Energy Demand Dynamics Considering High RE Penetration: Managing Uncertainties, Challenges, and Solutions

(Enerday 2024-exploring energy demand dynamics)

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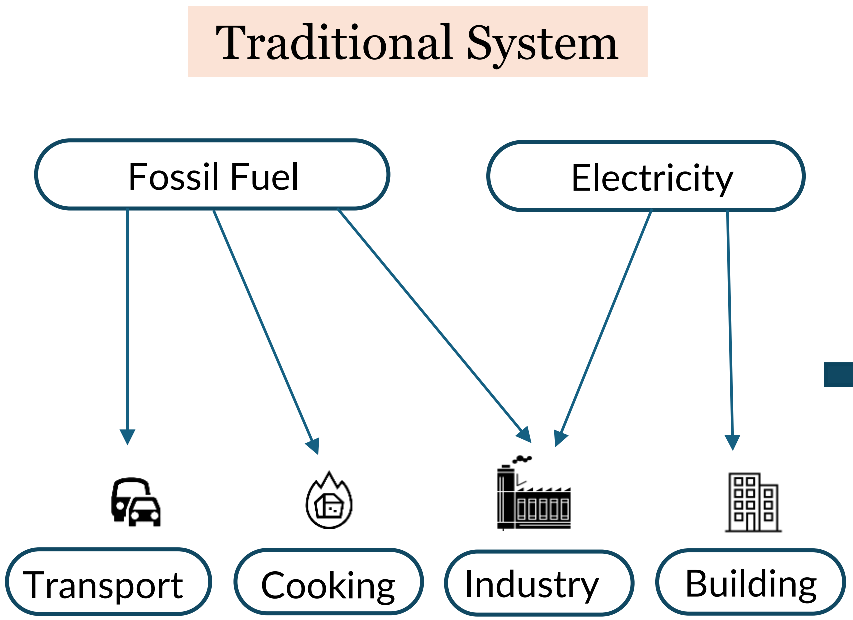
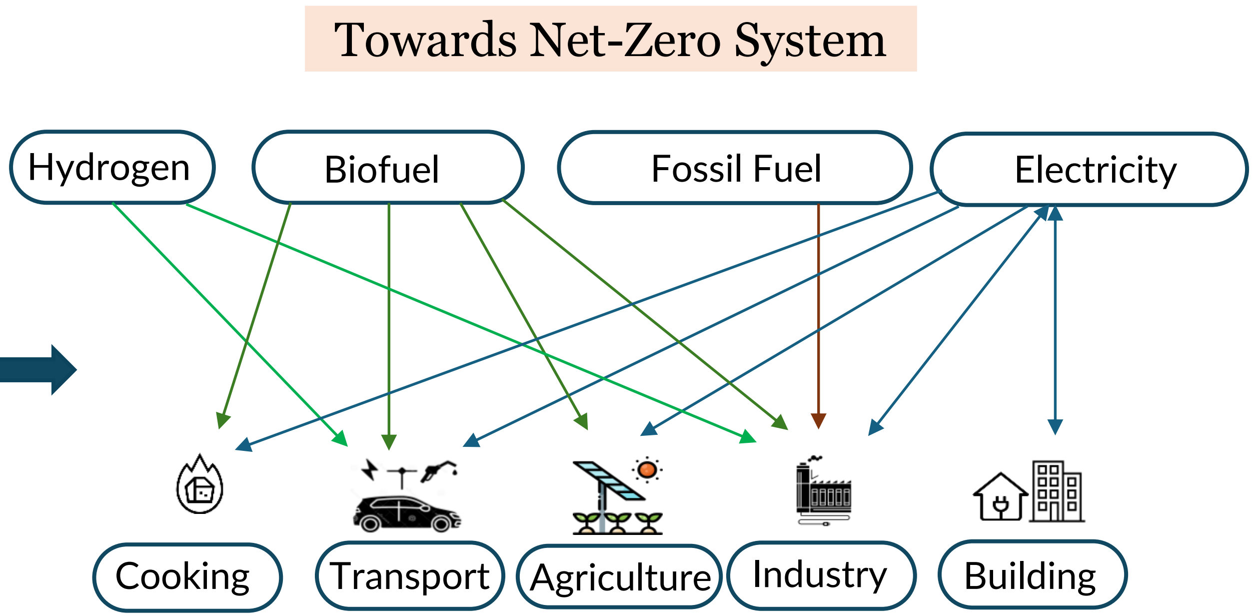
Agenda

- Introduction
- Transition in Demand Dynamics
- Drivers of Demand Dynamics
- Challenges
- Solutions
- Case Study: Hybrid Plant: Addressing Supply-Demand Balance
- Conclusion

Generation and Demand Dynamics





❑ **Conventional system**

- Fossil fuel-based
- Finite resources
- Non-commercial energy used

❑ **Major challenge of Non-Conventional system**

- Deployment of RE
- Selection of appropriate resources
- Technological conversion

Transition in Demand Dynamics

- Growing economy faster (PGDC)
- Shift towards the urbanization
- Increasing the cooling and heating demand
- World’s energy mix changes significantly

Population & Energy Consumption

Per capita rising

Population & Energy Consumption

Per Capita Static or Falling

*PGDC: Power generation in developing countries
https://www.energymix.co.nz/our-consumption/increasing-demand/#growing-economies-increase-demand

