Flexible Resources Initiative of the U.S.-India Clean Energy Finance Task Force

Least-Cost Pathway for India's Power System Investments through 2030

Mr. Balawant Joshi

Idam Infrastructure Advisory Private Limited

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Contents

Flexible Resource Initiative (FRI): State Study Overview

What did we do?

- Assess a **least-cost resource mix** for the states of Maharashtra, Karnataka, Gujarat, and Rajasthan up to 2030.
- Comprehensive **system expansion** and **hourly operational modeling** at individual power plant level using **PLEXOS**.
- Identify concrete **policy / regulatory solutions**.

What did we find?

- PLC cases in these four states can **meet ~36 % (~181 GW) of India's non fossil fuel target** of 500 GW by 2030.
- **No thermal capacity addition** in the least cost pathway of any of the states
- With **adequate storage** (battery &/or PSH) and other flexible resources **(load shift)**, grid operations would be **stable even during high stress periods**.
- Need **policy / regulatory interventions** (resource adequacy framework, storage regulations, capacity markets, wider/deeper energy markets)

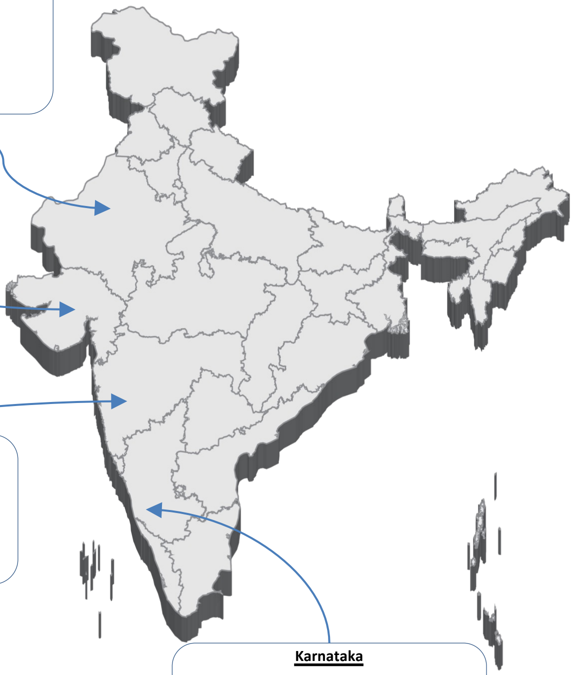
Overview of States

Rajasthan

Energy Consumption: 1,01,271 MU
RE Generation: 36,844 MU
Thermal Generation: 51,366 MU
Number of Consumers: 1,51,96,099
RE Potential: 160.8 GW

Gujarat

Energy Consumption: 1,39,201 MU
RE Generation: 27,307 MU
Thermal Generation: 49615 MU
Number of Consumers: 1,88,21,273
RE Potential: 120.2 GW



Maharashtra

Energy Consumption: 1,84,899 MW
RE Generation: 10,760 MU
Thermal Generation: 1,12,404 MU
Number of Consumers: 3,27,32,413
RE Potential: 109.4 GW

