CLEAN ENERGY SOLUTIONS CENTER
ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY
An Initiative of the Clean Energy Ministerial

21st CENTURY POWER PARTNERSHIP
AN INITIATIVE OF THE CLEAN ENERGY MINISTERIAL

Resource Adequacy and Flexibility: Keeping the Lights On

May 24, 2023

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Webinar & Speaker Introductions

Moderated by Dr. Doug Arent, National Renewable Energy Laboratory

May 24th, 2023

Agenda

- Overview of the Clean Energy Solutions Center
- Overview of the 21st Century Power Partnership
- Resource Adequacy in Decarbonizing Power Systems
- Ensuring Flexibility in Conventional Power Plants to Integrate Renewables
- Q&A

Webinar Speakers

Doug Arent

Executive Director of Strategic Public-Private Partnerships, **National Renewable Energy Laboratory**

Robert Horner

International Relations Specialist, **U.S. Department of Energy**

Jeff Logan

Chief Analyst, **National Renewable Energy Laboratory**

Gord Stephen

Grid Systems Research Engineer, **National Renewable Energy Laboratory**

Priyam Jain

Manager, **Grid Controller of India Ltd. (GRID-INDIA)**

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Overview of the Clean Energy Solutions Center

Presented by Robert Horner, U.S. Department of Energy

May 24th, 2023

The Clean Energy Solutions Center

OBJECTIVE

To accelerate the transition of clean energy markets and technologies.

RATIONALE

Many developing governments lack capacity to design and adopt policies and programs that support the deployment of clean energy technologies.

AMBITION/TARGET

Support governments in developing nations of the world in strengthening clean energy policies and finance measures

ACTORS

Leads:

Operating Agent:

NREL Transforming ENERGY

Partners:

More than 40 partners, including UN-Energy, IRENA, IEA, IPEEC, REEEP, REN21, SE4All, IADB, ADB, AfDB, and other workstreams etc.

ACTIONS

- **Deliver** dynamic services that enable *expert assistance, learning, and peer-to-peer sharing of experiences. Services are offered at no-cost to users.*
- **Foster** dialogue on emerging policy issues and innovation across the globe.
- **Serve** as a first-stop clearinghouse of clean energy policy resources, including policy best practices, data, and analysis tools.

UPDATES

Website:
www.cleanenergyministerial.org/initiatives-campaigns/clean-energy-solutions-center

Factsheet:
www.nrel.gov/docs/fy22osti/83658.pdf

Requests: Now accepting Ask an Expert requests!

The Clean Energy Solutions Center

Ask an Expert Service

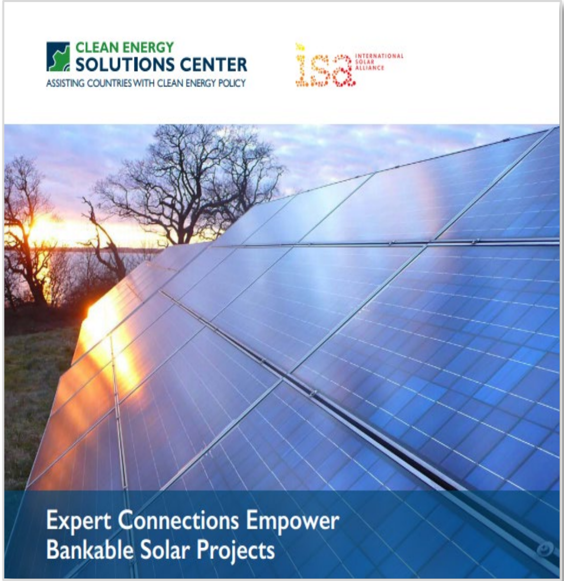
- Ask an Expert is designed to help policymakers in developing countries and emerging economies identify and implement ***clean energy policy*** and finance solutions.
- The Ask an Expert service features a network of more than **50** experts from over **15** countries.
- Responded to **300+** requests submitted by **90+** governments and regional organizations from developing nations since inception

Training and Capacity Building

- Delivered over **300** webinars training more than **20,000** public & private sector stakeholders.

Resource Library

- Over **1,500** curated reports, policy briefs, journal articles, etc.



For additional information and questions, reach out to Jal Desai, NREL, jal.desai@nrel.gov

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Overview of the 21st Century Power Partnership

Presented by Jeff Logan, National Renewable Energy Laboratory

May 24th, 2023

21CPP Objectives: Power System Transformation

Accelerating the transition to clean, efficient, reliable, and cost-effective power systems.

Evolving Generation Portfolios

Increasing Electrification of End-Uses

Smart Grid, Energy Efficiency & Demand Response

Cross Cutting Issues: Operations, Transmission, Distributed Generation, Market Design

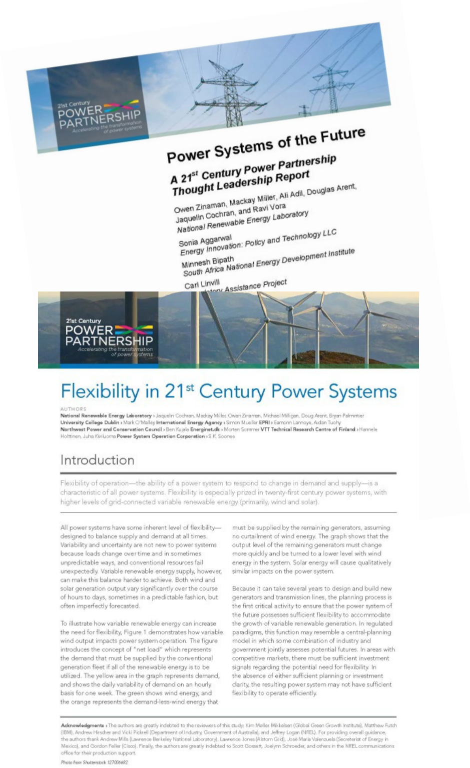
Coordinated Policies and Regulations for Planning, Building, and Operating Power Systems