India's Energy Dynamics

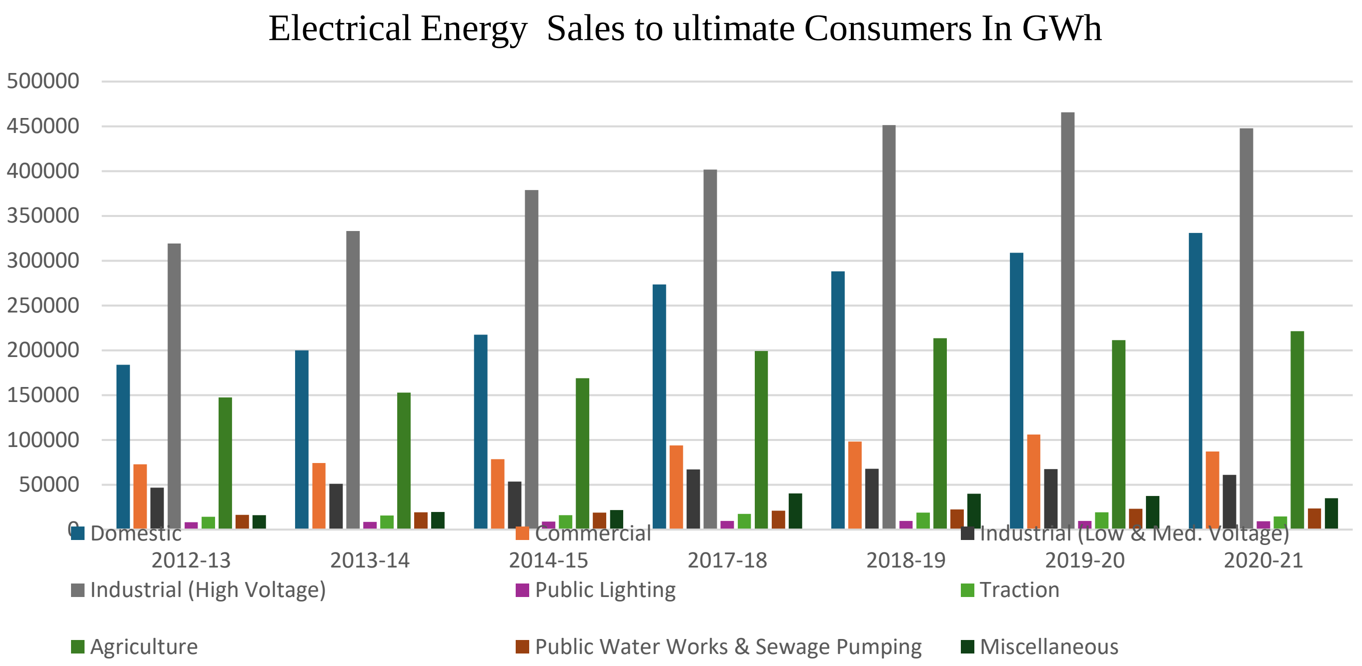


Fig. :1 Electrical energy sales to ultimate consumers

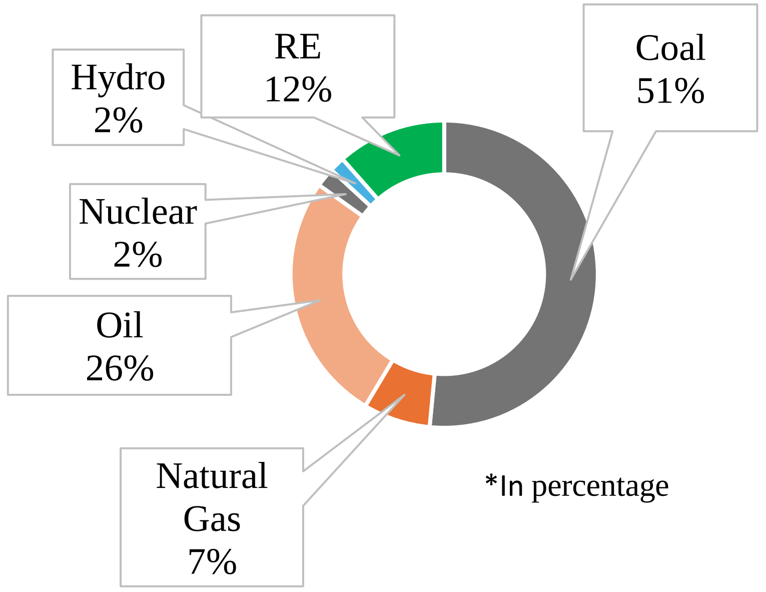


Fig. 2: India's total primary energy supply

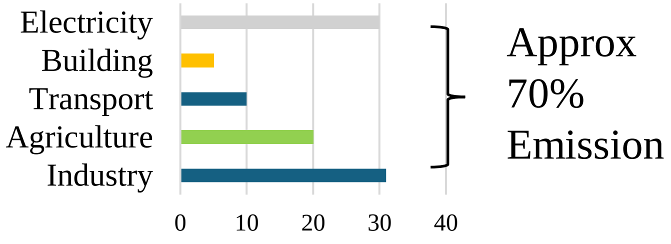


Fig. 3: CO_2 emission from different sectors of India

- RPO trajectory for each state (43.3% by 2030)
- 45% reduction in emission intensity by 2030 compared to 2005
- 50 % of non-fossil-based installed capacity of power by 2030
- Net Zero by 2070

Source: https://cea.nic.in/dashboard/?lang=en
https://vasudhapower.in/generation
https://pib.gov.in/FeaturesDeatils.aspx?NoteId=151141&ModuleId%20=%202

