



RE Grid Integration Study with India

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Sponsors and Official GOI Lead



Prepared by:



Grid Integration Studies: Our Purpose



- If India develops 100 GW of solar and 60 GW of wind energy, how would the system operate in 2022?
- What can policy makers do to lower the cost of operating this system and better integrate RE?
 - Note: Fixed costs considered as sunk cost

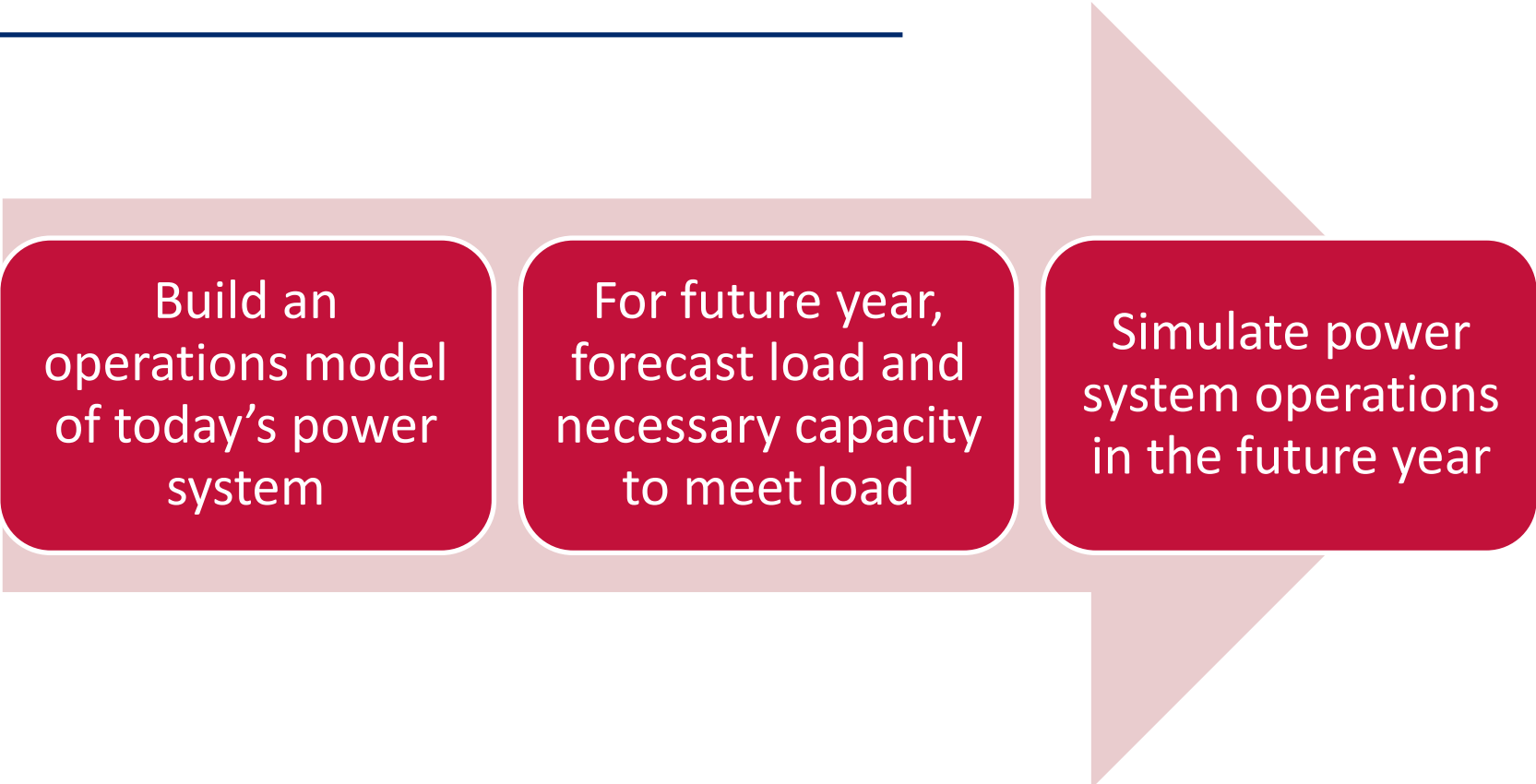
Stakeholder Participation

- Grid Integration Review Committee
 - Peer Review and Guidance
 - Over 150 Experts
 - Four sets of meetings

