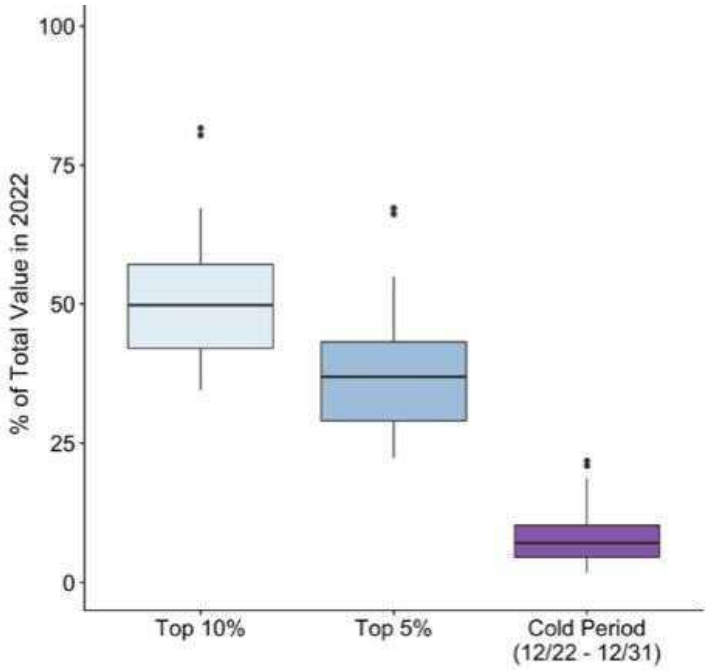
Cost of Congestion

- The difference in wholesale electricity prices between two locations largely represents the cost of congestion or, conversely, a key potential value of new transmission.
- While the congestion-based value of transmission analyzed here represents one of the largest sources of transmission value, transmission provides other benefits
  - Reliability, resiliency, and emission-reduction benefits
  - Transmission enables a lower cost set of generators to meet load than would otherwise be available.
- Wholesale power prices exhibit stark geographic differences and that increased transmission across many regional and interregional transmission links would have substantial economic value.
- Extreme conditions and high-value periods have an outsized role in driving this value

lbnl-transmissionvalue-fact_sheet-2022update-20230203.pdf (lbl.gov)

Transmission value concentrated

Small portion of total hours



concentrated in a small fraction of total hours.

- The most valuable 5% and 10% of hours accounted for a substantial portion of total annual transmission value through ‘congestion rent’
- Generally higher wholesale electricity prices leading to higher values across all hours.
  - Price volatility and spatial differences in price tend to increase with average prices.

lbnl-transmissionvalue-fact_sheet-2022update-20230203.pdf (lbl.gov)

Possible Barriers to setting a target

In EU, the target for all bidding zones will be 70% in 2026.

- Barriers include:
  - Loop flows due to a suboptimal configuration of bidding zones
  - Costly although insufficient re-dispatching
  - Lack of mechanisms to share the cost of re-dispatching.
  - Unilateral restrictions, such as allocation constraints and individual reductions of capacity
  - Lack of visibility on critical network elements other than the limiting ones.

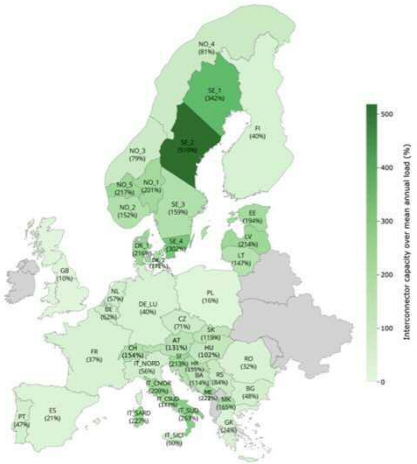
- Cross-zonal constraints most often limit commercial energy exchanges.
  - However, constraints internal to bidding zones are those that most affect the socio economic welfare.
  - Lifting both internal and cross-zonal constraints is key to achieving the 70% target.

Source: ACER Cross-zonal capacities and the 70% margin available for cross-zonal electricity trade (MACZT) 2023 Market Monitoring Report

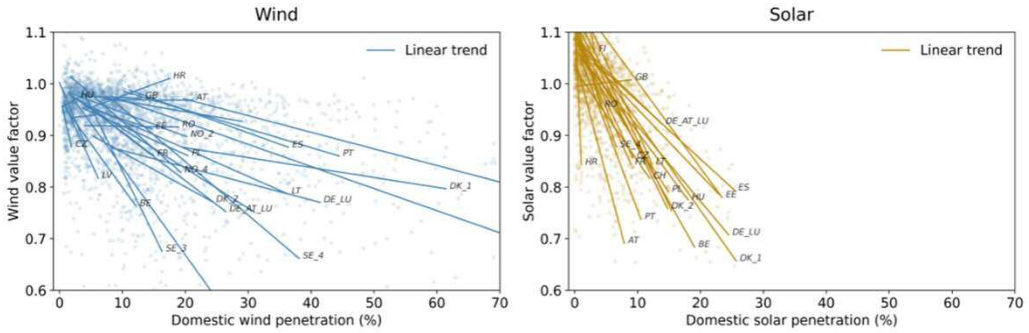
Effects of Renewables on Bidding Zones in EU