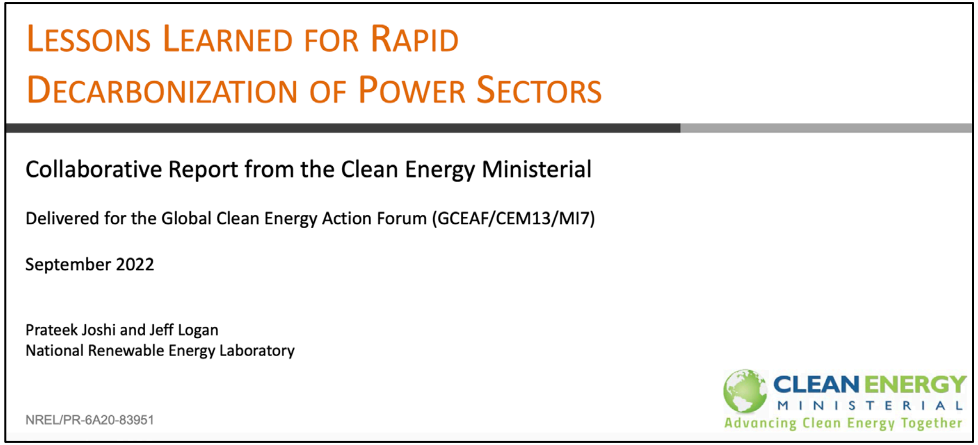
21CPP: Key Activities

Annual Program of Work Includes:

- "Thought-Leadership" studies that focus on generic power system transformation topics across the world
- In-country technical assistance, often as part of a larger development assistance effort, focused on *Coordinated Power System Planning & Operations, including technology innovation, policy, and regulation*
  - High-resolution grid integration studies often highlight this work.
- Information exchange, capacity building, fellowship programs, and other exercises to share lessons-learned and knowledge transfer.

Leading Practices





LESSONS LEARNED FOR RAPID DECARBONIZATION OF POWER SECTORS

Collaborative Report from the Clean Energy Ministerial

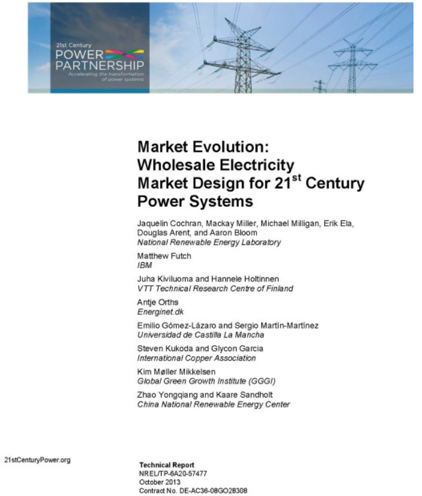
Delivered for the Global Clean Energy Action Forum (GCEAF/CEM13/MI7)