Electricity Demand Pattern

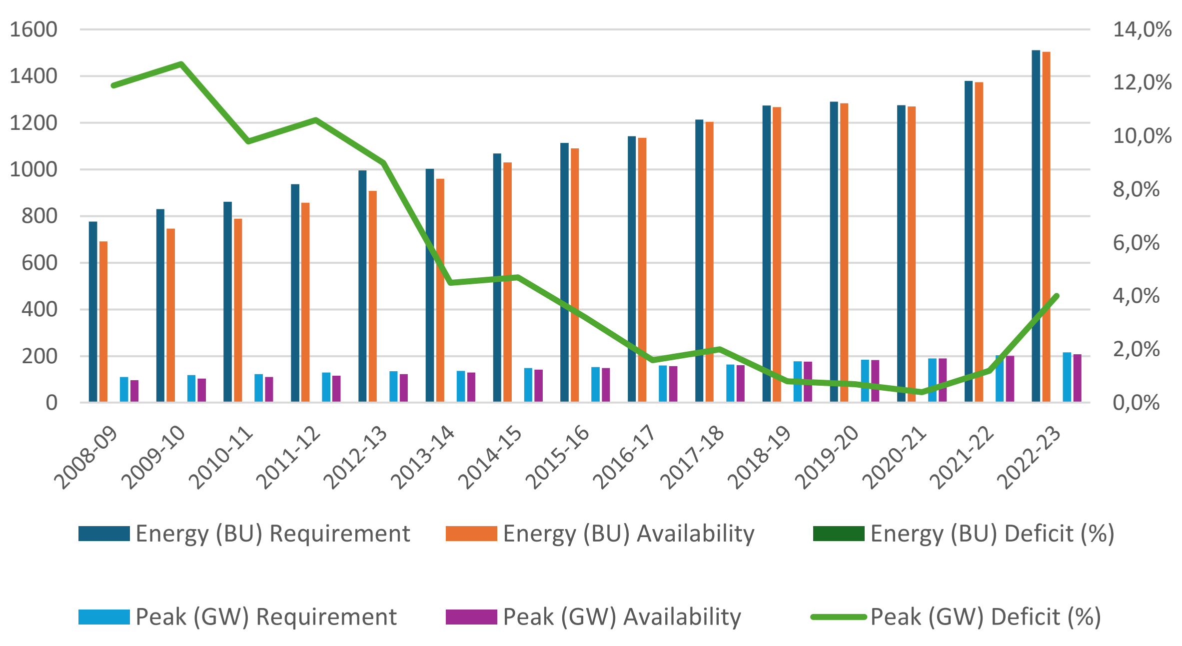


Fig. 4: Power Supply Position in India, 2008-09 to 2022-23

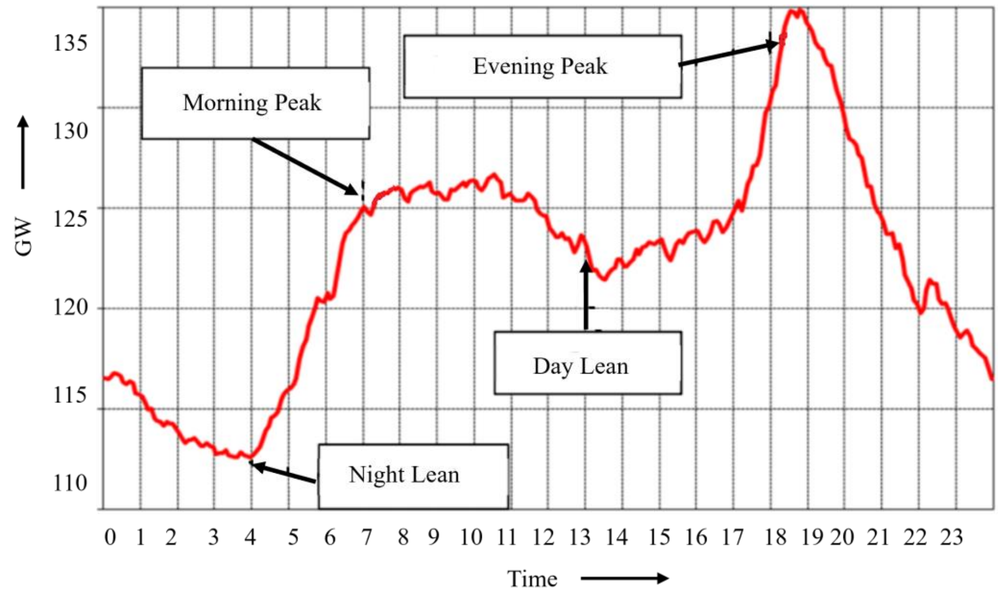


Fig. 5: load curve

- Shift in the peaks due to cooling load
- Changing the Day lean and Night lean due (by shifting agricultural load)
- Per capita consumption significantly rises

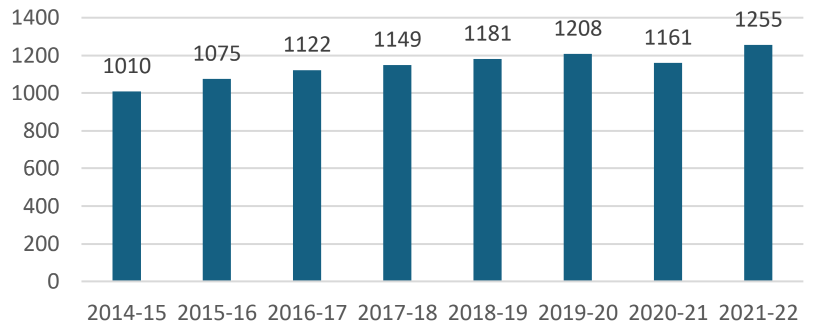


Fig. 6: Per Capita Consumption (kWh) Per Capita Consumption

https://cea.nic.in/dashboard/?lang=en
https://www.iitk.ac.in/npsc/Papers/NPSC2016/1570293957.pdf

[5]

Drivers of Increasing Demand Dynamics

Drivers

Demand side management

- Increasing variability in demand
- Shifting Agriculture load

  (Contributes about 17% to the total GDP)

  (210 Million pump sets)

Electrification of Transport & Industry sector

- Energy-efficient measures
- Shift to Electrical Vehicles

(FAME India Scheme, around 100 Billion)

Uncertainty in fuel prices

- Shift to electricity gird from the captive power generation

Carbon Intensity Reduction

- Reduction in carbon intensity of the economy by 45 % by 2030, over 2005 levels

https://beeindia.gov.in/en/programmes/demand-side-management-programme-dsm
https://heavyindustries.gov.in/fame-ii#:~:text=Government%20has%20approved%20Phase%2DII,for%20xEVs%20in%20the%20country.

Challenges Associated with High RE Integration

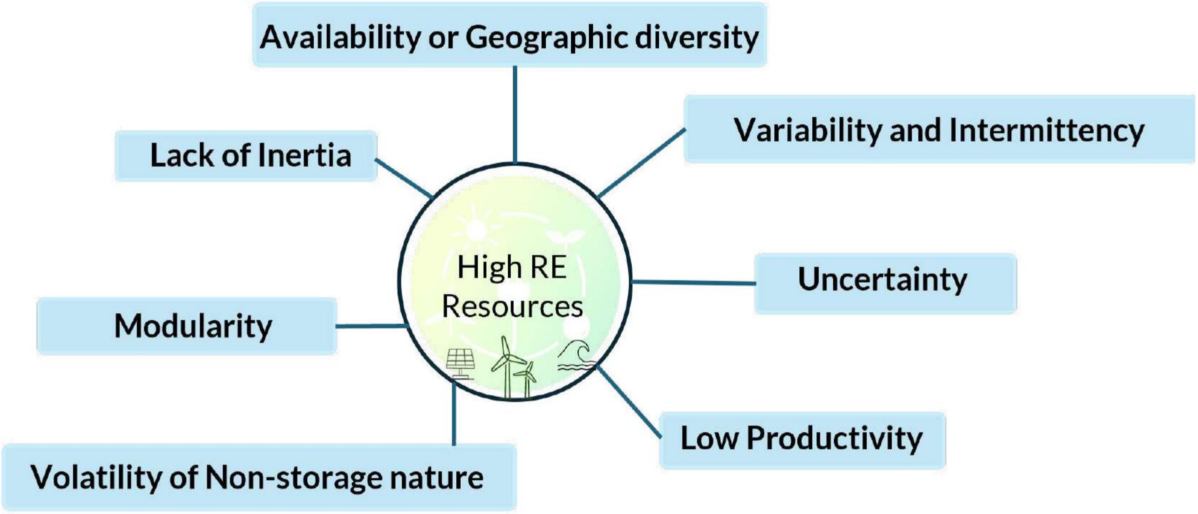


Fig. 7: Challenges of High RE Resources

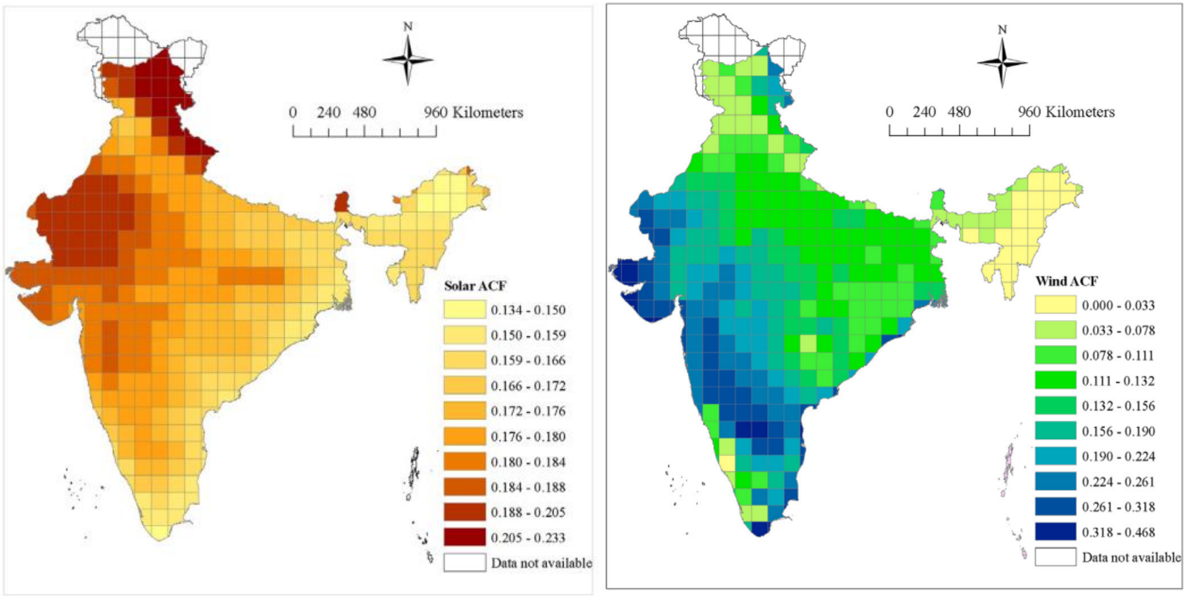
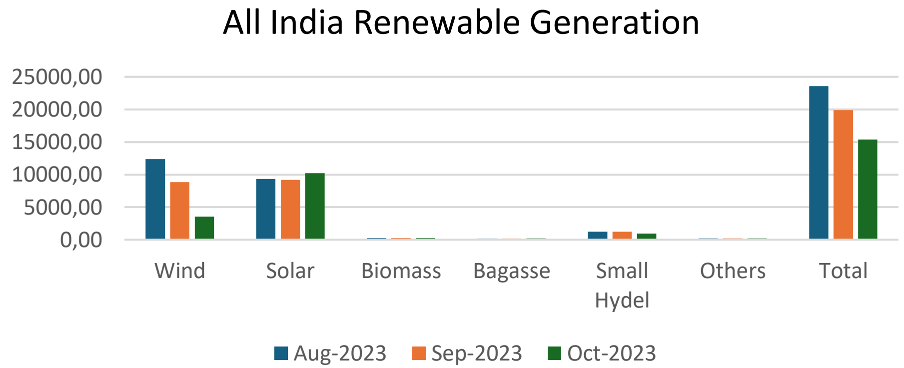