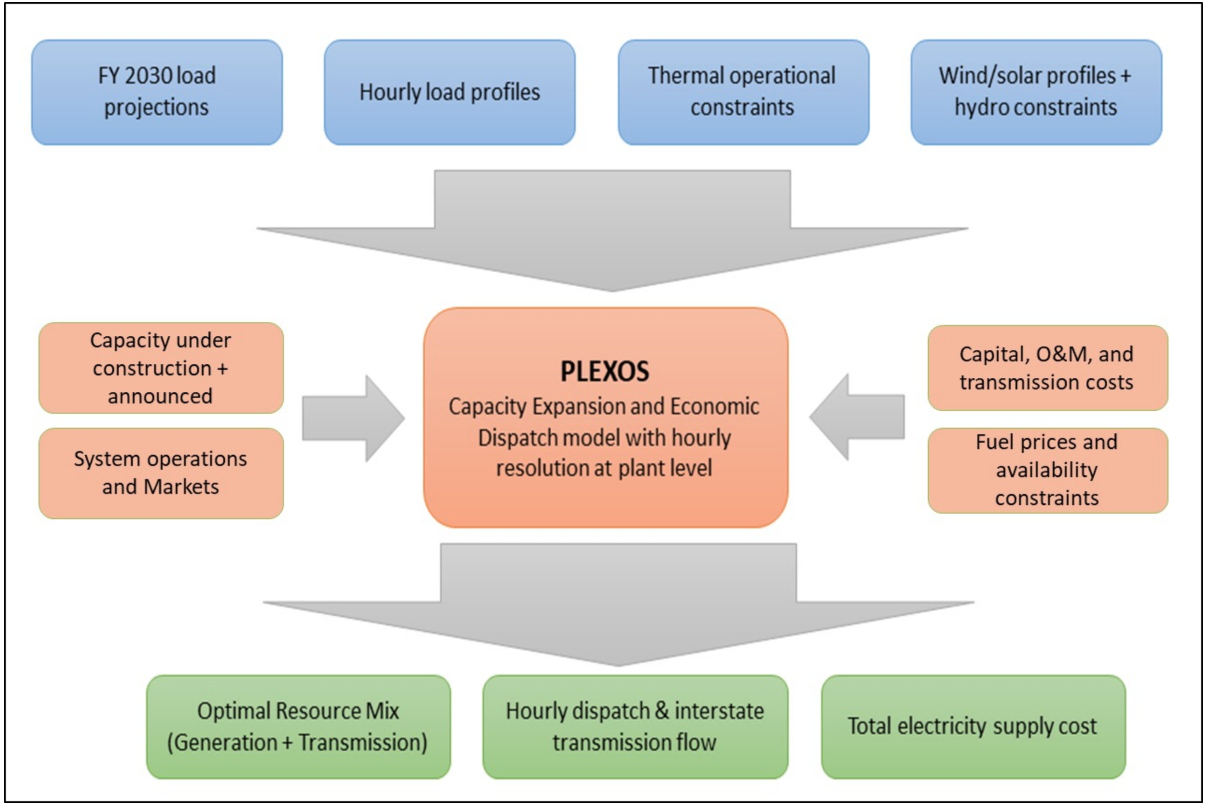
Karnataka

Energy Consumption: 75,711 MU
RE Generation: 21,884 MU
Thermal Generation: 31,164 MU
Number of Consumers: 2,77,10,217
RE Potential: 80.6 GW

FY 22-23	Total (all four states)	% Share in Country
Energy Consumption (MU)	5,01,082	33%
RE Generation (MU)*	96,760	61%
Thermal Generation (MU)*	2,44,549	22%
Number of Consumers**	9,44,60,002	29%
RE Potential (GW)	471	45%

** Data Available - April 22 to February 23*
*** Data Available till March 2021*

Modelling Methodology



Modelling Approach and Premise

Scenarios

Current Policy Scenario:	Primary Least Cost Scenario:	Sensitivities Case:
Pathway for States to meet 500 GW of solar and wind nationally by 2030 considering present rate of installation of RE in the State	Least cost pathway for States to meet 500 GW of solar and wind nationally by 2030	High RE installation Scenario.

Demand forecast & AG Load shift

- Electric Power Survey (EPS) based demand and energy projections.
- Considered load shift of 5000 MW in Karnataka, Maharashtra and Gujarat.
- Ag. Shift has not been considered in Rajasthan (Primary least cost case).

Harnessing VRE Potential

- Considered MNRE targets by 2022 and MNRE potential for solar and wind generation
- Max. yearly built up constraint for solar and wind generation.

Cost parameters & assumptions

- **Capital cost considered (Rs Cr/MW)**
  - Solar : 4.20 in 2020 to **2.94** by2030
  - Wind: 6.62 in 2020 to 5.96 by 2030
  - Battery : 6.30 in 2020 to **3.77** by 2030