Across 30 bidding zones during 2015-2023

- Negative effects of domestic market penetration
- Cross-border effects on wind and solar value.
  - The negative effects of domestic and neighboring solar penetration on solar value are stronger than those of wind, as solar generation is more strongly correlated across time and space.
- Higher connectedness of bidding zones implies a trade-off
  - Mitigates the negative effect of domestic market penetration but exacerbates the effects of neighborir market penetration.



European bidding zones and interconnector capacity

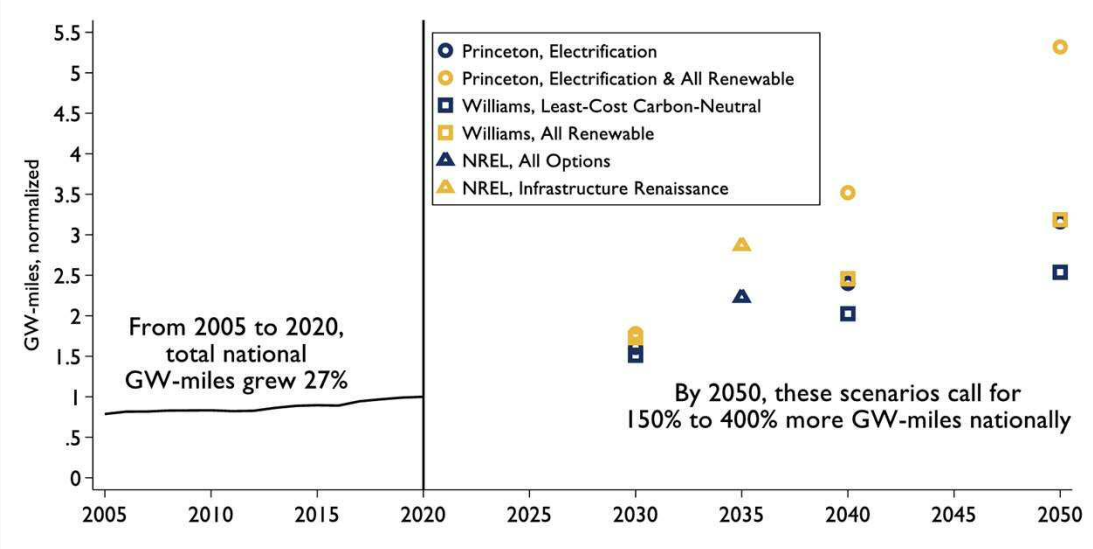


Monthly wind/solar value factor vs. market penetration for European bidding zones

Cross-border cannibalization: Spillover effects of wind and solar energy on interconnected European electricity markets
Clemens Stiewe, Alice Lixuan Xu, Anselm Eicke, Lion Hirth

Decarbonization

More and more transmission…net zero target by 2070…



Note: This figure juxtaposes historical US electricity transmission capacity (normalized to one in 2020) with the future capacity called for in three prominent decarbonization studies (Princeton, 2021, Williams et al., 2021, and NREL, 2022b). The left-hand side of the figure was created by the authors using data on transmission miles from FERC Form 1, 2005-2020 (Catalyst Cooperative, 2022). Details on the conversion from FERC's miles data to our reported GW-miles are provided in this paper's data archive.

Transmission Impossible? Prospects for Decarbonizing the US Grid Lucas Davis, Catherine Hausman, and Nancy Rose June 2023 Published in Journal of Economic Perspectives, 37(4), 155-180, 2023WP338.pdf (berkeley.edu)

The Bottom Line

Way Forward

- Each of the following four factors, progressively, raise the need for transmission

  (a) economics, (b) reliability, (c) resilience and (d) emissions/environmental
- Regulatory mechanisms in India still focuses almost exclusively on reliability only
- Policy target number for reliability (LOLP etc.) is there in generation adequacy
  - In case of transmission, it is defined qualitatively (vague)
  - Depends on many factors and the mind set of the planner and the scenarios factored
- Need for system level urgency indicators for transmission adequacy planning
  - Resilience standard needs to have more dimensions to cover for a range of extreme weather events (heatwaves, droughts, etc.) and the nature of impacts they may have on MW and MWh requirements.

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13. Transmission Impossible? Prospects for Decarbonizing the US Grid Lucas Davis, Catherine Hausman, and Nancy Rose June 2023 Published in Journal of Economic Perspectives, 37(4), 155-180, 2023WP338.pdf (berkeley.edu)

Thank You !