Detailed Deep Dive on Capacity Expansion Results for India States

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2nd International Conference on Large-Scale Grid Integration of Renewable Energy in India

Delhi, 6 September 2019

Objectives

In collaboration with Central Electricity Authority (CEA),

- Develop **state-of-the-art planning tools and datasets** to inform generation and transmission planning decisions
- Increase **the technical rigor and granularity** of planning models
- Evaluate a range **of possible futures** for India's power system

The Regional Energy Deployment System (ReEDS)

ReEDS finds the mix of generation, transmission, and storage technologies that meet anticipated requirements of the electric sector at least cost

The model selects *what* to build, *where* to build it, and *when*

ReEDS Overview

- Type of model
- Temporal scope & resolution
- Geographic scope & resolution
- Technology options
- Unique features

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linear optimization model
implemented in GAMS using the CPLEX Solver

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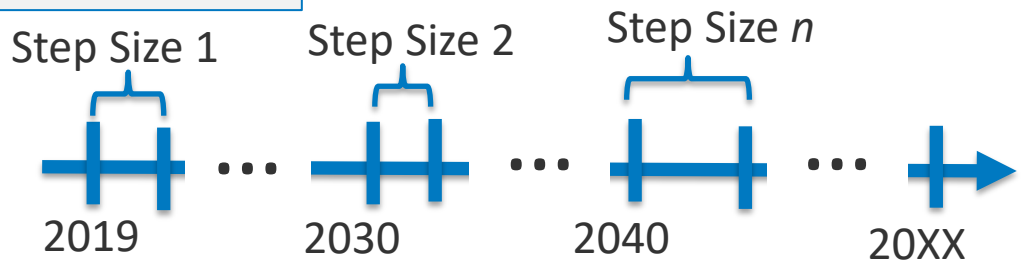
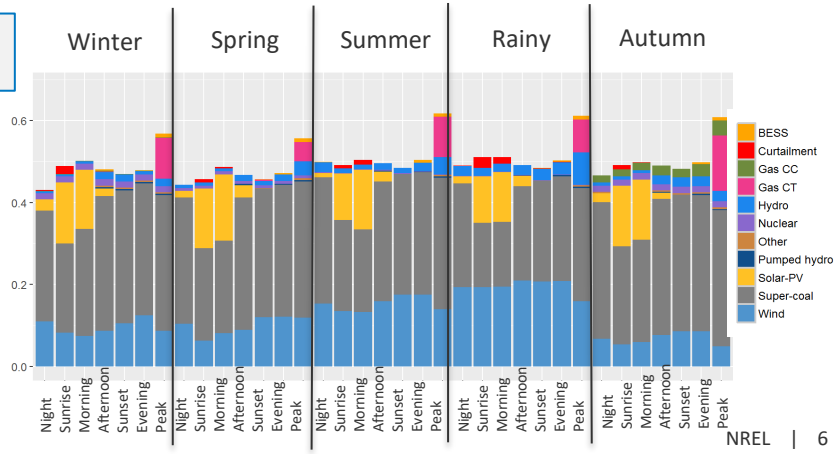
Model years