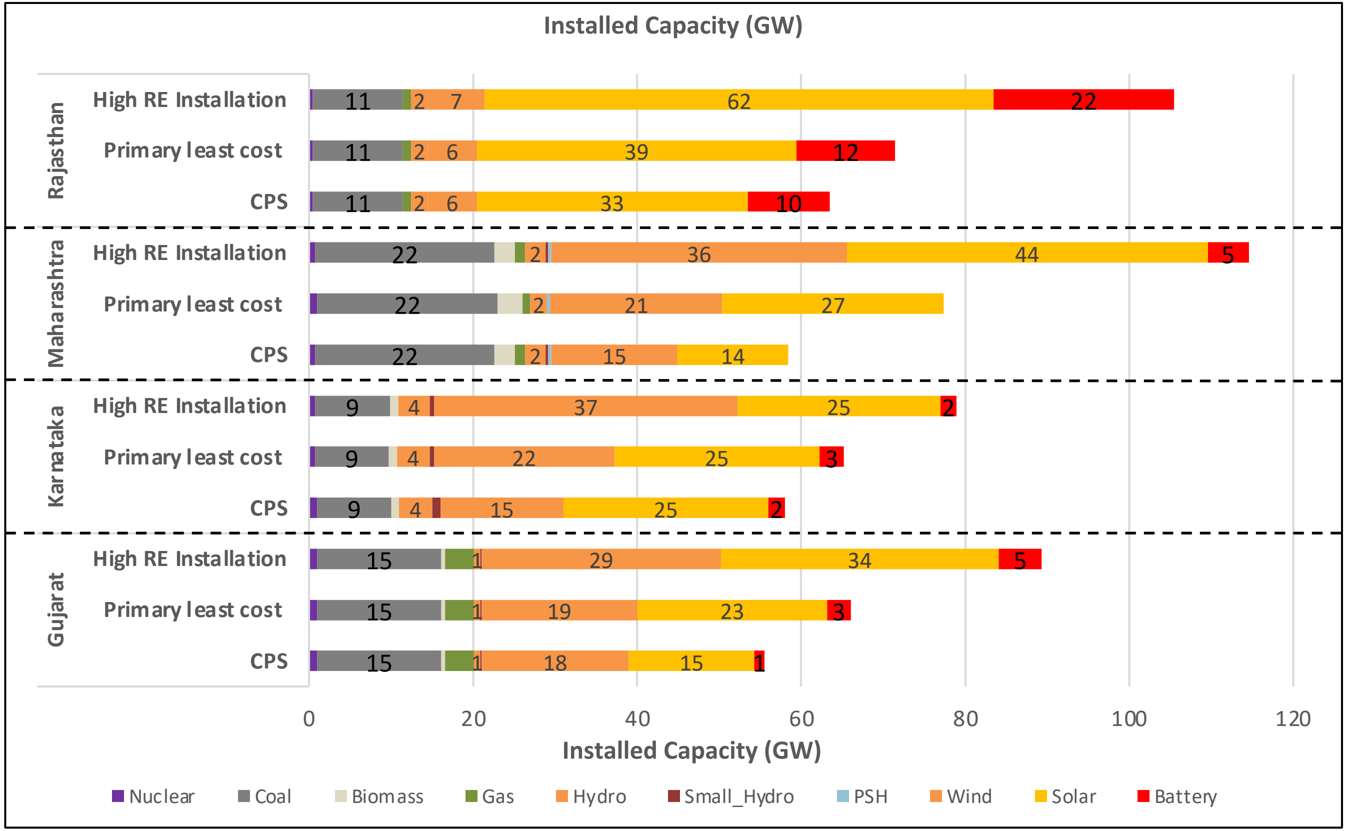
Salient Assumptions

State	Gujarat	Karnataka	Maharashtra	Rajasthan
Ag-Shift (MW)	5000	5000	5000	No
Coal Capacity Considered (MW)	15095	9172	20527	10525
Pumped Storage Hydro Capacity	No	No	Yes (Bhira, Ghatghar)	No