September 2022

Prateek Joshi and Jeff Logan
National Renewable Energy Laboratory

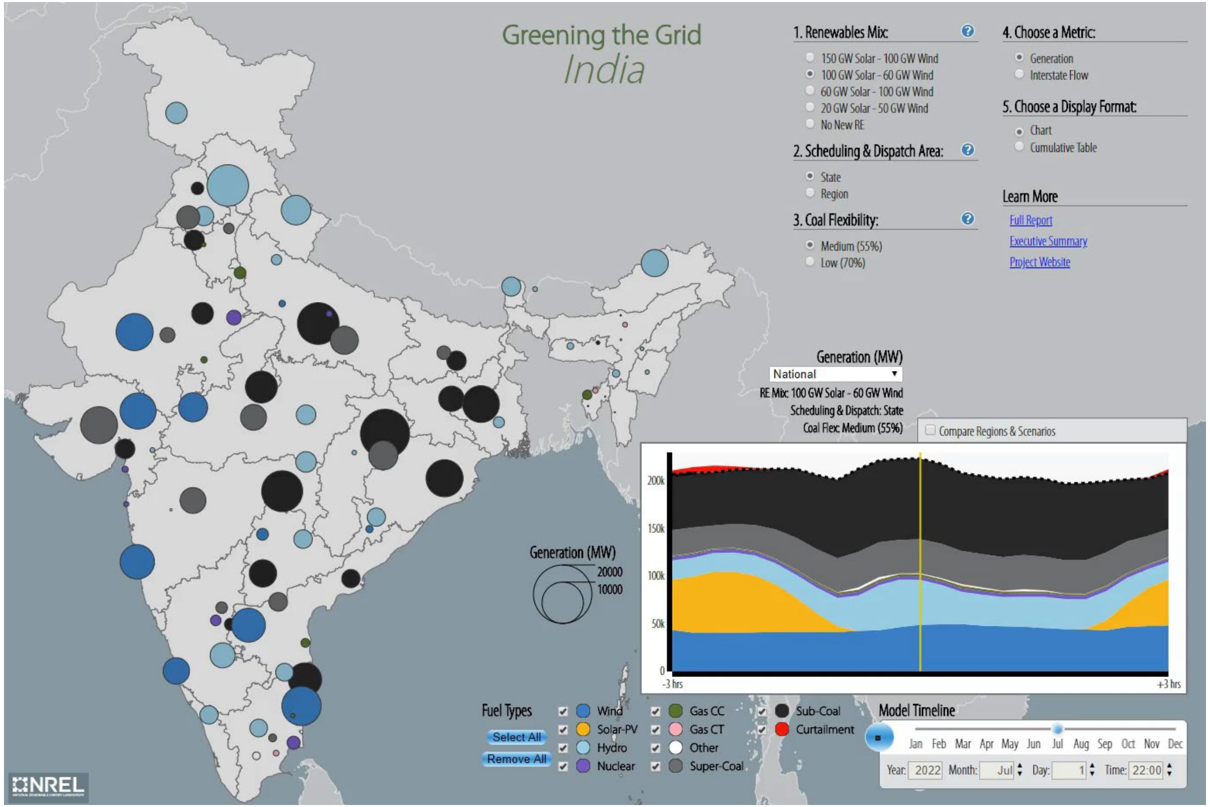
NREL/PR-6A20-83951

CLEAN ENERGY MINISTERIAL
Advancing Clean Energy Together



India Grid Integration Study

http://www.nrel.gov/india-grid-integration



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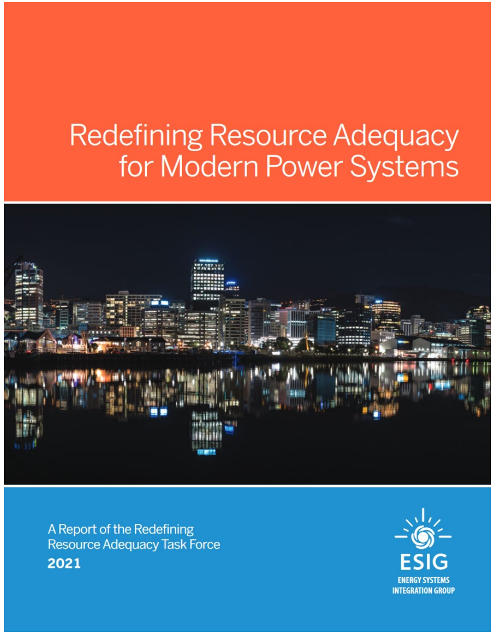
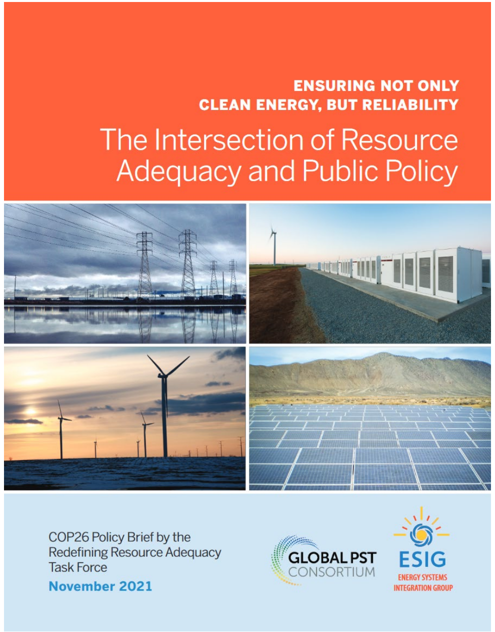
Resource Adequacy in Decarbonizing Power Systems

Presented by Gord Stephen, National Renewable Energy Laboratory (NREL)

May 24th, 2023

Today's content based on…





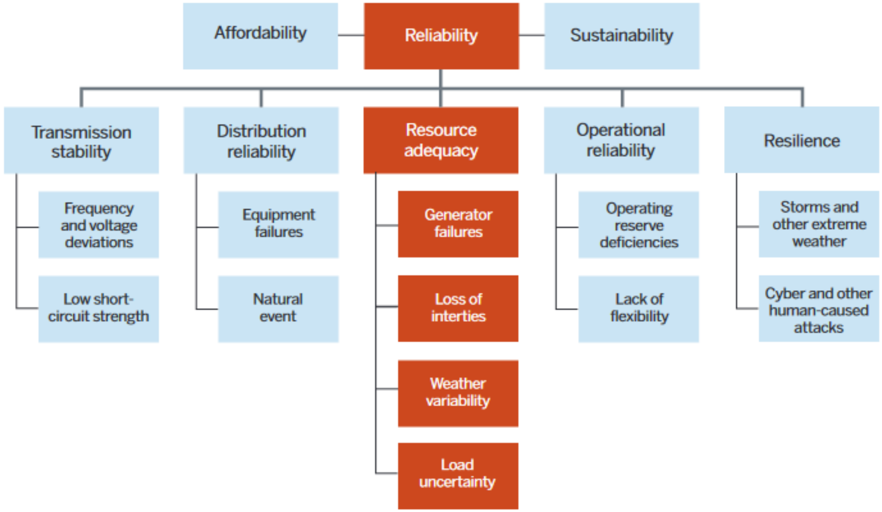
https://www.esig.energy/resource-adequacy-for-modern-power-systems/

What is resource adequacy?

"Resource adequacy (RA) studies assess whether a power system has an appropriate set of resources to maintain continuous service to demand, with a desired level of certainty"

Resource Adequacy for a Decarbonized Future: A Summary of Existing and Proposed Resource Adequacy Metrics, EPRI, April 2022

- RA is just one aspect of grid reliability and overall grid performance

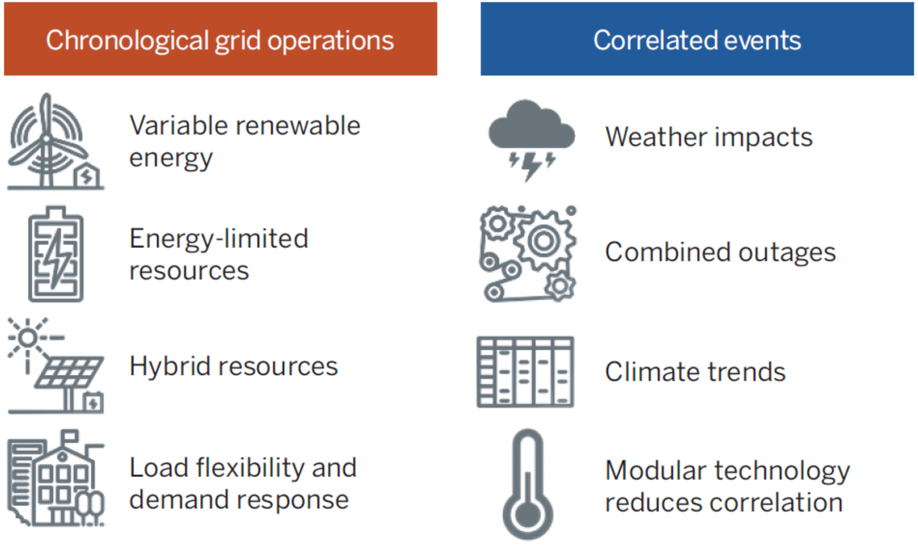


Source: Energy Systems Integration Group.

Why modernize resource adequacy analysis?

- Historical adequacy assessment focused on independent mechanical outages of thermal generating units

- Resource interactions and risk drivers in modern power systems can look dramatically different



Source: Energy Systems Integration Group.