Dispatch periods



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- **Geographic scope & resolution**
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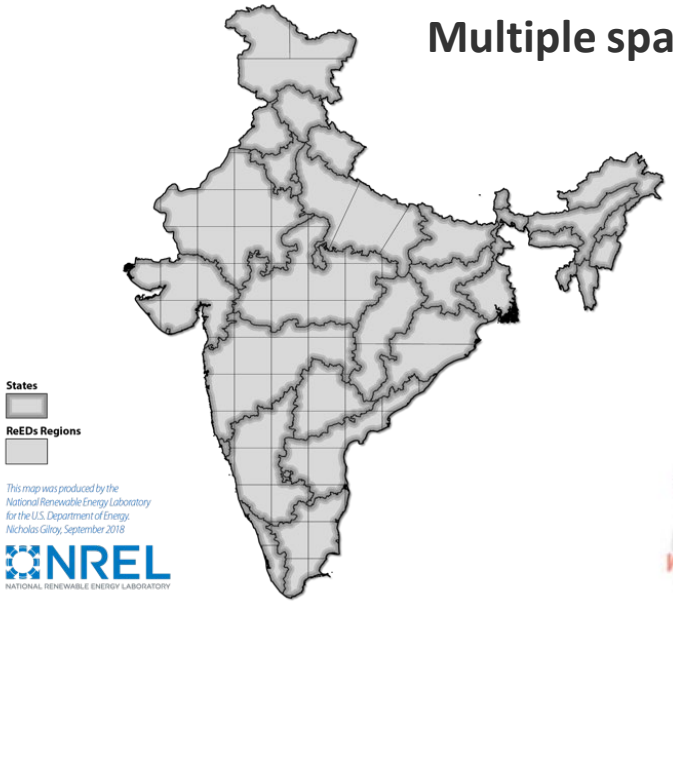
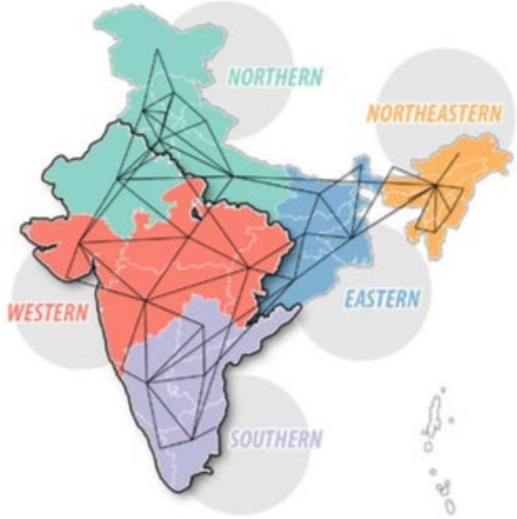
Multiple spatial layers





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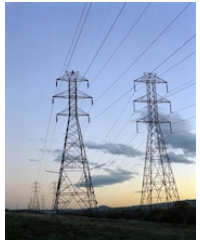

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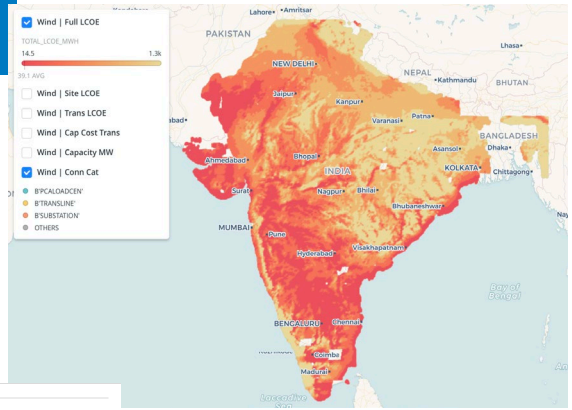
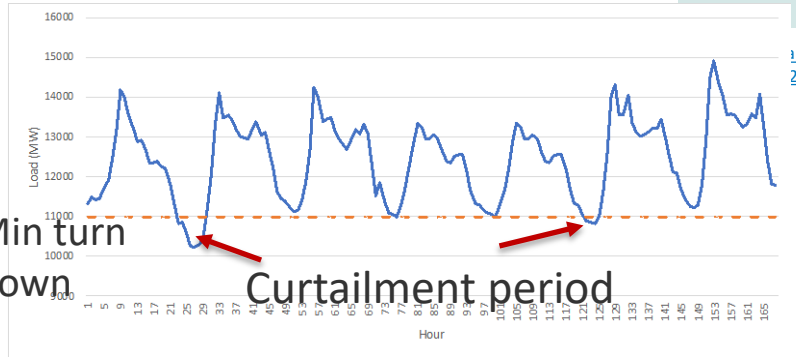
Resource Supply Curves





VRE Integration

Model Flexibility

ReEDS-India Study Scenarios

Scenario	Description
Base	Capacity and demand growth based on CEA National Electricity Plan and 19th Electric Power Survey
Low Solar Cost	Solar PV capital costs decline more rapidly than Base scenario
Low Battery Cost	Lower initial capital cost for Battery Energy Storage System (BESS)
New Gas	Gas availability for electricity generation increases in future years
Responsive Load	Demand response and/or load shifting leads to 10% reduction in peak load while total annual energy is unchanged
Lower Load	Lower than expected demand growth leads to 10% reduction in peak load and 5% reduction in off-peak load