	National (New Delhi)	Southern (Bengaluru)	Western (Mumbai)
1 st GIRC	13/10/15	15/10/15	19/10/15
2 nd GIRC	19/4/16	21/4/16	22/4/16
3 rd GIRC	18/7/16	20/7/16	22/7/16
4 th GIRC	17/2/17	20/2/17	22/2/17

More than 2000 person hours

Methodology Overview



Build an
operations model
of today's power
system

For future year,
forecast load and
necessary capacity
to meet load

Simulate power
system operations
in the future year

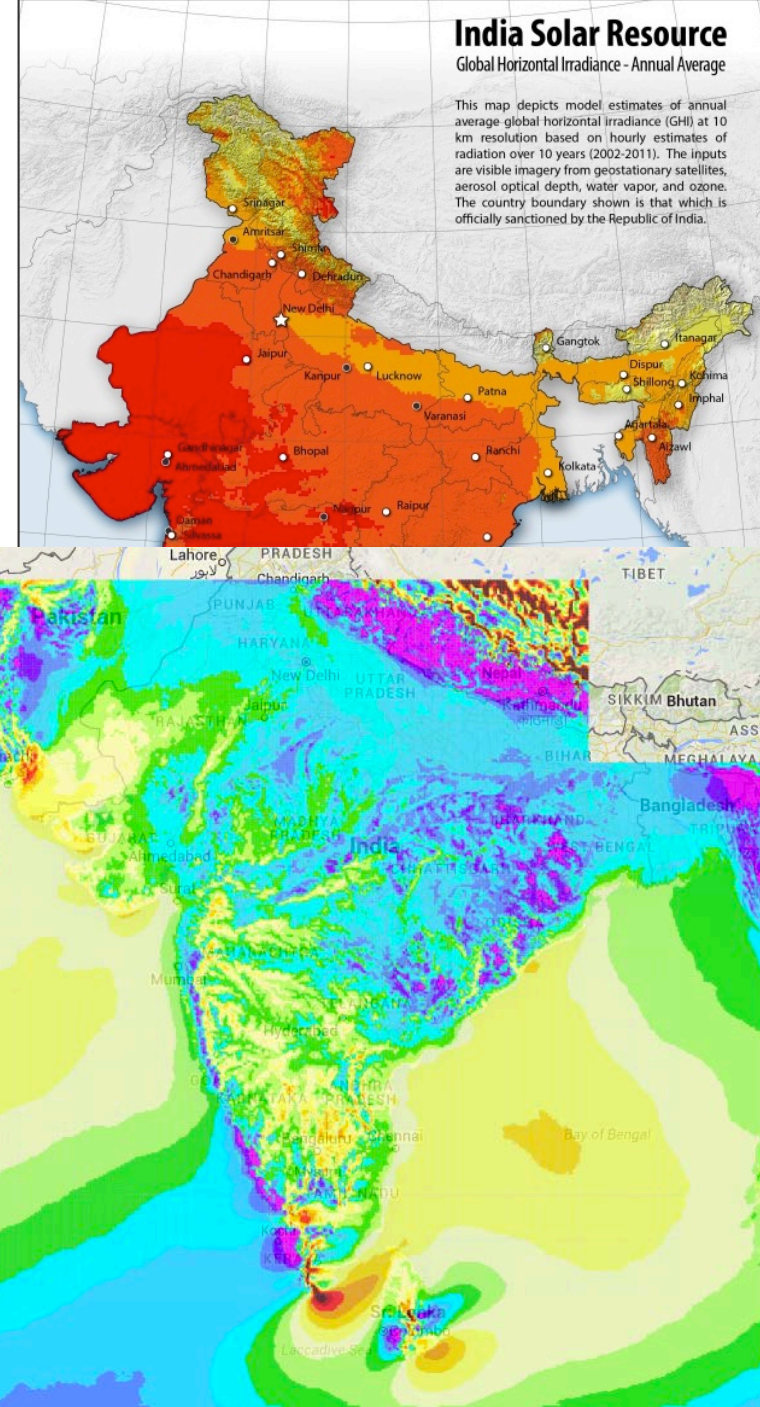
Greening the Grid uses the PLEXOS production cost
model

Studied scenarios

Scenario name	Solar (GW)	Wind (GW)	Description
No New RE	5	23	Wind and solar capacities installed as of 2016
20S-50W	20	50	Total installed capacity as targeted in Green Energy Corridors & National Solar Mission
100S-60W	100	60	Current Government of India target for 2022
60S-100W	60	100	Solar and wind targets reversed in comparison to official target
150S-100W	150	100	Ambitious RE growth