Six Principles for Resource Adequacy Analysis

Principle 1
Quantifying size, frequency, duration, and timing of capacity shortfalls is critical to finding the right resource solutions.

Principle 2
Chronological operations must be modeled across many weather years.

Principle 3
There is no such thing as perfect capacity.

Principle 4
Load participation fundamentally changes the resource adequacy construct.

Principle 5
Neighboring grids and transmission should be modeled as capacity resources.

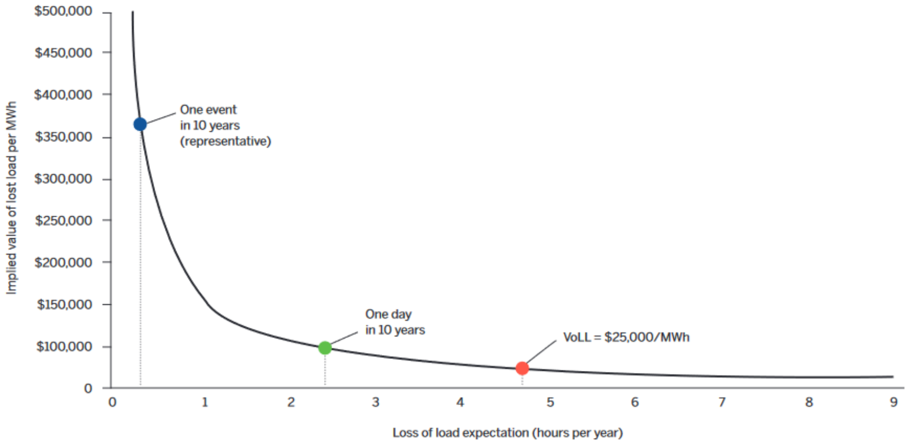
Principle 6
Reliability criteria should be transparent and economic.

Principle 6: How much adequacy do we need?

- Both technical and economic factors need to be considered when defining an “acceptable” adequacy level
- Electricity shortfalls are undesirable, but so are high system costs
- Need to find the balance that is appropriate for the specific system context