Demand Projections

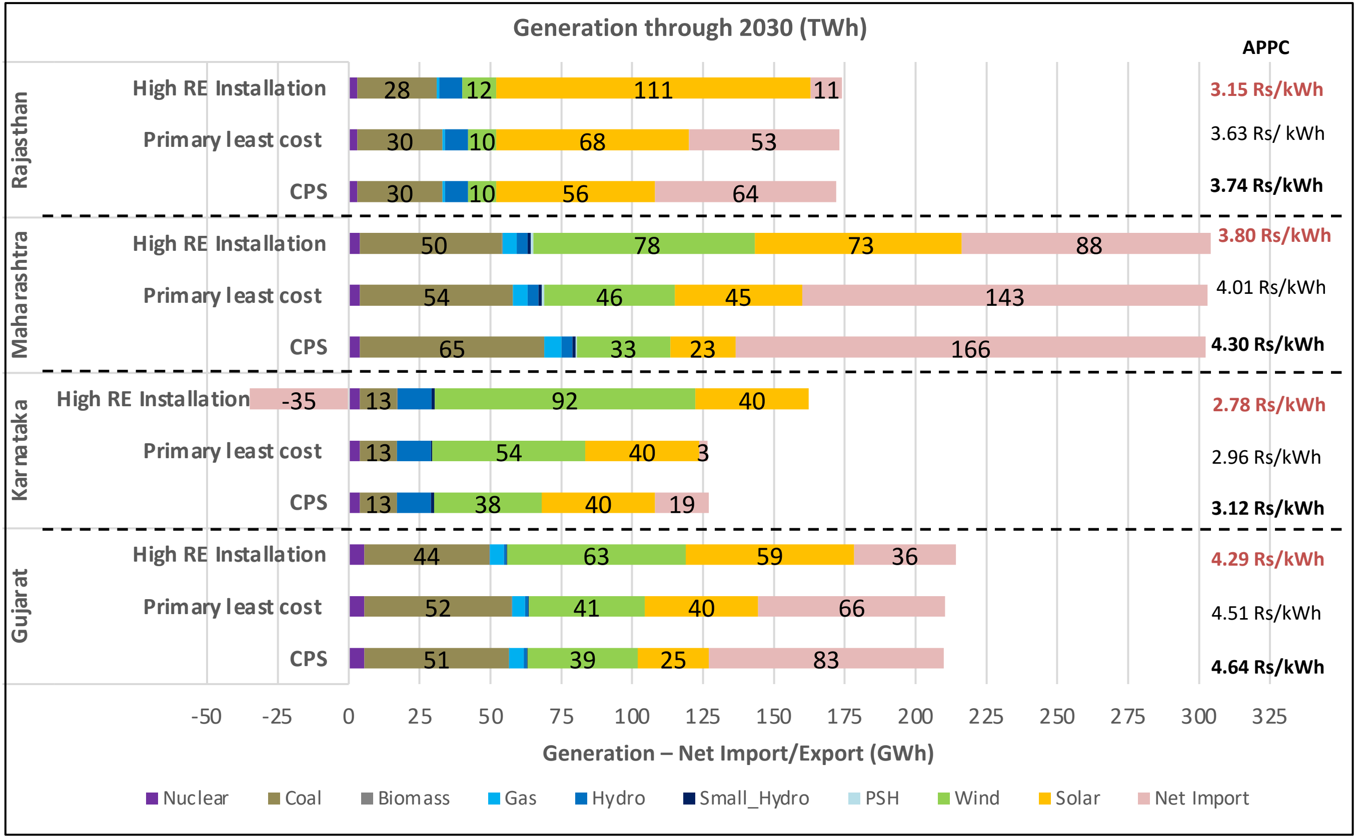
State	Gujarat	Karnataka	Maharashtra	Rajasthan
Tariff (TWhr)	185	121	207	150
EPS (TWhr)	213	128	303	173
Difference (EPS/Tariff)	15.14%	5.78%	46.38%	15.33%

Investment Scenarios till 2030 - Comparison of Installed Capacity



- **No new thermal additions** through 2030 in any of the 4 states
- **Need of energy storage** with increased variable RE capacity
- **Aligning state policies & ecosystem** to further accelerate deployment of RE capacity addition per year to harness maximum possible RE potential.