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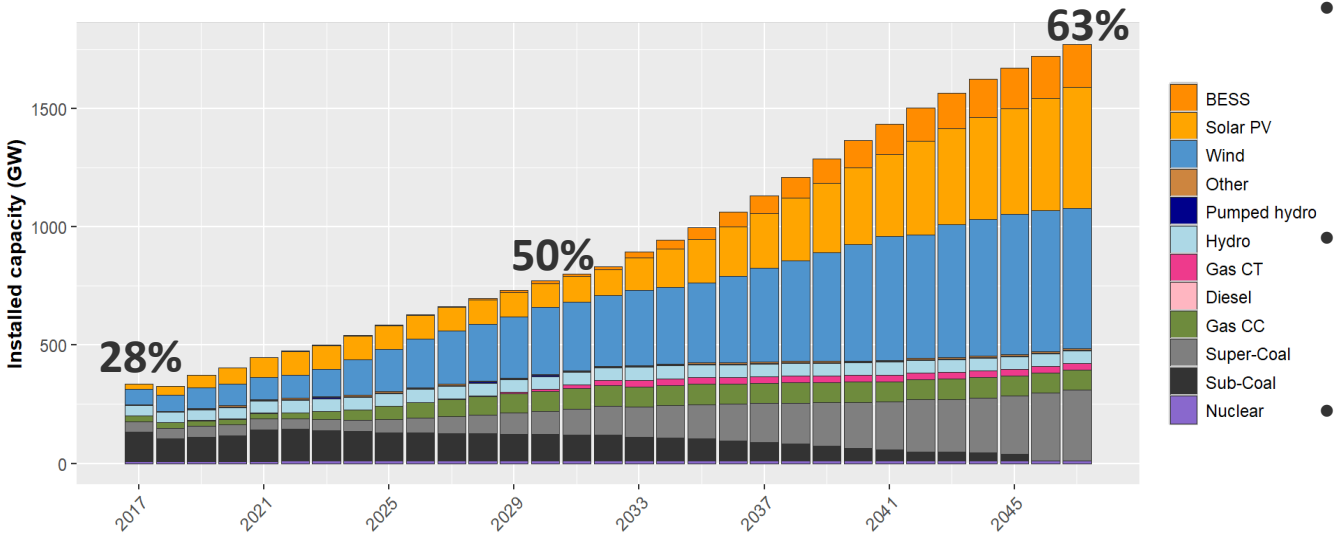
From thermal to renewable: India's electricity supply is poised for significant shifts

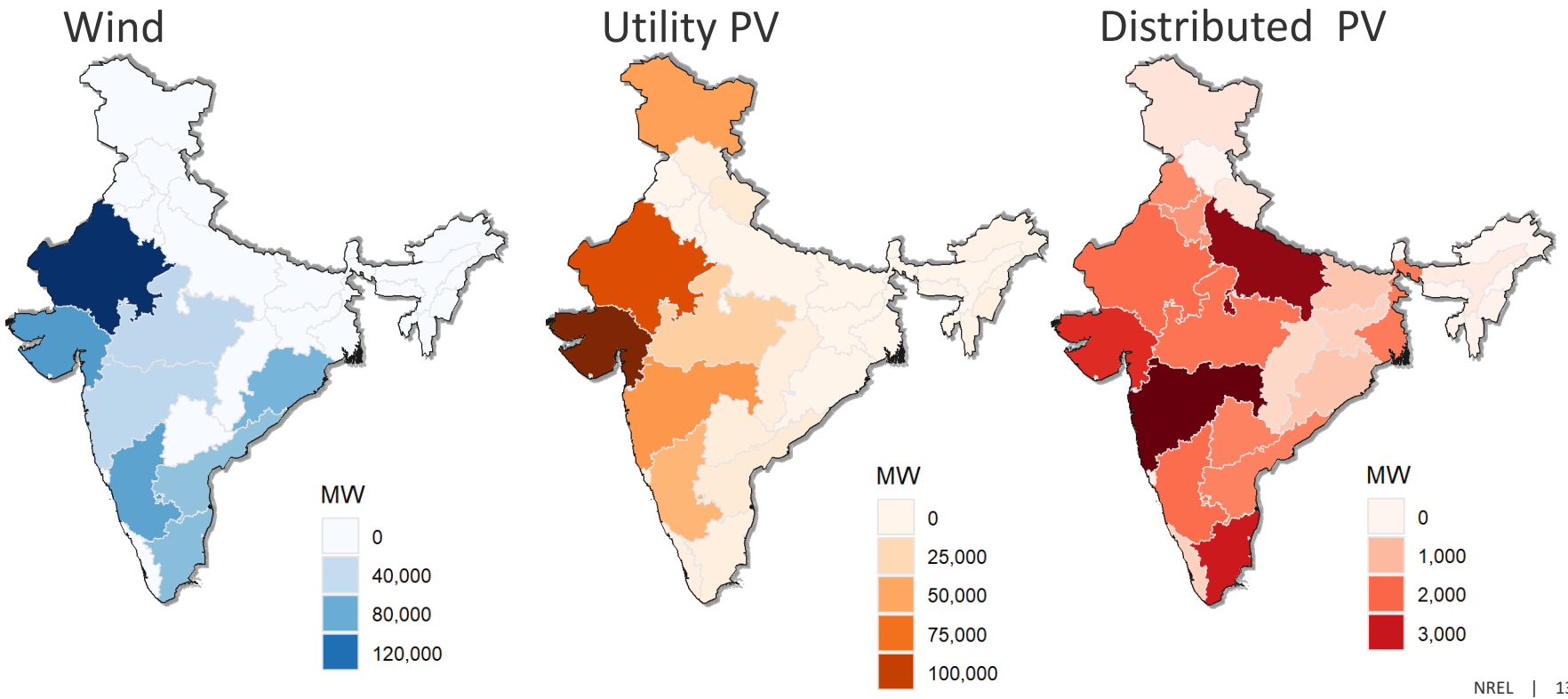
Evolution of India's generation mix, 2017-2047