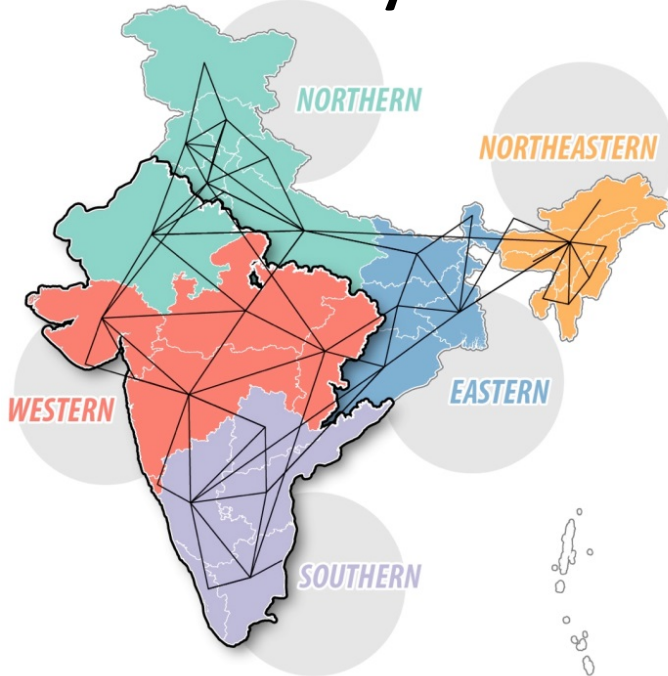
Modeling features

- High-resolution wind and solar resource data (both forecasts and actuals)
 - Wind: 5-minute weather profiles for each 3 x 3 km² area
 - Solar: 1-hour weather profiles for each 10 x 10 km² area, including impact of aerosols
- Unique properties for each generator
- CEA/CTU projections of properties and locations of new lines and power plants for 2022
- Enforced state-to-state transmission flows
- Interregional transmission limits that adhere to reliability standards



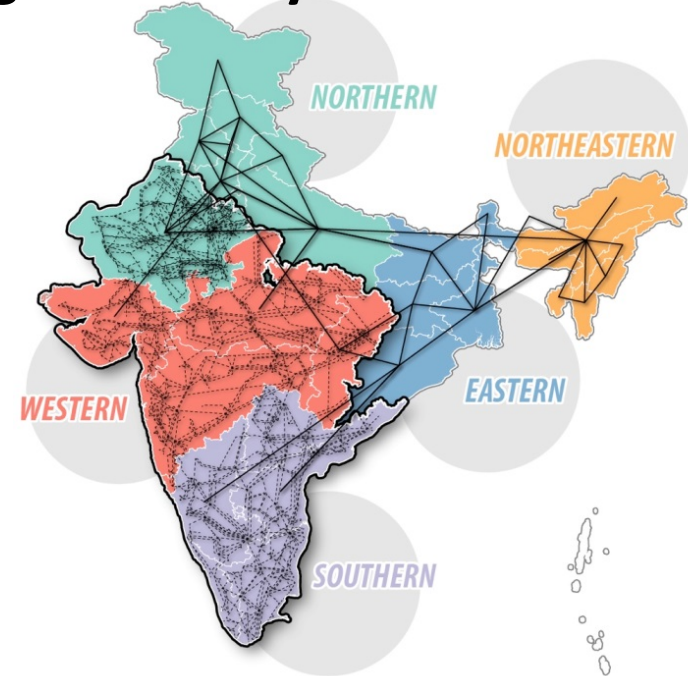
Transmission representation in the model