Investment Pathway through 2030 - Comparison of Generation

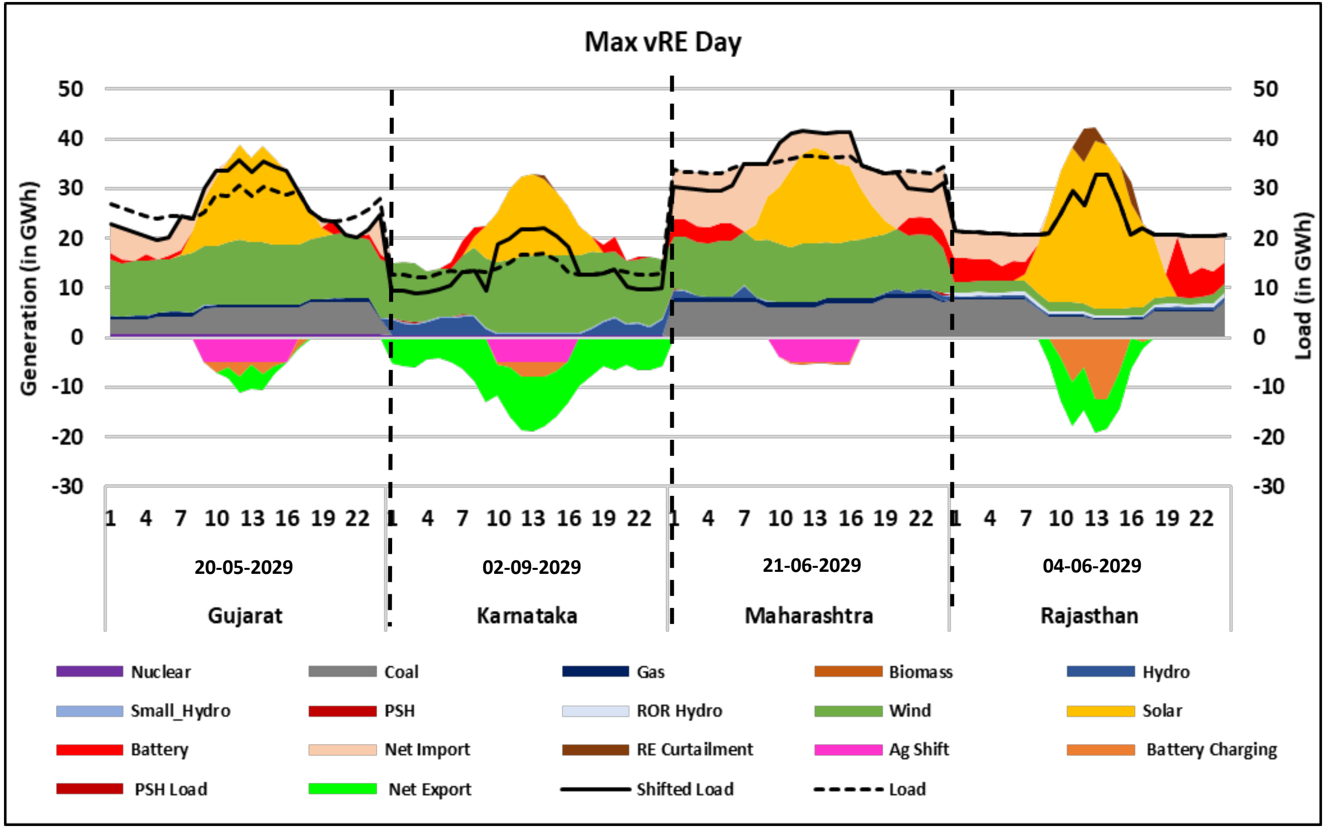


- **With increase in generation from cheaper RE, dependability on import of power decreases and cost of power procurement decreases.**

- CO_2 emission intensity decreases from FY23 to FY 30 as:
  - Rajasthan from * 0.54 to 0.26 kg/kWh (53 % decrease)
  - Maharashtra from *0.67 to 0.35 kg/kWh (48 % decrease)
  - Karnataka from *0.23 to 0.11 kg/kWh (53 % decrease)
  - Gujarat from *0.63 to 0.37 kg/kWh (41 % decrease)

*Note : *Numbers are for primary least cost case*
Specific CO2 emission tCO2/MWh = 1.04 for coal and tCO2/MWh=0.92 for import of power (CEA : CMD-CO2 baseline database (version 16.0_2019-20)

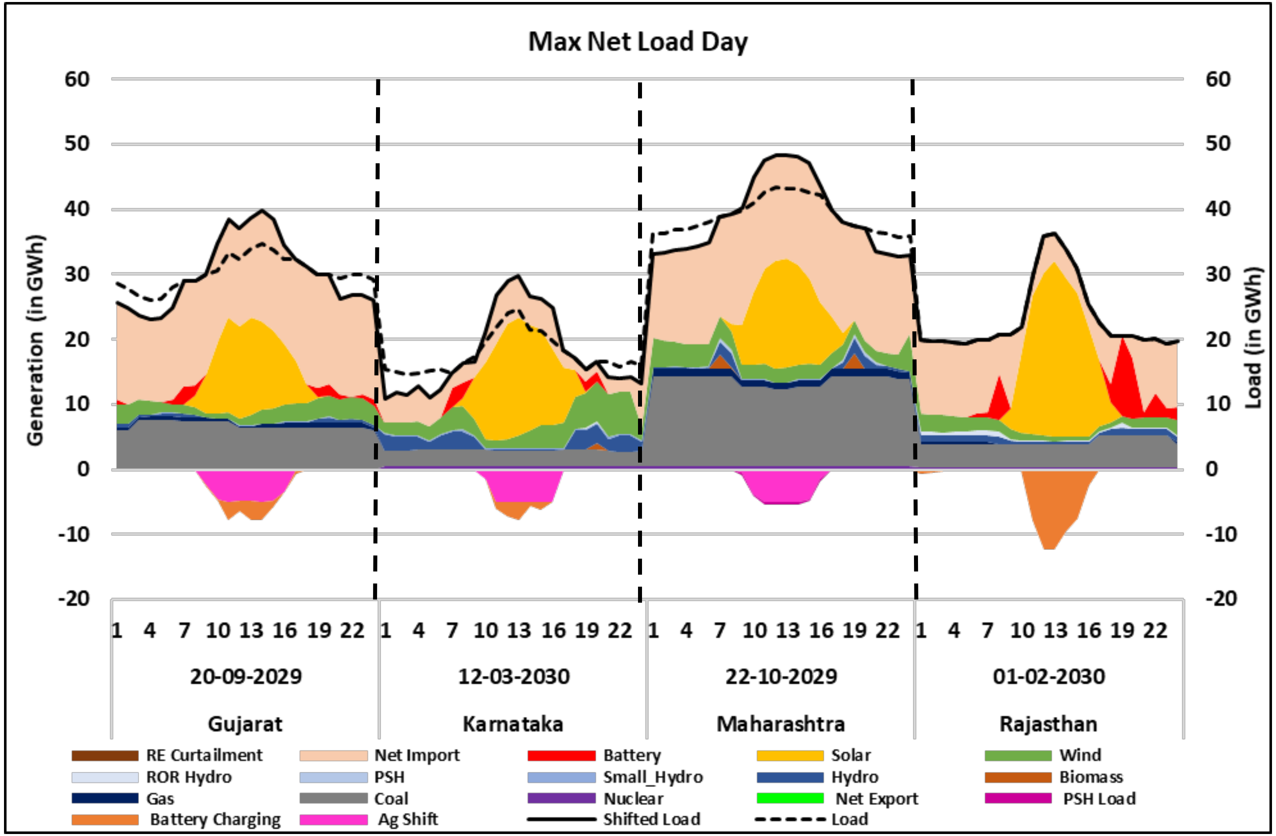
Max vRE day: Dependable Grid during High Stress Periods