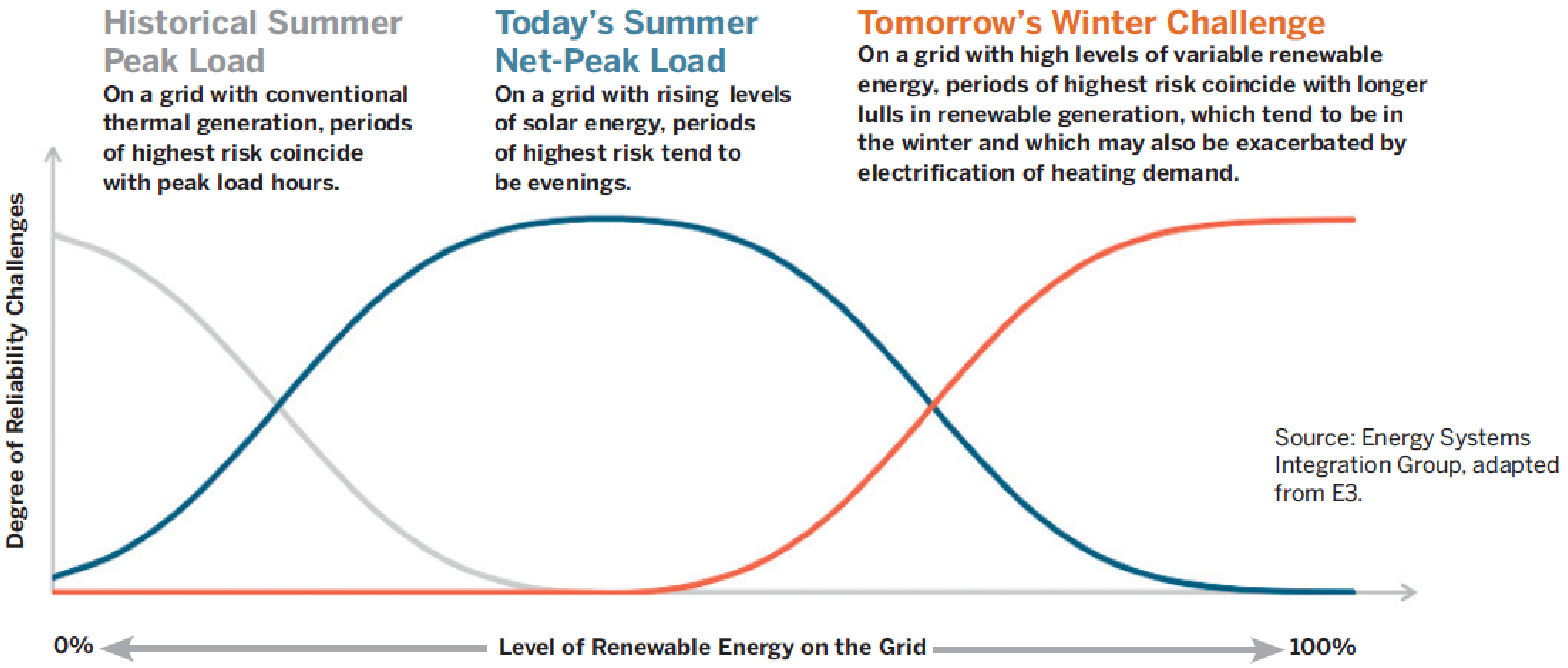
Benefit of reliability

Cost of reliability

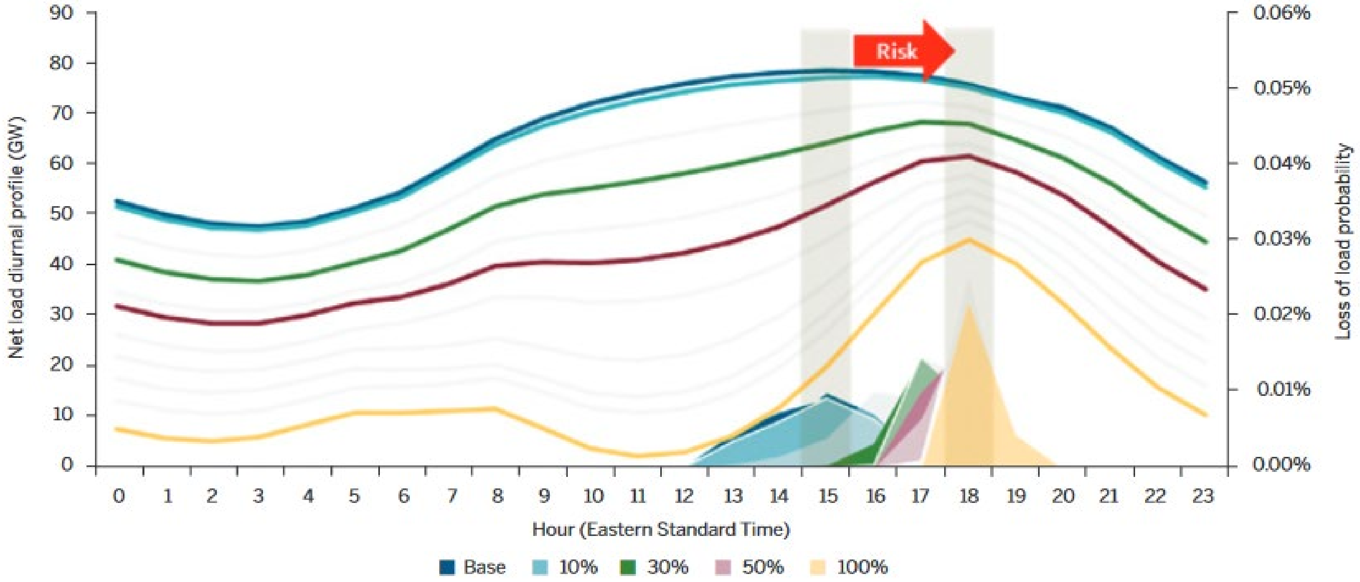


Source: Regulatory Assistance Project / Hogan and Littell (2020).

Principle 2: Study chronology and multiple weather years



Principle 1: Identify specific risk characteristics

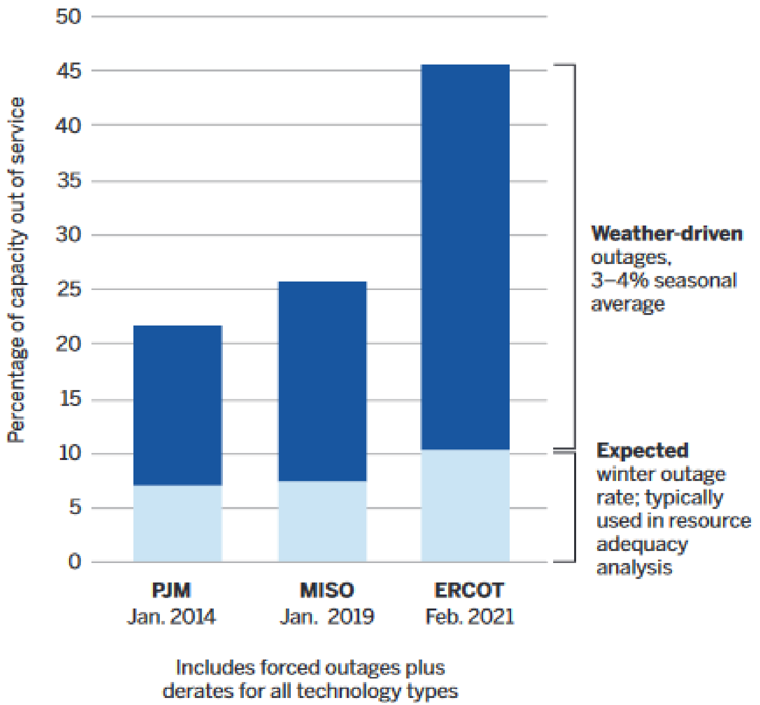


Source: Midcontinent Independent System Operator (2021).

Principle 3: No perfect capacity

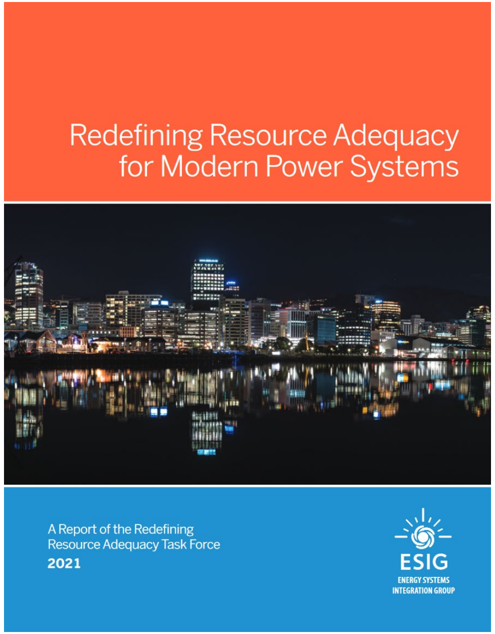
- All generating resources, including thermal generation, face unavailability risks

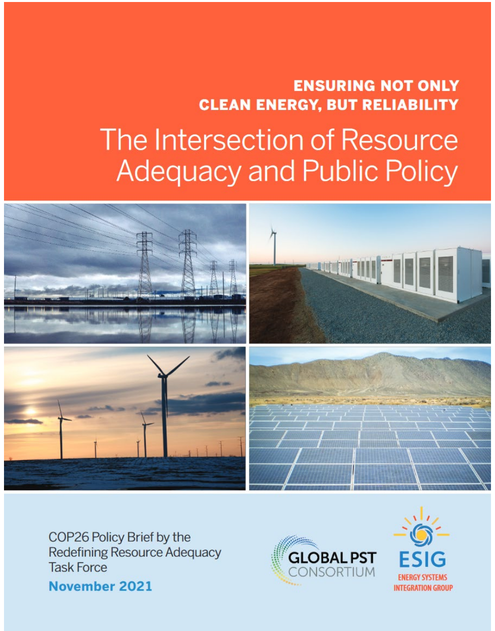
- Need to better capture this risk (including timing, outage correlation, and common-mode failures) when considering system adequacy and comparing potential adequacy investments



Source: Energy Systems Integration Group.