National study



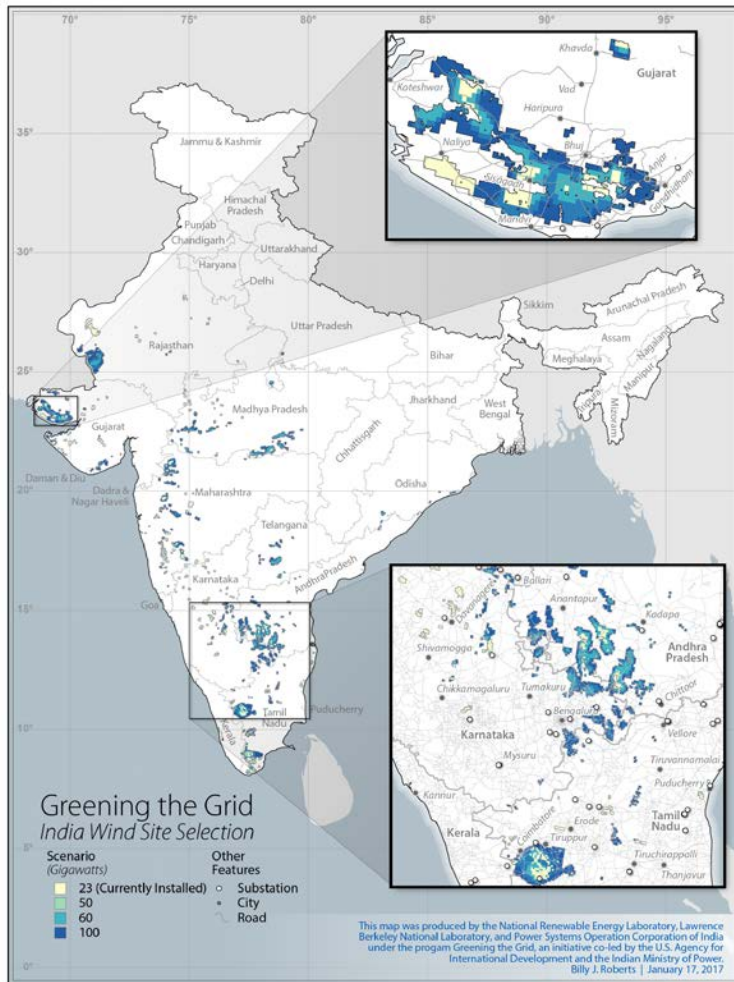
- All generation and transmission located on a single node per state plus union territories (36 nodes total)
- No enforced intrastate transmission constraints

Regional study

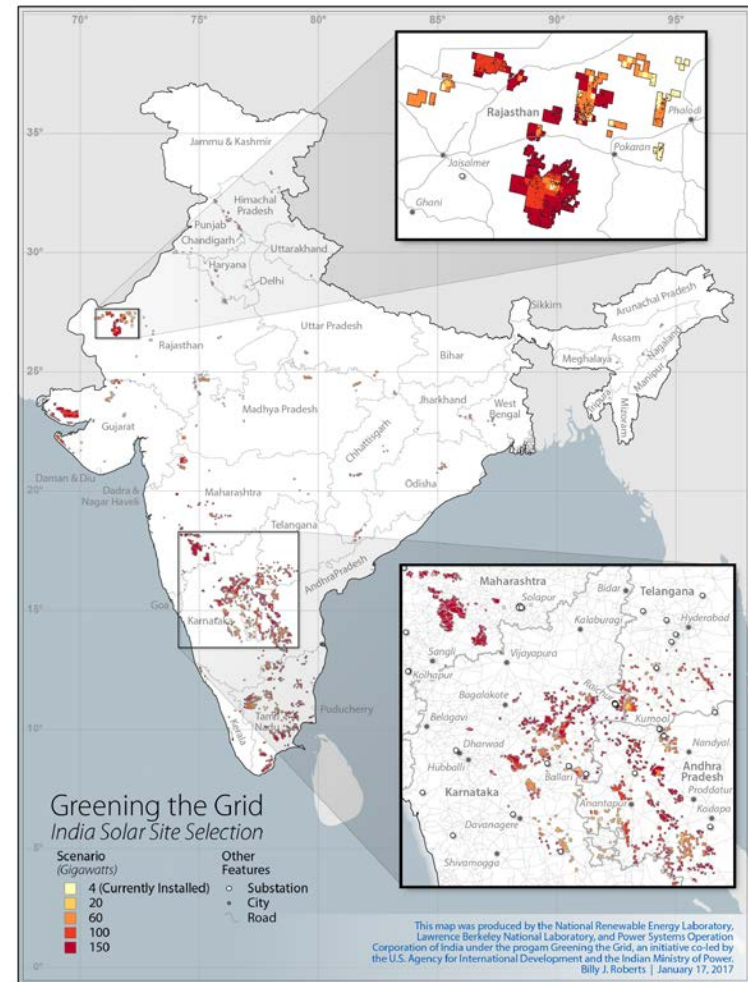


- Full, planned transmission system in Southern and Western Regions plus Rajasthan (3,280 nodes)
- Loading limits enforced on all relevant intrastate lines; congestion limits enforced on all high-volume intrastate lines (>400 kV)