Fig. 8: Annual capacity factor for solar PV plants and on-shore wind plants

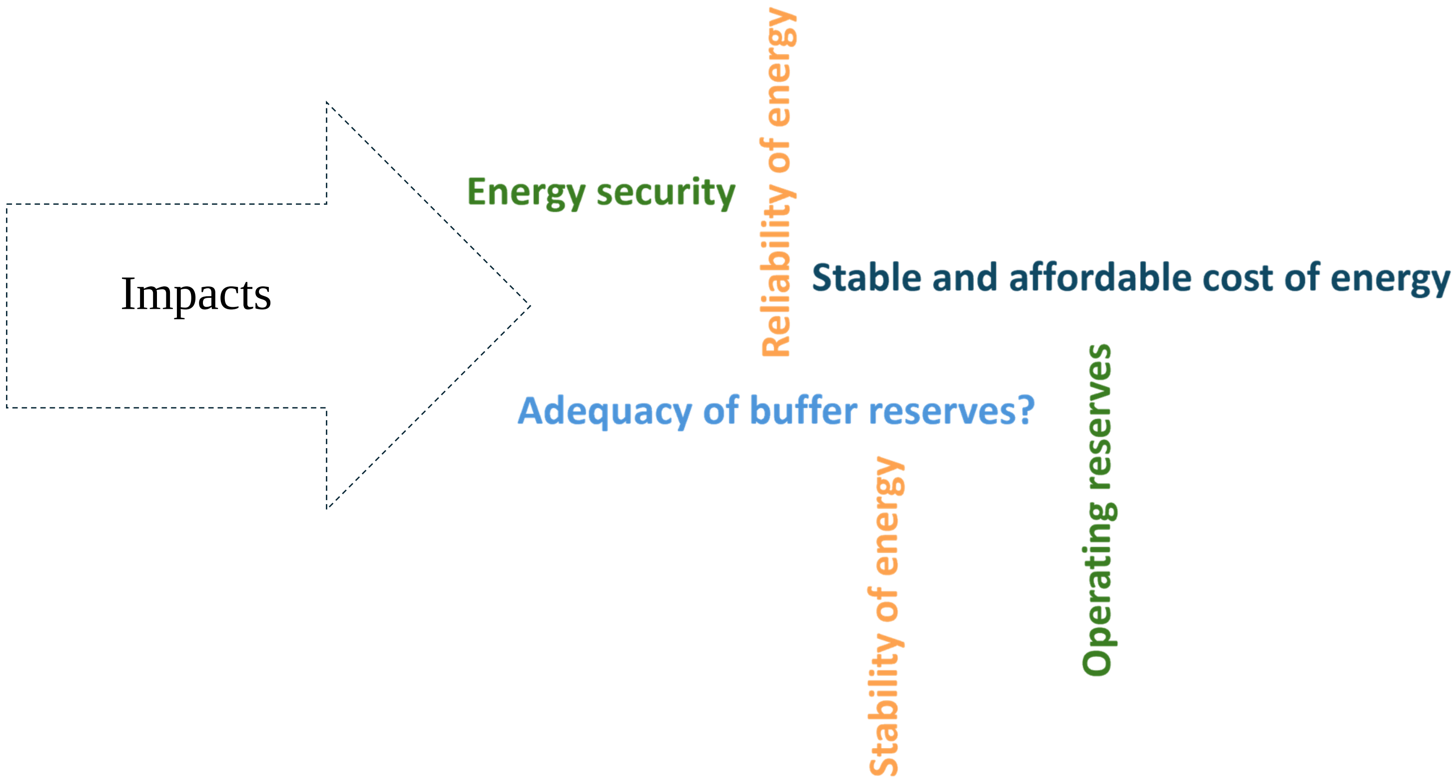
- Economically managing supply-demand equilibrium:
  - ✓ Non-linear escalation of costs as RE penetration intensifies.

- Technical requisites for grid reliability with RE resources:
  - ✓ Innovative technological solutions tailored to the specific mix of RE technologies employed



https://cea.nic.in/dashboard/?lang=en
Jain, A., Das, P., Yamujala, S., Bhakar, R., & Mathur, J. (2020). Resource potential and variability assessment of solar and wind energy in India. *Energy*, *211*, 118993.

Impact of High RE on Demand Dynamics



- Operational
- System Voltage profiles
- System Reliability
- Stability of power system