Full reports, executive summaries and fact sheets

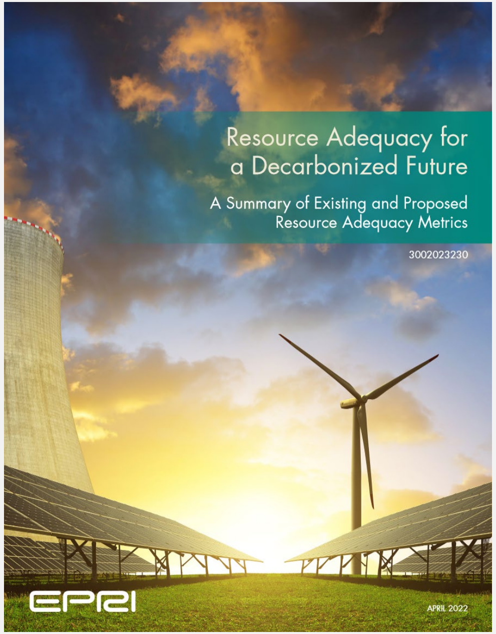




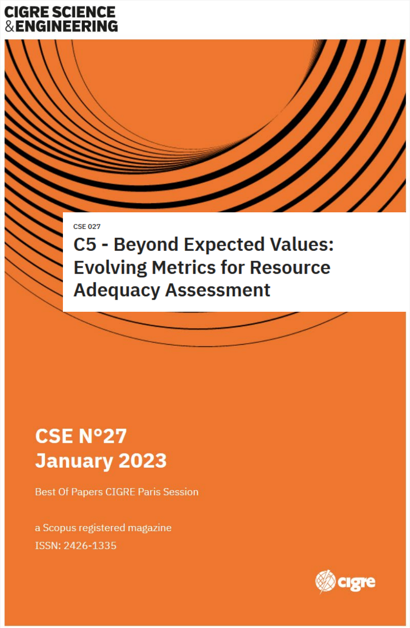
https://www.esig.energy/resource-adequacy-for-modern-power-systems/

Further resources

Adequacy Risk Metrics

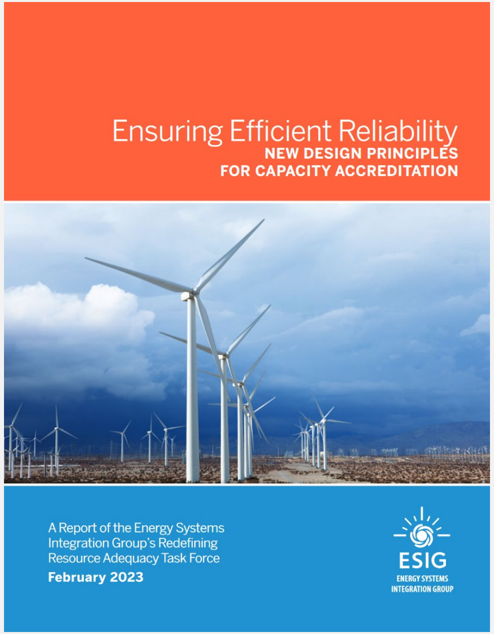


https://www.epri.com/research/products/000000003002023230



https://cse.cigre.org/cse-n027/c5-beyond-expected-values-evolving-metrics-for-resource-adequacy-assessment

Capacity Accreditation



https://www.esig.energy/new-design-principles-for-capacity-accreditation/

Further resources

Metric	Abbreviation	Units	Definition
Loss-of-load expectation	LOLE	Time periods/year*	Average number of event-periods per year* across all of the random samples simulated. The LOLE metric can be applied to any time period length, and must be clearly defined by the user.
Loss-of-load hours	LOLH	Hours/year*	Average event-hours per year* across all of the random samples simulated.
Loss-of-load days	LOLD	Days/year*	Average event-days per year* across all of the random samples simulated.
Loss-of-load years	LOLY	Years/study horizon	Average event-years per study horizon across all of the random samples simulated.
Loss-of-Load probability	LOLP	%	Calculated as the total number of event-periods divided by the total number of time periods sampled. The LOLP metric can be applied to any time period length and study horizon, and must be clearly defined by the user.
Loss-of-load events	LOLEv	Events/year*	Average count of events per year* across all of the random samples simulated.
Expected unserved energy	EUE	MWh/year*	Average load not served per year* due to shortfall events across all of the random samples simulated.
Normalized expected unserved energy	nEUE	%	Average load not served per year* due to shortfall events across all of the random samples simulated, calculated as a percentage of system load.

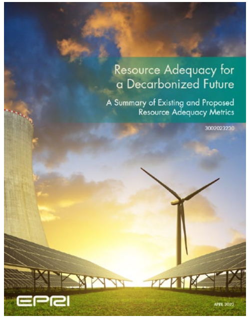
Method	Type	Computational Burden	Data Requirements
Effective Load Carrying Capability	Probabilistic	+++	+++
Equivalent Firm Capacity	Probabilistic	+++	+++
Equivalent Conventional Power	Probabilistic	+++	+++
Installed Capacity	Approximation	+	+
Unforced Capacity	Approximation	+	+
Generation Over Peak Load	Approximation	+	++
Generation Over Net Peak Road	Approximation	+	++
Generation Over Peak LOLP Hours	Approximation	++	++

+ = low, ++ = medium, +++ = high

Country or Region	RA Metrics/Criteria	Entity Calculating RA Metric
North America [20,21]		
MISO	LOLE ≤ 0.1 days/year	MISO
MRO-Manitoba Hydro	LOLE ≤ 0.1 days/year	Manitoba Public Utilities Board
NPCC-Maritimes	LOLE ≤ 0.1 days/year	Maritimes Sub-areas and NPCC
NPCC-New England	LOLE ≤ 0.1 days/year	ISO-NE and NPCC
NPCC-New York	LOLE ≤ 0.1 days/year	NYSRC and NPCC
NPCC-Ontario		
NPCC-Québec		
PJM Interconnection		
SERC-C		
SERC-E		
SERC-FP		
SERC-SE		
SPP		
TRE-ERCOT[3]		
WECC-AB		
WECC-BC		
WECC-WPP-US & RMRG [22]		
WECC-SRSG		
WECC-CAMX [23]		
Hawaii [24]		