- **Wind and solar present least-cost options** to meet future electricity demand
- Investments in **batteries begin 2022**
- The share of **coal in the generation mix** may have already peaked

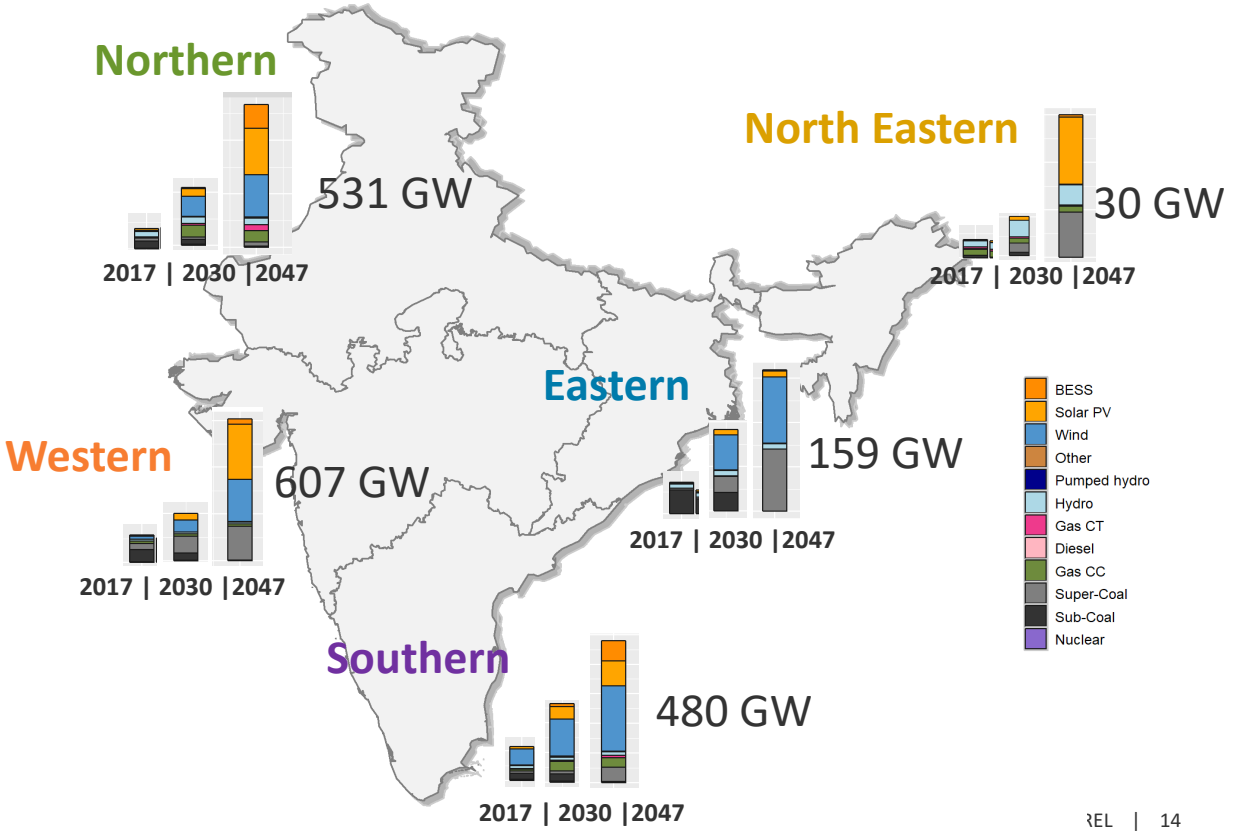
Wind and Solar investments capitalize on resources, land availability, transmission, and proximity to load centers