Energy Supply-Demand Balance Coordination

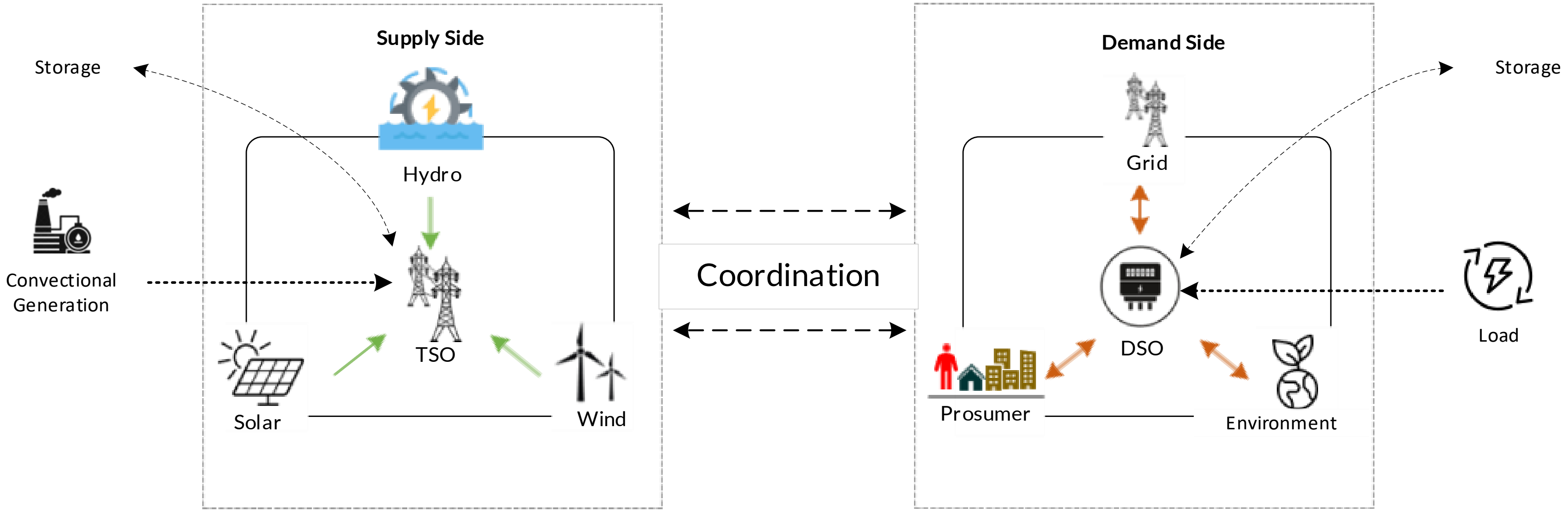


Fig. 9: Framework of the supply and demand considering High RE

- Large-scale electricity storage
  - Pump hydro, grid-scale battery energy storage
- Gas and Hydrogen thermal generation
  - Dispatchable combined cycle gas or hydrogen turbine produce electricity as needed
- Interconnection
  - Import and export

- Transport Demand Side Response (DSR)
  - Smart charging and vehicle-to-Grid
- Residential DSR
  - Smart home energy management, Domestic battery storage Heat pumps with thermal storage
- Industrial & Commercial DSR
  - Behind the meter generation and storage, Commercial heat pump flexibility
- Electrolysis
  - Hydrogen to electricity

Solutions of High RE Integration Considering Demand Dynamics

Demand-Supply Balance with High RE Integration

- Flexible coal-fired plant
  - ✓ Fast dispatch
  - ✓ Accurate RE forecasting
  - ✓ Modified reserve management
- Energy storage system
- Green hydrogen
- Hybrid plants

Solutions

Flexible coal-fired plants

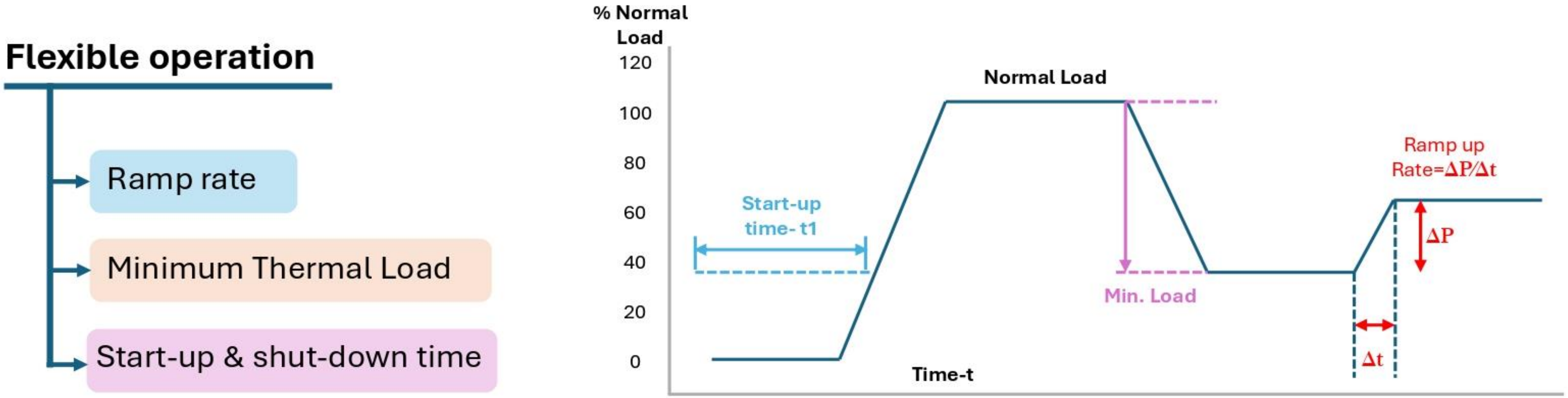


Fig. 10: Attributes of Flexible operation

- Flexible operation of the coal-fired plants provides a stable, secure, and reliable power supply
- To implement flexibility, it is necessary to identify thermal units that are both economically and technically viable to maintain the demand and supply balance

Indian Prospective

- Observed that the average day-wise flexibility: 8- 10% in 2009 to15-18% in 2019.
- Average daily thermal generation range:15-17 GW.
- Maximum flexibility required: 56GW (During winter)

https://cea.nic.in/old/reports/others/thermal/trm/flexible_operation.pdf
https://posoco.in/wp-content/uploads/2020/05/Flexibility-Analysis-of-Thermal-Generation-for-RE-Integration-in-India-1.pdf

Energy Storage Solutions, P2H and Demand Side Management

- Reduce peak demand
- Lower electricity costs
- Promote energy efficiency
- Improve reliability
- Improve sustainability

Smart Meter National Programme

- Launched in year 2009
- 1,04,60,295- Installed meters
- Aim: Deploying 250 Million

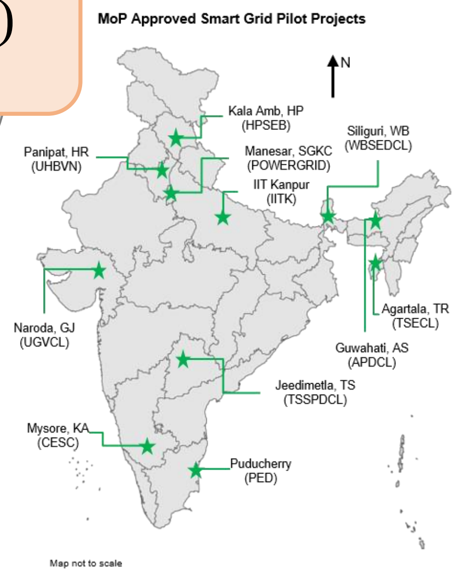
DSM

Power to Hydrogen (P2H) technologies

Energy storage solutions

- During peak demand times
- Balance supply and demand in real time
- Potentially improving grid stability

- Can be used as energy storage conversion devices
- To make RES more reliable and efficient
- It can store excess energy (off-peak period)
- Generate electricity via fuel cells



National Hydrogen Mission

- 5 MMT of green hydrogen by 2030
- 60-100 GW electrolyzer installations
- 125 GW RE for green hydrogen production
- 50 MMT of carbon abatement cumulatively

Energy Storage Obligation trajectory: 4% by 2029-30
Pilot Project: Fatehgarh III (Rajasthan): 500/1000 MWh Standalone BESS

*DSM: Demand Side Management
https://www.nsgm.gov.in/en/sg-pilot
https://mnre.gov.in/national-green-hydrogen-mission/

Hybrid Power Plants

- The hybrid system is the combination of two or more than two RES that work in grid-connected mode or standalone mode
- Hybrid projects aggregate capacity in India: 4360 MW