Country or Region	RA Metrics/Criteria	Entity Calculating RA Metric
Europe [18,25]		
Belgium [26]	LOLH ≤ 3 hours/year LOLH95[5] ≤ 20 hours/year	Elia Group
France [27]	LOLH ≤ 3 hours/year	RTE
Great Britain [28]	LOLH ≤ 3 hours/year	National Grid ESO
Ireland and Northern Ireland [29]	LOLH ≤ 8 hours/year (Ireland) LOLH ≤ 4.9 hours/year (Northern Ireland)	EirGrid and SONI
Netherlands [30]	LOLH ≤ 4 hours/year	TenneT
Poland [31]	LOLH ≤ 3 hours/year	PSE
Portugal [27]	LOLH ≤ 5 hours/year	REN
Spain [27,32]	PRM ≥ 10% (Mainland) LOLI	REE
Oceania		
Australia-NEM [33]	NEU	
Australia-NT [34]	NEU	
Australia-WEM [35]	PRM NEU	
New Zealand [36,37]	WE WE WC	
Africa		
South Africa [38]	EUE OC Base < 5(	

Country or Region	RA Metrics/Criteria	Entity Calculating RA Metric
Asia		
India [39]	LOLP[9] ≤ 0.2% NEUE ≤ 0.05%	CEA
Indonesia [40]	PRM (2019–2028) ≥ 30% (National)	Ministry of Energy and Mineral Resources
Japan [41]	PRM (2020–2029) ≥ 8% per region	OCCTO
Laos [42]	PRM (2020–2030) ≥ 15%	Ministry of Energy and Mines
Malaysia [43]	LOLE ≤ 1 days/year	TNB
Philippines [44]	PRM (2017–2040) ≥ 25%	DOE
Singapore [45,46]	LOLH ≤ 3 hours/year	EMA
Thailand [47,48]	PRM (2015–2036) ≥ 15%	EGAT
Vietnam [49]	LOLH ≤ 12 hours/year per region	MOIT
Middle East		
Saudi Arabia [50]	PRM (2016) ≥ 8–10%	SEC
Oman [51]	LOLH ≤ 24 hours/year	OPWP
Qatar [52]	PRM (2019) ≥ 6%	KAHRAMAA



https://www.epri.com/research/products/000000003002023230

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Ensuring Flexibility in Conventional Power Plants to Integrate Renewables

Presented by Priyam Jain, Grid Controller of India Ltd.

May 24th, 2023

Outline

- Overview of Indian Power System
- Growing Need for Flexibility
- Flexibility Service Providers
- Role of Thermal Generators in providing requisite Flexibility
- Thermal Flexibilization – Key Initiatives
- Way Forward

Dimensions

~417 GW
generation capacity

220 GW+
peak demand

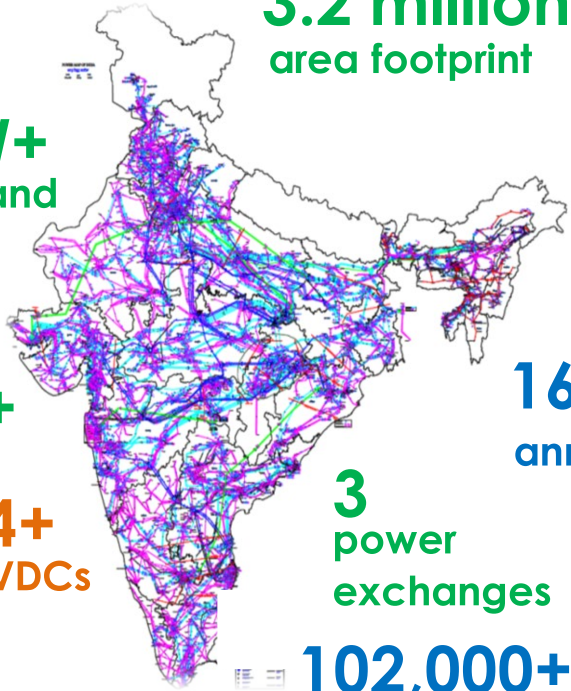
> 4.5 TWh
daily energy met

468977 ckm+
EHV transmission

~172 GW
renewables
(including large Hydro)