Assumptions about the 2022 Power System



Locations of installed wind capacity for each scenario



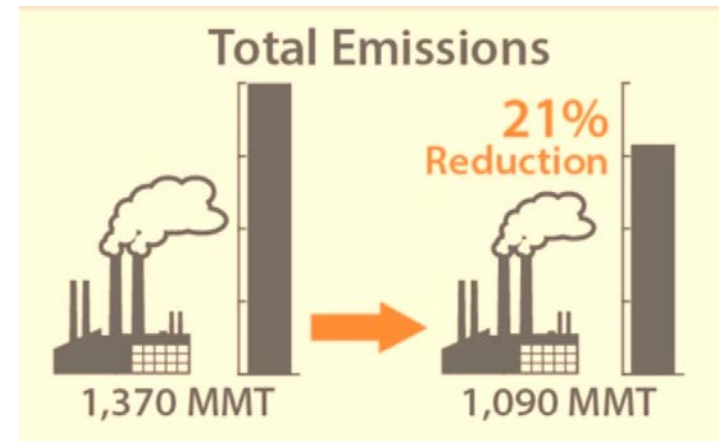
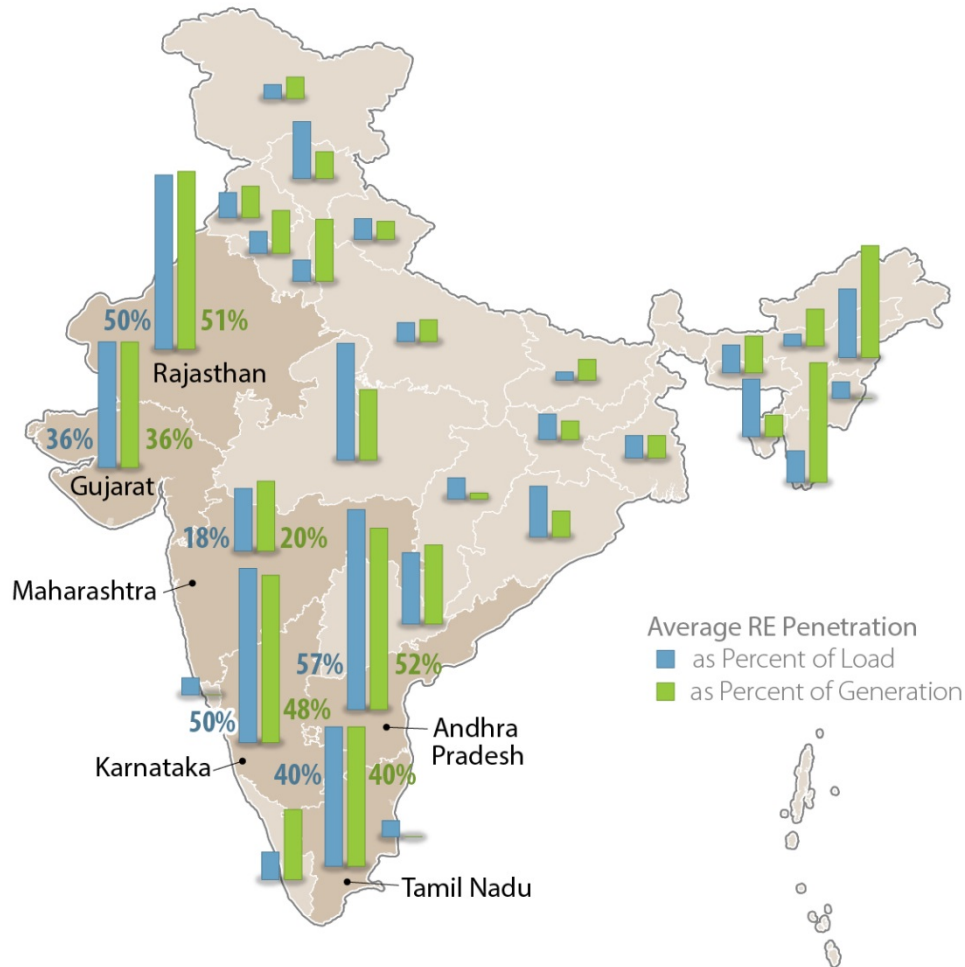
Locations of installed solar capacity for each scenario