2047 RE Capacity



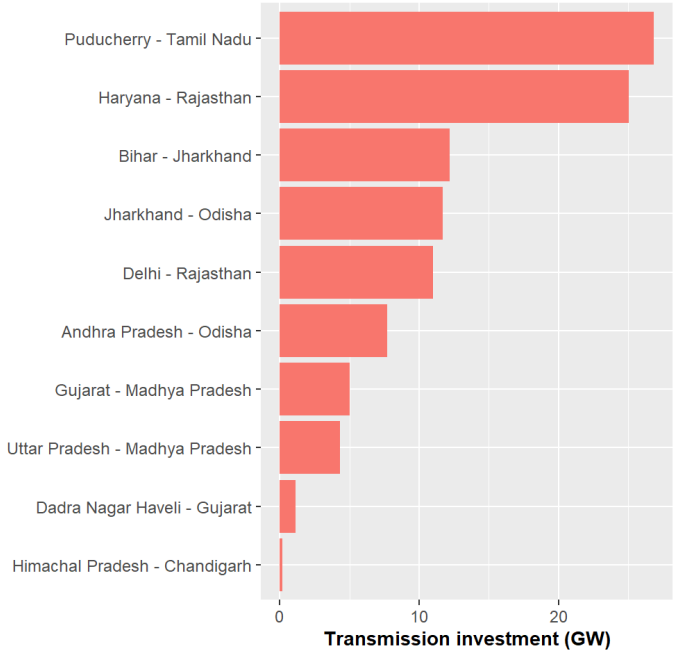
Variations in available resources drive differences in regional investments

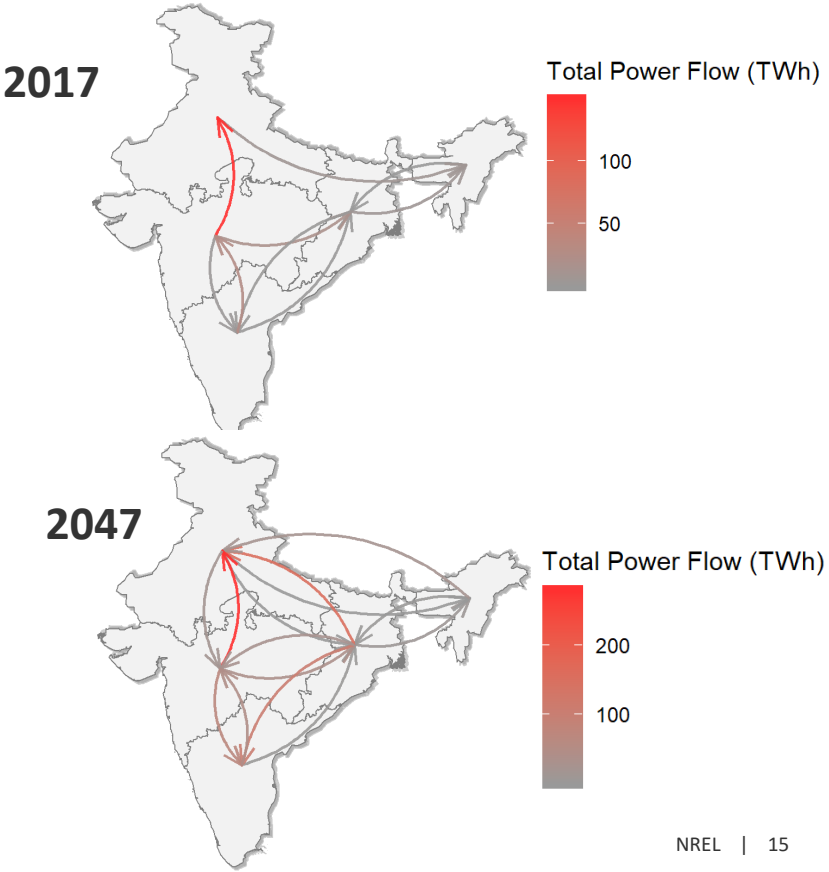
- **Coal persists** in ER, NER, and WR
- **Gas and battery capacity** provide flexibility in RE-based NR and SR in 2047