National Wind-Solar Hybrid Policy-2018

- Scheme for setting up of 2500 MW Inter State Transmission System (ISTS) connected wind solar hybrid projects
- Provide a framework for large grid connected wind-solar photovoltaic (PV) hybrid system

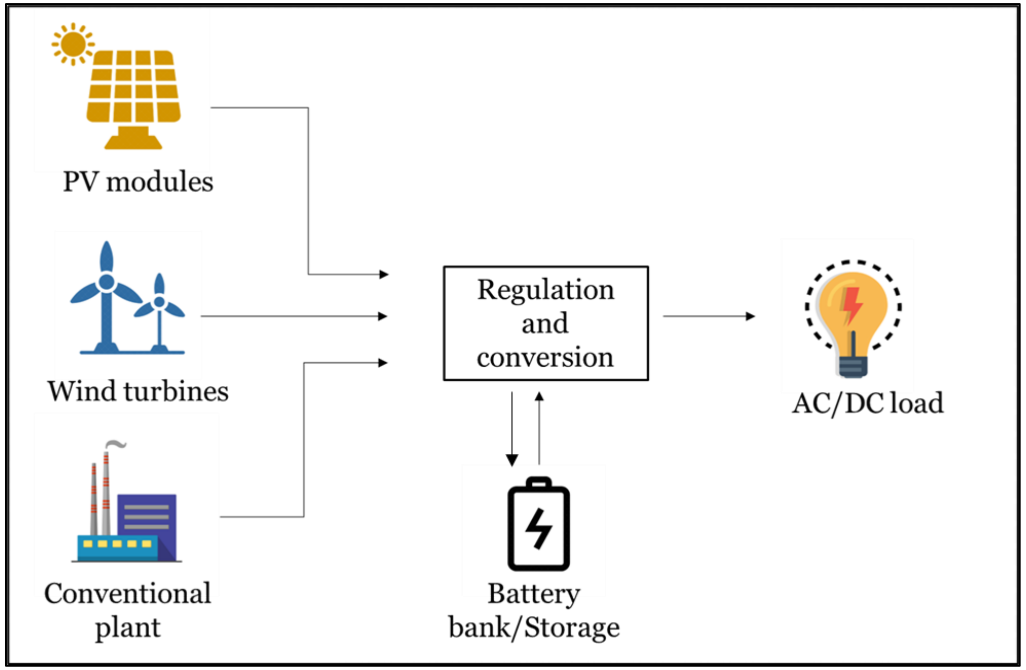


Fig. 11: Hybrid Power Plant

Under-construction Hybrid Power Projects

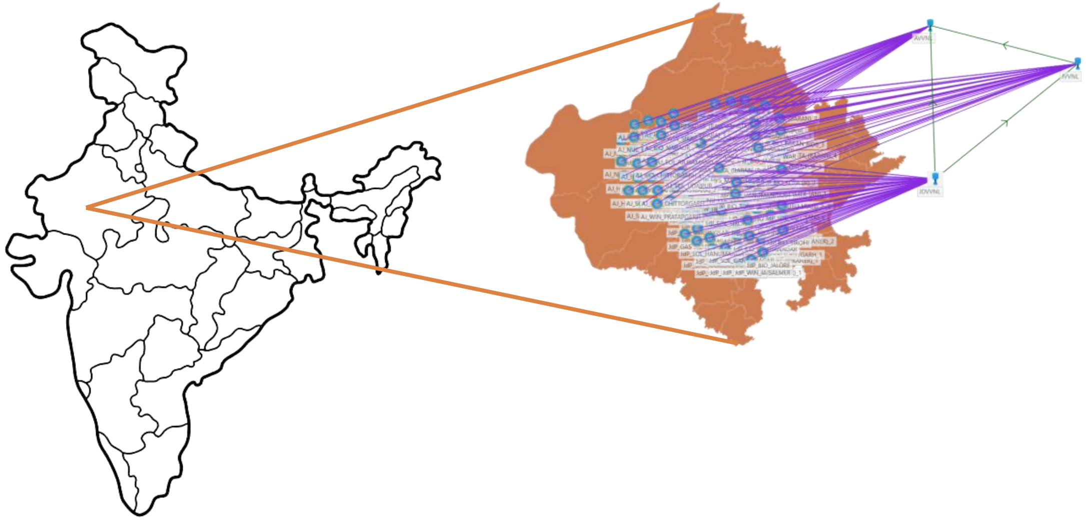
S.No.	Scheme	Total Capacity Awarded (MW)
1	1200 MW ISTS-Connected Wind- Solar Hybrid Power Projects (Tranche-I)	840
2	1200 MW ISTS-Connected Wind- Solar Hybrid Power Projects (Tranche-III)	1110
3	400MW ISTS-connected Round-the-clock (RTC) RE Power (RTC-1)	400
4	1200 MW ISTS-Connected RE Projects with assured Peak Power Supply in India (ISTS-VII)	1200
5	1200MW ISTS-connected Wind Power Projects (Tranche-IV)	1050
	Total	4600

Hybrid Pilot Projects: 6/10 in Rajasthan

Case Study: "Hybrid Plant: Addressing Supply-Demand Balance"

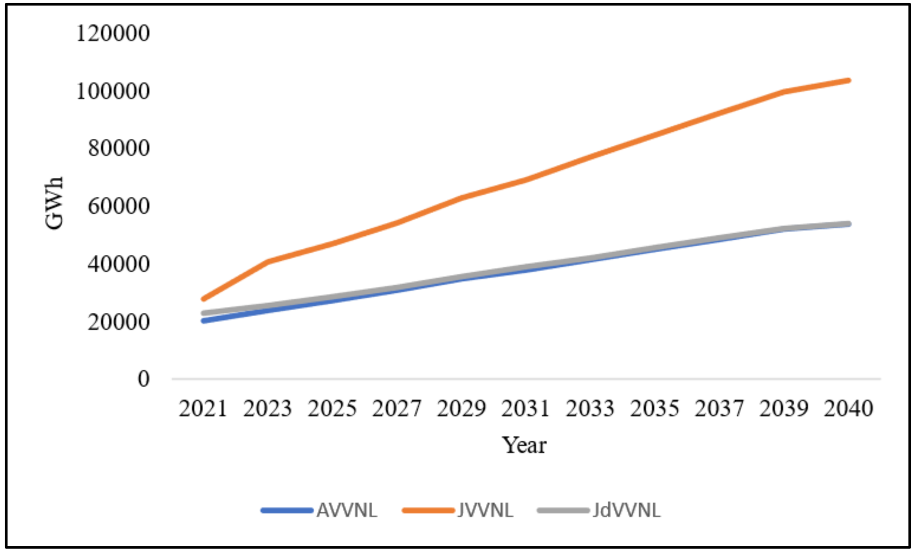
Geographical coverage → **Rajasthan State (India)**

- Largest state covering 10.4% total geographical area of India
- Total install RES capacity: 23.8 GW
- Solar potential:142 GW
- Maximum Solar Radiation Intensity: 6-7KWh/Sq. m/day (more than 325 days in a year)
- Wind Potential: 1,27,750 MW
- Hybrid capacity commissioned:1,690 MW