India's Power System in 2022— Achieving System Balance Every 15 Minutes

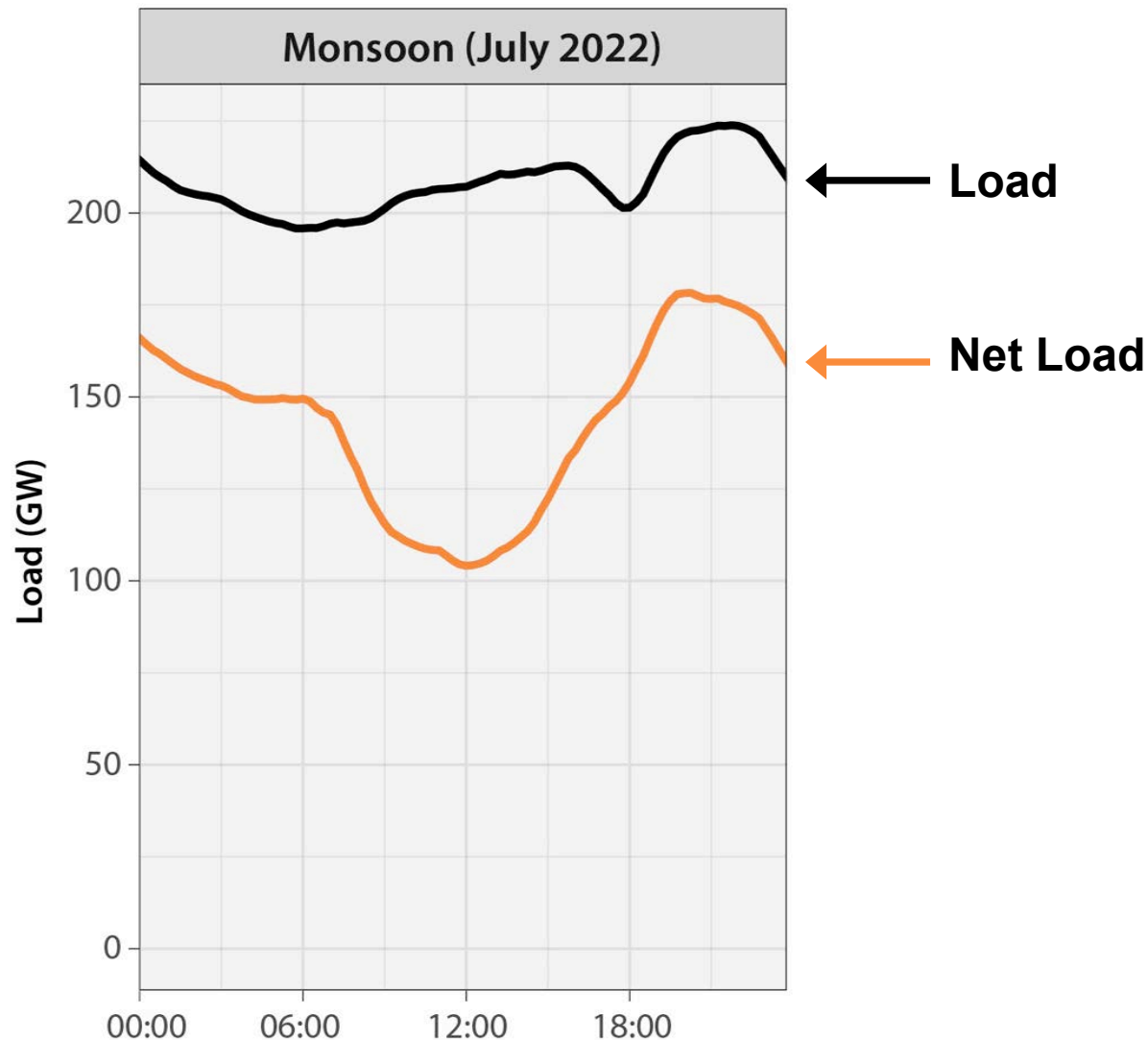


Key Findings

Annual impacts: 175 GW RE can meet 22% of India's annual electricity demand with minimal RE curtailment



Daily impacts: Existing flexibility in the coal-dominated system can manage RE variability



Retiring 46 GW of coal (20% of coal capacity) may not negatively affect operations