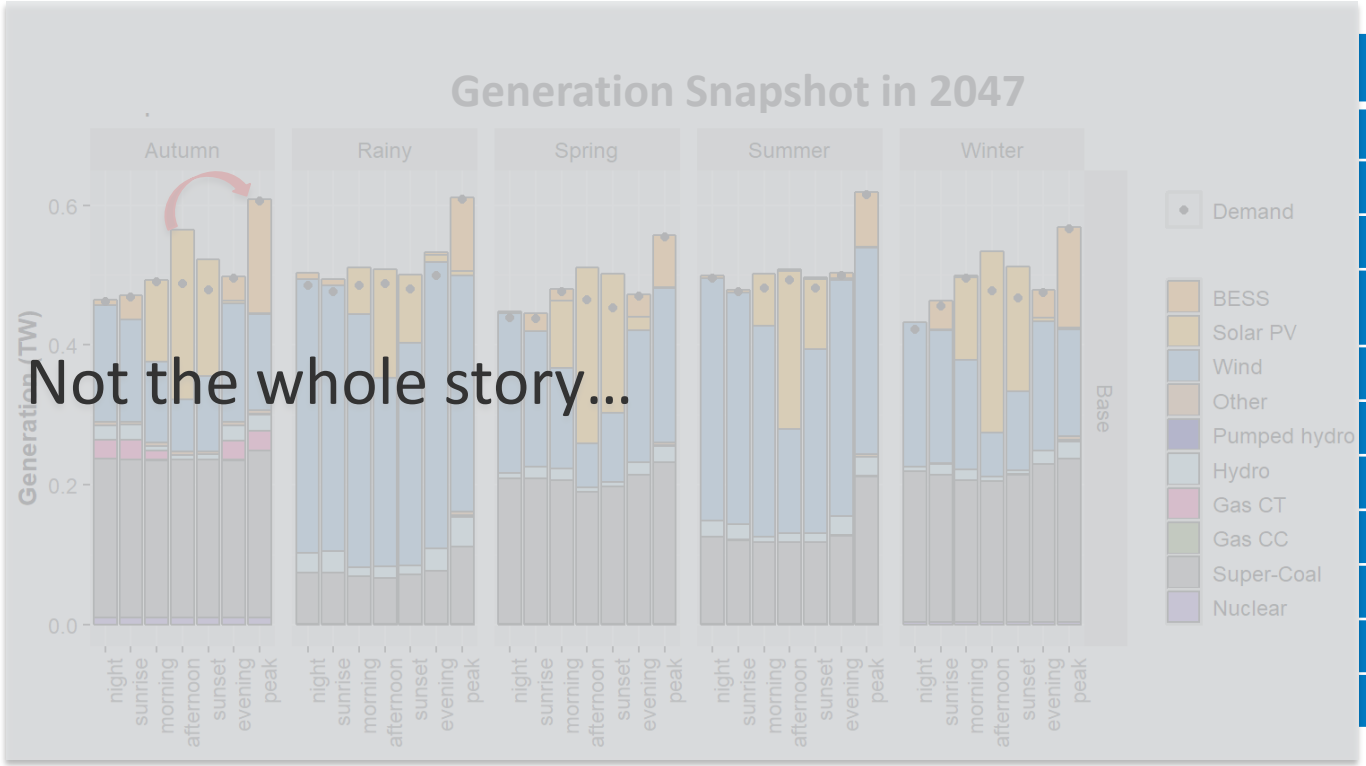
Transmission investments enable high RE states to evacuate excess generation