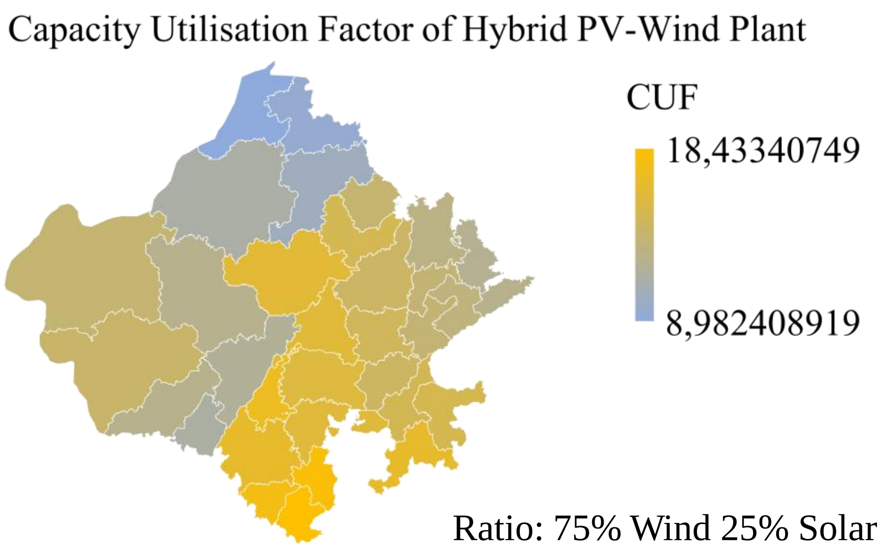
Specific Parameters and assumption

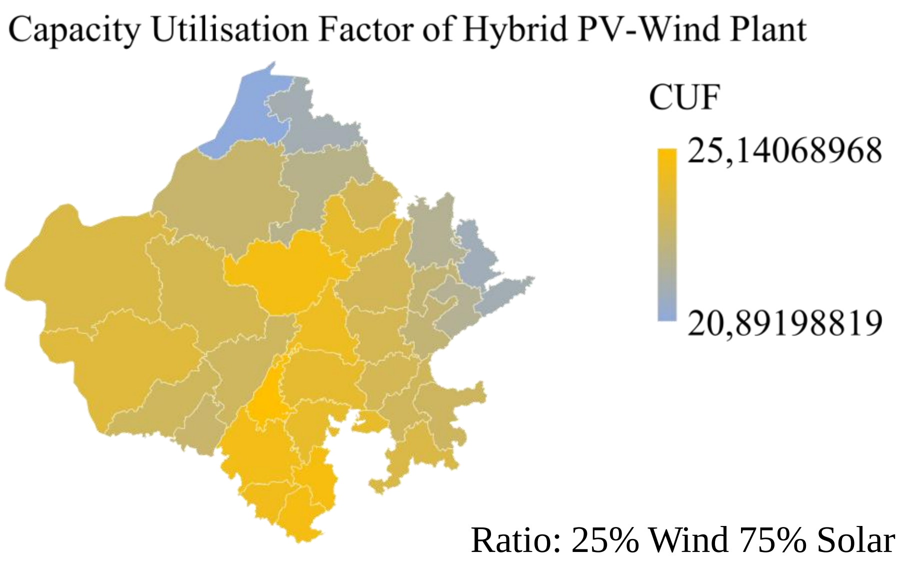
Sectoral coverage	Power sector
Time horizon	Long term: 22 year
Spatial resolution	AVVNL, JVVNL, JdVVNL
Analytical approach	Bottom-up

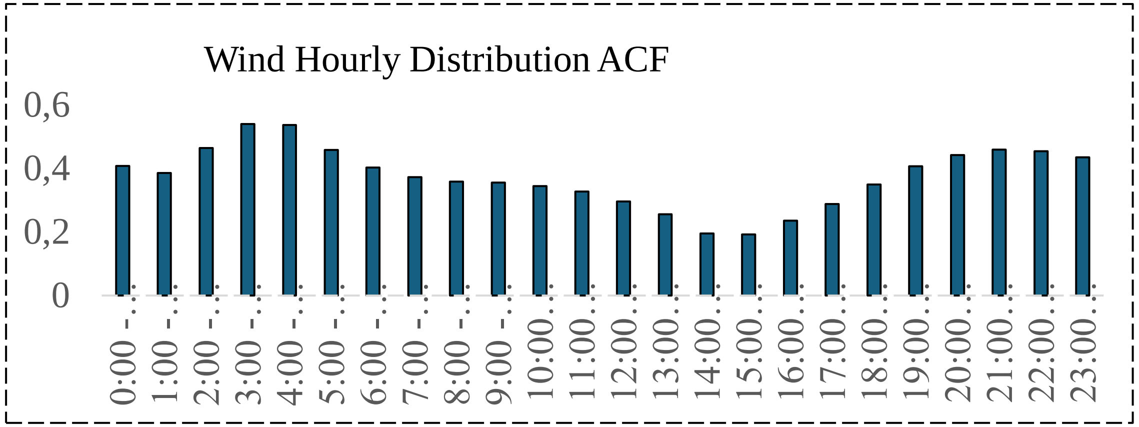


https://finance.rajasthan.gov.in/docs/budget/statebudget/2023-2024/economicreviewE.pdf

Case Study: “Hybrid Plant: Addressing Supply-Demand Balance”







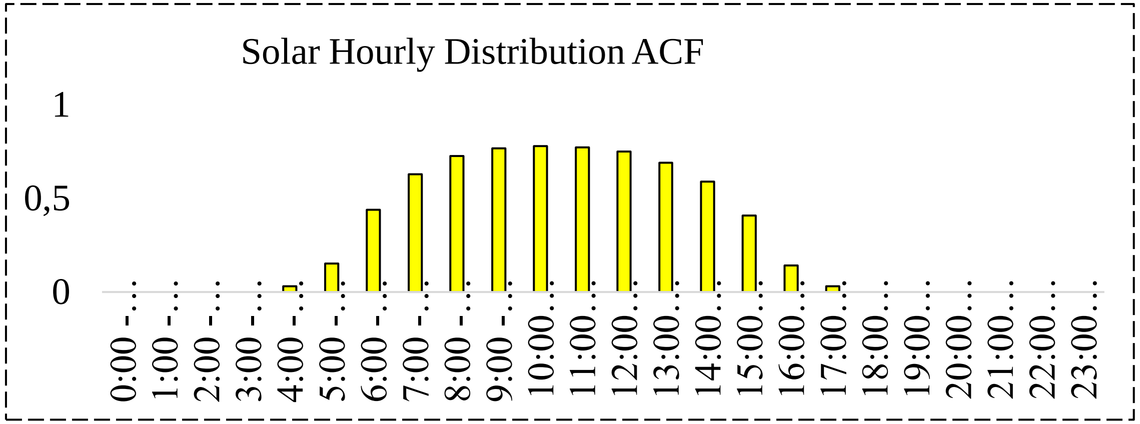


Fig. 12: Capacity Utilisation Factor of Hybrid PV-Wind Plant

Case Study: “Hybrid Plant: Addressing Supply-Demand Balance”