Max vRE Day:

- System is stable even without much thermal generation support
- Rajasthan and Karnataka has some RE curtailment on high RE days.
- RE contribution at instantaneous peak load on Max vRE day for Gujarat is ~91%, for Karnataka is ~183%, for Maharashtra is 47%, and for Rajasthan it is 105%.

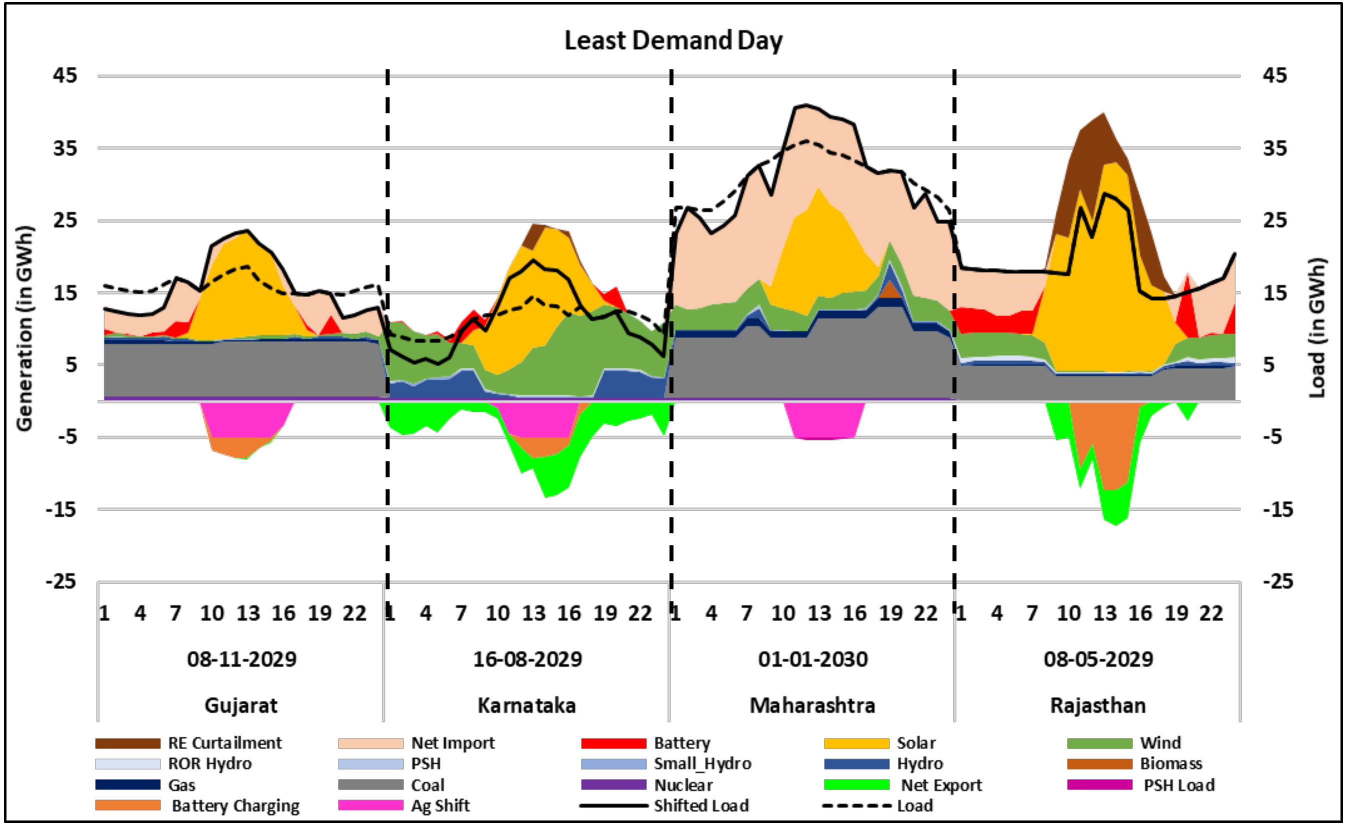
Max Net Load Day: Seasonality of RE Generation