Transmission Investments, 2017-2047





Batteries and gas plants used to meet peak demand

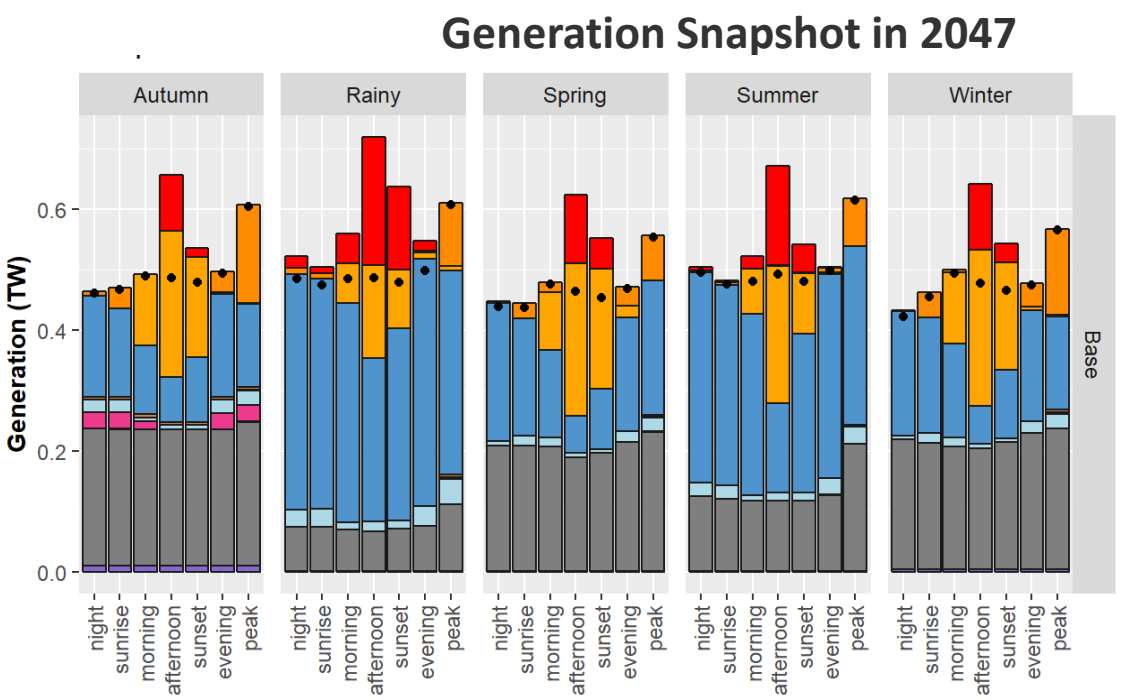


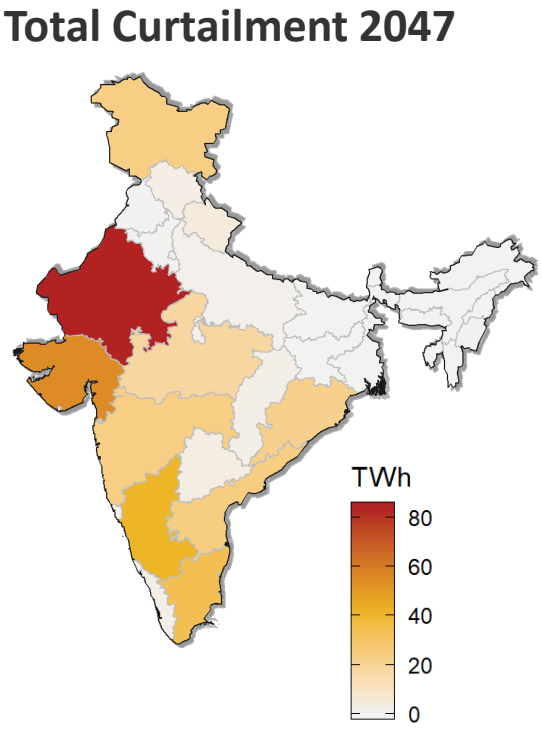
Not the whole story…

Evolution of generation mix (% of total)

Technology	2017	2047
Solar PV	3	14
Wind	24	42
Other	~0	~0
Pumped hydro	~0	~0
Hydro	9	3
Gas CT	~0	~1
Diesel	~0	~0
Gas CC	2	~0
Super-Coal	21	32
Sub-Coal	40	0
Nuclear	2	1