	No Hybridisation	Hybridisation	
Technologies	Reference Case	Case 1	Case 2
Storage (GW)	124	116	52
Solar genration share	54.60%	46.15%	41.44%
Wind genration share	4.40%	3.57%	3.59%
Hybrid generaton Share	-	9.02%	19.62%
Coal share	29.40%	35%	26.30%

Table : Comparison of storage demand in different scenarios

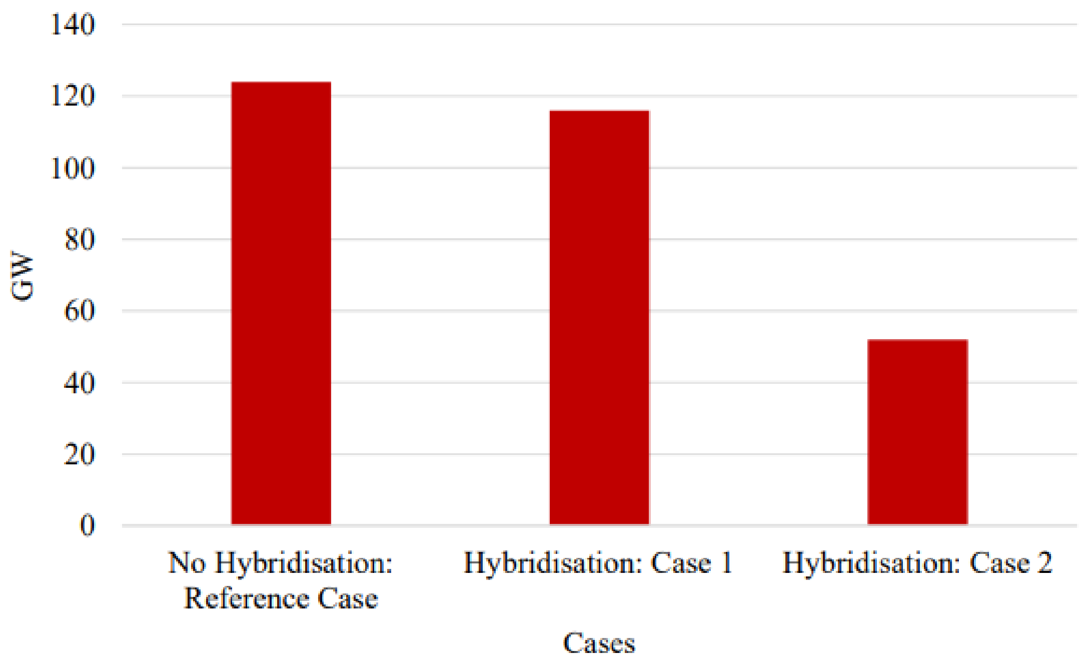


Fig. 13: Storage Requirement

Benefits

- Smoothen out variability of output generation
- Reduce the cost of transmission infrastructure
- Reduce the land requirement

Conclusion

- Support utilities to predict and manage peak demand periods accurately
- Optimizes cost of expansion projects by optimizing existing infrastructure
- Helps utilities identify efficient & cost-effective locations for energy storage systems
- Potential capacity shortage
- Transmission infrastructure upgradation areas
- This study highlights possible solutions implemented globally that effectively address these challenges, including supply-demand balancing considerations in India's highly RE-integrated systems.

THANK YOU

POWER MANAGEMENT RESEARCH

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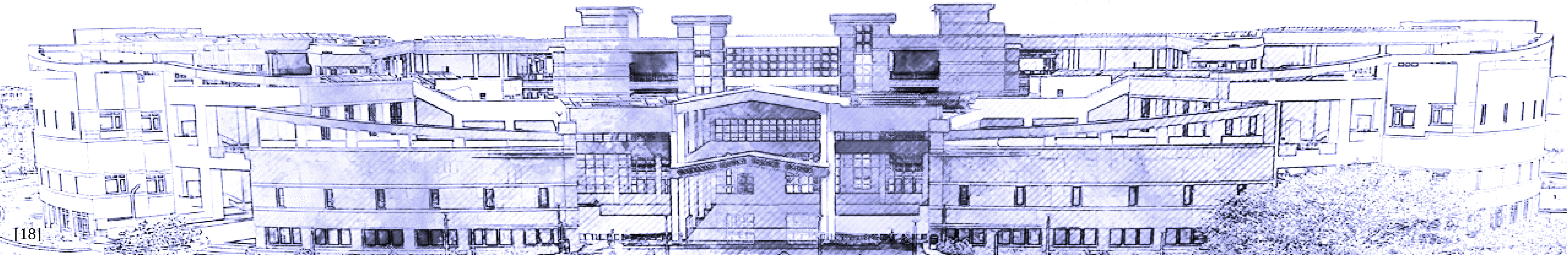

Details of under construction Hybrid Renewable Energy Projects (SECI)							
S.No.	Name of the project	Name of the Developer	project location (Village/District/State)	Project Capacity Awarded (MW)	Project Capacity Commissioned (MW)	Under Construction Capacity (MW)	Date of completion Scheduled
1	1200 MW ISTS-Connected Wind- Solar Hybrid Power Projects (Tranche-I)	SBE Renewables Ten Private Limited	Jaisalmer,Barmer,Rajasthan	450	0	450	29.09.2022 or actual date of LTA, whichever is later
2	1200MW ISTS-connected Wind Power Projects (Tranche-III)	AMP Energy Green Private Limited	Neemba village, fatehgarh, Jaisalmer Rajasthan	130	0	130	Actual date of LTA operationalization
3	1200MW ISTS-connected Wind Power Projects (Tranche-III)	Adani Hybrid Energy Jaisalmer Five Limited	Jaisalmer, Rajasthan	600	0	600	44980
4	1200MW ISTS-connected Wind Power Projects (Tranche-III)	ABC Renewable Energy Private Limited	Nuthimadugu, Anantapur Dt. A.P and Chodiya Village, Jaisalmer, Rajasthan	380	0	380	Actual date of LTA operationalization
5	400MW ISTS-connected Round-the-clock (RTC) RE Power (RTC-1)	Renew Surya Roshni Private Limited	400MW Rajasthan+300MW Maharashtra+300MW Koppal Karnataka+300MW Gadag,Karnataka	400	0	400	45144
6	1200 MW ISTS-Connected RE Projects with assured Peak Power Supply in India (ISTS-VII	Greenko AP01 IREP Private Limited	Kurnool, Andhra Pradesh	900	0	900	02.08.2023 (690 MW); 27.11.2023 (210 MW)
7	1200 MW ISTS-Connected RE Projects with assured Peak Power Supply in India (ISTS-VII	Renew Surya Ojas Private Limited	Karnataka	300	0	300	45351
8	1200MW ISTS-connected Wind Power Projects (Tranche-IV)	M/s NTPC Renewable Energy Limited	Dayapar, Kutch, Gujarat	450	0	450	45290
9	1200MW ISTS-connected Wind Power Projects (Tranche-IV)	Project Ten Renewables Power Pvt limited	Pavagada, Karnataka	450	0	450	45290
10	1200MW ISTS-connected Wind Power Projects (Tranche-IV)	Kotuma Wind Parks Pvt Ltd	Karnataka, Rajasthan	150	0	150	45290

https://cea.nic.in/wp-content/uploads/rpm/2022/10/Under_Construction_Report_31.10.22.pdf