Max Net Load Day:

- Thermal generation is low in Karnataka and Rajasthan.
- Maharashtra would require significant thermal generation.
- RE contribution at instantaneous peak load on Max net load day for Gujarat is ~45%, for Karnataka is 81%, for Maharashtra is ~43%, and for Rajasthan it is 77%.

Least Demand Day: Seasonality of Load



Least Demand Day:

- Because of low demand, Rajasthan and Karnataka has RE
- Even during lowest demand, Maharashtra imports power, suggesting that the State should particularly focus on increasing its share.
- RE contribution at instantaneous lowest load on least demand day for Gujarat is ~41%, Karnataka it is 73%, for Maharashtra is ~10%, for Rajasthan is 85%.

Summary of State Level Studies

	Gujarat	Karnataka	Maharashtra	Rajasthan
Total RE optimal capacity by 2030 (Solar + Wind)	42 GW (23 + 19)	46 GW (25 + 22)	48 GW (27+21)	45 GW (39+6)
Storage Requirement	3 GW	3 GW	0.9 GW	12 GW
RE generation as % Total generation (*excluding import) in 2030	56 %	75%	57%	65%
RE as % Total energy in 2030	38%	73%	30%	45%
Net Importer or Exporter by 2030	Net importer	Net importer	Net importer	Net importer
Average Power Purchase Cost (FY 23)	4.60 Rs/kWh	3.66 Rs/kWh	4.06 Rs/kWh	3.95 Rs/kWh
Average Power Purchase Cost (FY 30)	4.51 Rs/kWh	2.96 Rs/kWh	4.01 Rs/kWh	3.63 Rs/kWh

Key Findings

The Least Cost Capacity Expansion is pointing to the following results:

- With adequate storage (Battery &/or PSH) and establishment of other flexible resources (load shift), the grid operations would be stable & dependable even during high stress periods.
- No coal investment is cost effective through 2030 in any of the States.
- However, import of cheaper coal power from states like Chhattisgarh, Madhya Pradesh, & Jharkhand
- Complementary FRs working in tandem maintains grid dependability.
- Share of RE in total energy - Guj 38%, Kar 73%, MH 30%, Raj 45%
- If seasonal storage is developed, Karnataka can become net zero faster than other states.
- CO_2 emissions intensity decrease considerably for all States from FY 23 to FY 30.

Key Policy Recommendations (1/3)

Specific resource availability.

- Karnataka exhausts its present known solar potential (24.7 GW) before 2030
- Other States also exhaust substantial portion of their known RE potential by 2030,
- The States need to reassess their RE potential as present RE potential assessment was carried out nearly a decade ago.

Resource adequacy framework

- Need for accurate demand forecast - Guidelines for state load forecasts and planning reserve margin studies.
- States such as Karnataka and Rajasthan show almost nil thermal generation during high RE seasons
- Need to sell thermal/ extra RE generation during these periods.
- This would require a proper resource planning and adequacy framework.
- RA Framework is required to drive planning and procurement strategies and avoid potential future stranded assets.
- Integration of resource adequacy requirement into discom-level planning and procurement.
- Market reforms to enable capacity procurement to avoid under/over-contracting and stranded assets.

Key Policy Recommendations (2/3)

Development of transmission both intra and inter-state.

- States with high RE also show higher RE curtailment, especially during high RE seasons.
- Both inter and intra-state transmission should be augmented.
- Development of transmission infrastructure to handle capacity expansion and increasing export/import.

Promotion of Flexible Resources.

- Regulatory framework for energy storage.
- Promotion of flexible resources such as demand side management including Ag and industrial load shift.
- Results show that Rajasthan would suffer high RE curtailment during high solar season, partly because of limited demand management tools like agricultural shift. This could be avoided by adopting demand management approaches like shifting night-time load to solar hours.

Key Policy Recommendations (3/3)

Focus on demand side management and other FRs

- Results show that Rajasthan would suffer high RE curtailment during high solar season, partly because of limited demand management tools like agricultural shift.
- This could be avoided by adopting demand management approaches like shifting night-time load to solar hours.