Change in coal plant load factors after
46 GW of coal plants are retired



46 GW coal (205 units)
operate very little in a
high-RE future

A system with 175 GW of
RE could support some
combination of higher
demand growth or
retirements of generation

Strategies for better operation can reduce the cost of RE integration and reduce curtailment



Coordinated operations
across states



Lower technical
minimums for
coal plants

Cost savings

RE curtailment

State

Scheduling and dispatch

As operated in
2014

70%

Technical minimum

INR
6300
crore
annually

3.5%

1.4%

Regional

Scheduling and dispatch

55%

Technical minimum

Batteries do not add value to RE integration from scheduling/dispatch perspective

- 2.5 GW batteries reduce RE curtailment and peak coal consumption
- But batteries charge during the day, in part on coal, and have efficiency losses
- Electricity savings from reduced RE curtailment (1.2 TWh) is offset by battery efficiency losses (2.0 TWh)
- Total coal generation is not affected
- CO₂ emissions do not decline

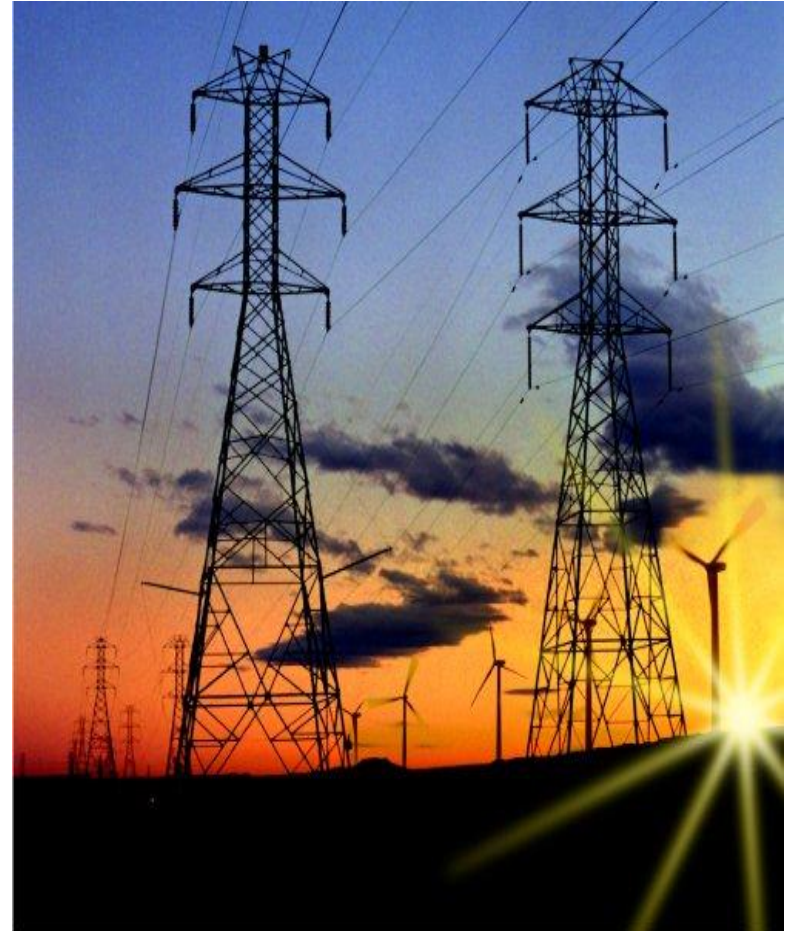
Batteries provide value for other reasons outside scope of study:

- Local transmission congestion, ancillary services...

BATTERY STORAGE	
100 GW SOLAR, 60 GW WIND	
NORMAL OPERATIONS (NO BATTERY STORAGE)	2.5 GW BATTERY STORAGE
230,000 INR Crore Annual Production Cost	0.33% Savings annually ₹
1.4% Renewable Energy Curtailment	1.1% Renewable Energy Curtailment

Priority Takeaways

- 1 India's power system has significant latent physical flexibility to integrate 175 GW RE with existing plans
- 2 Harnessing this flexibility is the key challenge. Need appropriate regulations, markets, incentives...
- 3 For example, consider ways at the state level to compensate coal plants for operating flexibly
- 4 Additional planning could identify optimal locations for new RE and associated inter- and intrastate transmission



Source: NREL PIX 19498

www.nrel.gov/india-grid-integration

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