VRE curtailment reaches 8% in 2047

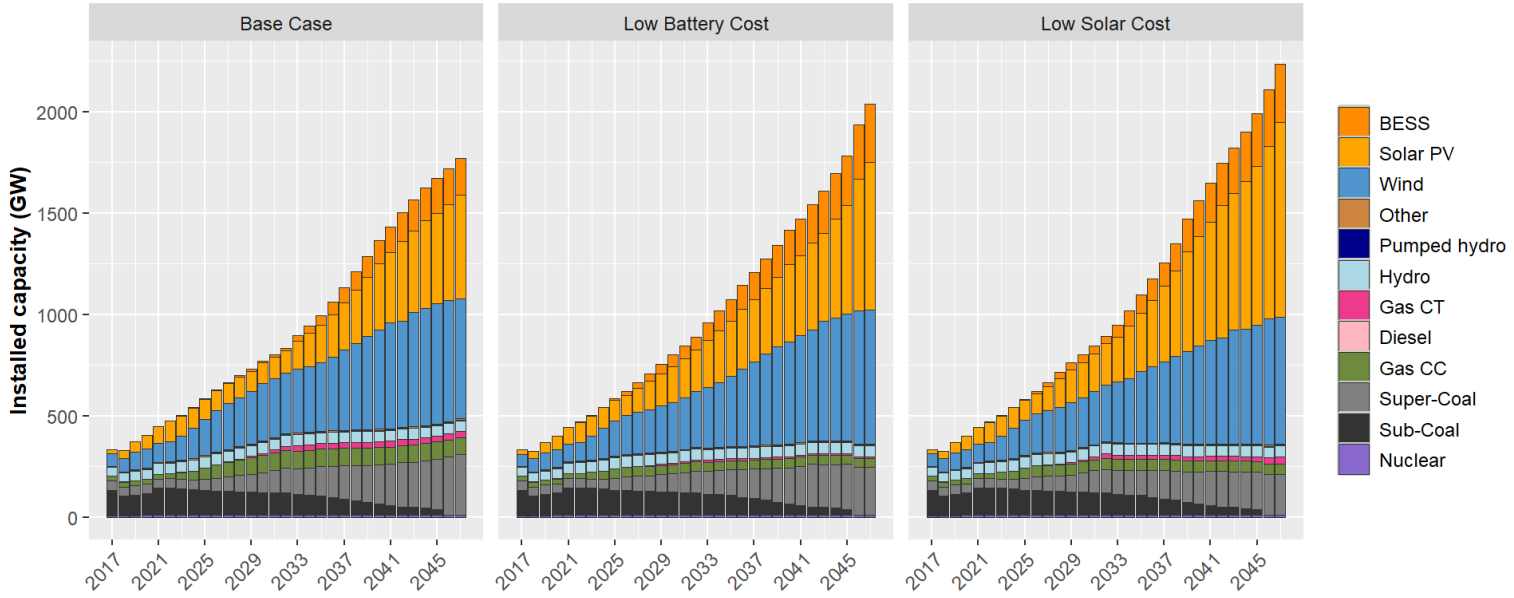




Technology Cost Scenarios

Scenario	Description
Base	Capacity and demand growth based on CEA National Electricity Plan and 19th Electric Power Survey
Low Solar Cost	Solar PV capital costs decline more rapidly than Base scenario
Low Battery Cost	Lower initial capital cost for Battery Energy Storage System (BESS)
New Gas	Gas availability for electricity generation increases in future years
Coal Flex	Coal fleet achieves minimum generation level of 40%
Responsive Load	Demand response and/or load shifting leads to 10% reduction in peak load while total annual energy is unchanged
Lower Load	Lower than expected demand growth leads to 10% reduction in peak load and 5% reduction in off-peak load

Flexibility enables higher penetrations of VRE



2047 Results		Base	Low Battery Cost	Low Solar Cost
VRE Penetration	(GW)	1147	1189	1497
	(% generation)	56	70	69
Curtailment	(%)	8	7	9

Additional Scenarios

Scenario	Description
Base	Capacity and demand growth based on CEA National Electricity Plan and 19th Electric Power Survey
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Additional scenarios show marginal impacts on the final capacity mix in 2047

- **New Gas: gas availability for electricity generation increases in future years**
  - Increased gas capacity leads to more wind and solar, less coal
- **Flat Load Growth:** shifting load from peak periods to other times of day
  - Less need for Supercritical Coal and Gas CT to meet peak demand
  - Slight increase in wind and solar capacity
- **Low Load Growth**: A 10% reduction in peak load and 5% reduction in off-peak load results in a 2% decrease in total installed capacity in 2047
  - Mix of generation and transmission investments remain largely unchanged

Key Takeaways

- India's electric power system is poised for a transformation from **thermal to renewable power**
- Under current demand and cost projections**,** **national capacity targets can be achieved** through least-cost planning
- At higher penetration levels, access to **cost-effective sources of flexibility** become increasingly important and some level of **curtailment** may be economic
- Changes in **demand growth and gas availability** have **marginal impacts** on long-term investment trends

Open-source ReEDS coming soon

Thank you

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www.nrel.gov