Land allotment and development for RE

- Results show that a total 181 GW RE could come up by 2030 in 4 states.
- This would require huge land and thus States need to identify land and develop innovative land use policies that would enable higher RE installation.

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WattGuru
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Contact:

Balawant Joshi
+91 98214 21630

Ajit Pandit
+91 98211 08222

Email: contact@idaminfra.com

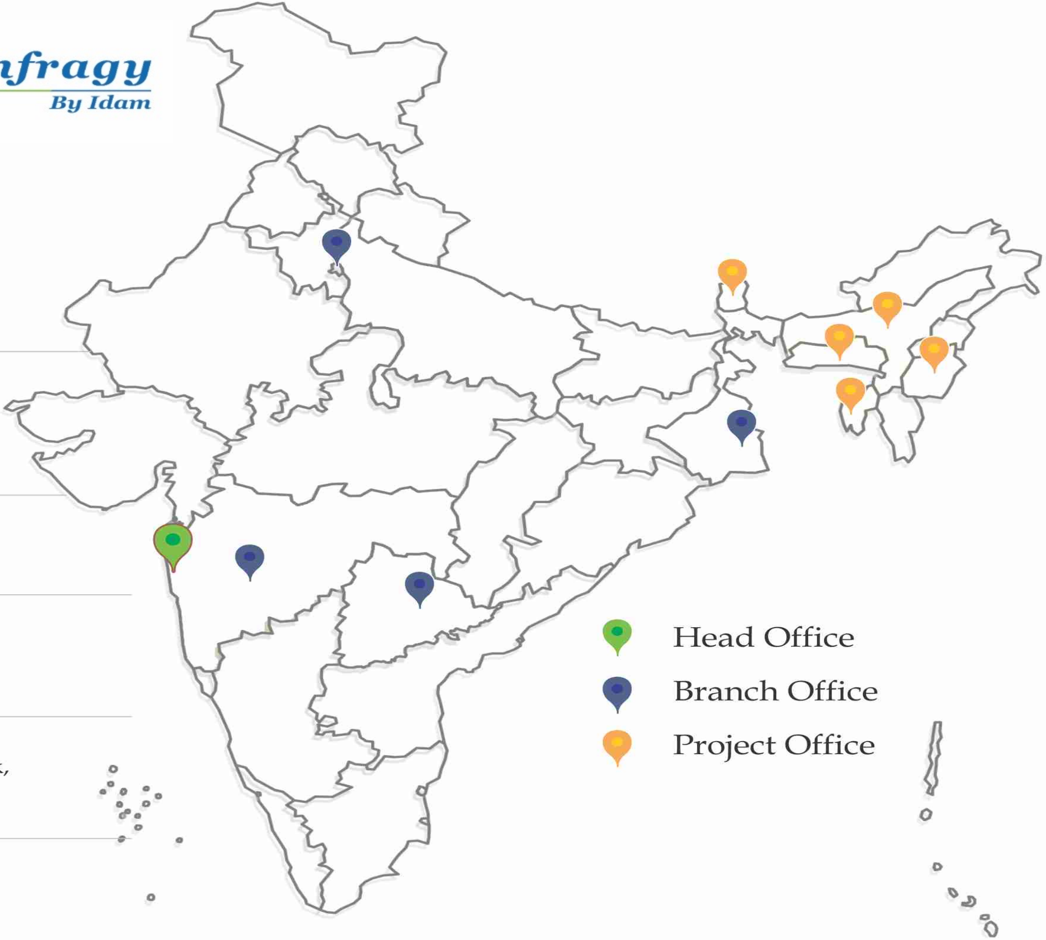
MUMBAI
Quest Coworks Pvt. Ltd., Technopolis Knowledge Park,
5th Floor, Mahakali Caves Road, Chakala, Andheri East,
Mumbai – 400 093
Phone: +91 22 6862 0300

PUNE
1st Floor, Teerth Technospace,
Mumbai-Bengaluru Highwar, Baner, Pune - 411 045

DELHI
Awfis Space at Awfis, L29 - L34, 1st Floor, Connaught Place,
New Delhi – 110 001
Phone: +91 22 6862 0300

KOLKATA
Awfis, Godrej Waterside, 12th Floor, Tower II, DP-5, DP Block,
Sector V, Salt Lake, Kolkata - 700 091, West Bengal
Phone: +91 33 4604 8993

HYDERABAD
House No. 3-51, Flat No. 201, Abhishek Towers,
Balanagar, Hyderabad – 500 042
Phone: +91 91369 20664



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