14+
HVDCs

~ 112 GW
inter-regional capacity



3.2 million km²
area footprint

1.4 Billion+
people served

4.5 GW+
international exchanges

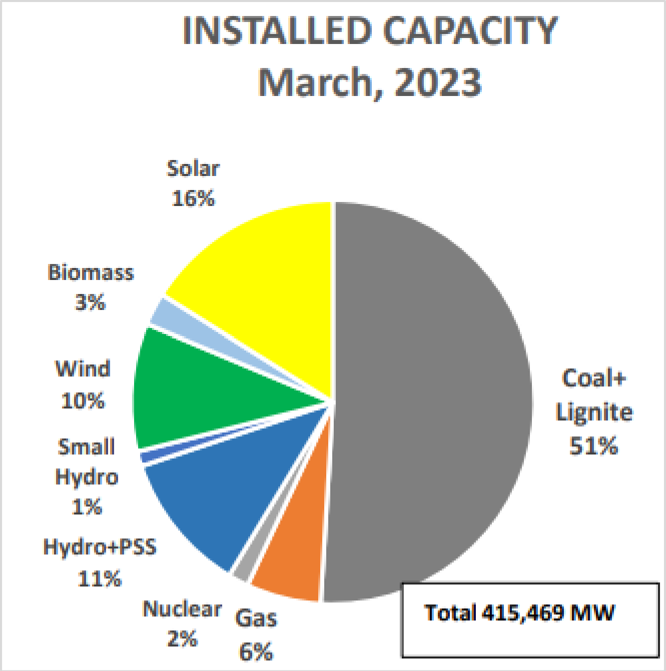
169 TWh+
annual market trades

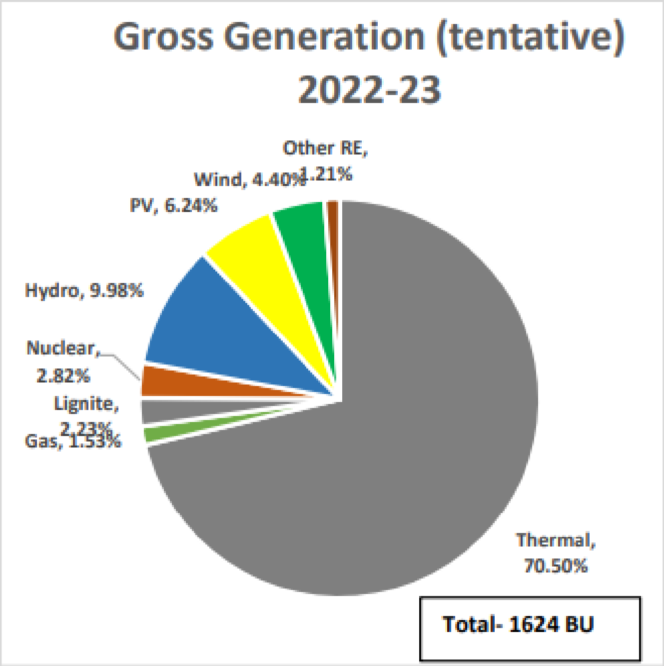
3
power exchanges

6000+
market participants

102,000+
market transactions

Indian Power System – Current Capacity and Generation Mix





BU = TWH

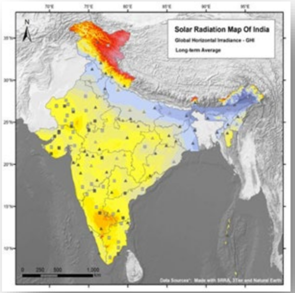
Source: CEA Report On Optimal Generation Capacity Mix for 2030 (Ver 2.0)
https://cea.nic.in/wp-content/uploads/notification/2023/05/Optimal_mix_report__2029_30_Version_2.0__For_Uploading.pdf

Clean Energy Transition in India

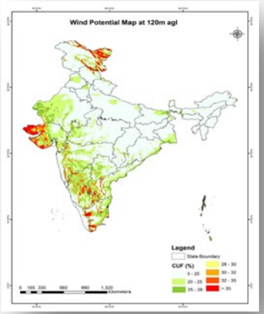
Present Total Installed Capacity ~417 GW
Present Renewable Installed Capacity ~ 172 GW
Present Solar + Wind Installed Capacity ~110 GW

Solar Potential ~ 750 GW, Wind Potential @ 120 mtr agl ~ 700 GW
Off-shore wind potential ~ 70 GW (coast of Gujarat & Tamil Nadu)

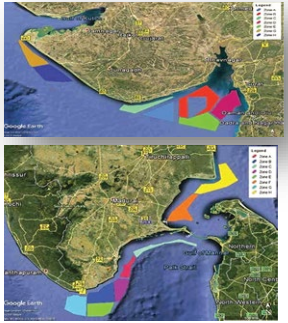
Solar Radiation Atlas



Wind Atlas



Offshore Wind

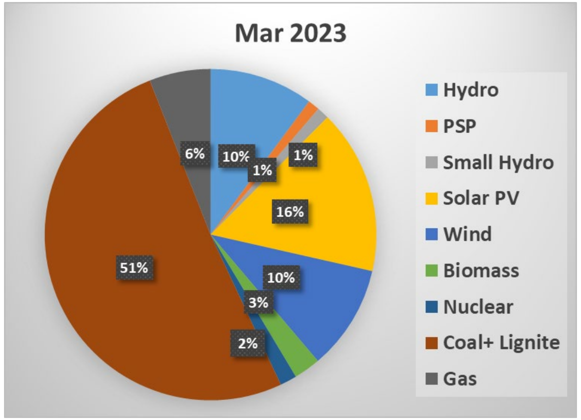


Region/State (FY 2022-23)	Annual VRE Penetration (Energy Terms)	Maximum Daily VRE* Penetration (Energy Terms)	Maximum Instantaneous VRE Penetration (Energy Terms)
Rajasthan	14.57	35.81	56.00
Northern Region	10.56	18.36	46.75
Gujarat	15.44	35.80	55.80
Madhya Pradesh	11.01	32.40	53.90
Maharashtra	10.10	23.00	37.21
Western Region	11.03	23.10	35.13
Karnataka	27.52	65.38	132.00
Andhra Pradesh	20.50	58.59	81.00
Tamil Nadu	18.42	50.08	77.00
Telangana	12.17	17.63	49.00
Southern Region	16.91	36.32	61.00
All India	11.01	20.40	31.80

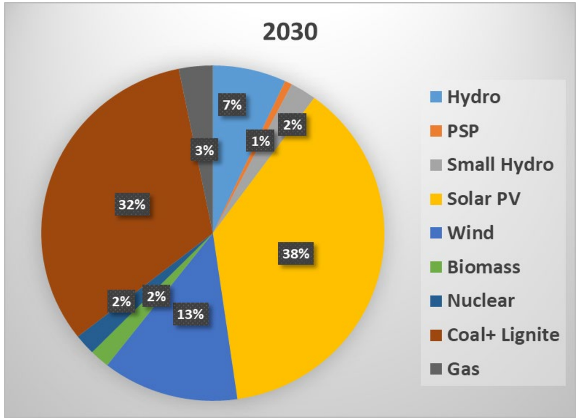
*VRE:Wind and Solar only

Clean Energy Transition: Roadmap

ALL INDIA INSTALLED CAPACITY (MW)			
Resource	**Mar 2023**	**Mar 2030**	**% Addition**
Hydro	42104	53860	28%
PSP	4746	5350	13%
Small Hydro	4944	18986	284%
Solar PV	66780	292566	338%
Wind	42633	99895	134%
Biomass	10802	14500	34%
Nuclear	6780	15480	128%
Coal+ Lignite	211855	251683	19%
Gas	24824	24824	0%
Total	**415469***	**777144****	87%
BESS	0	41650 (5-hr)	



Total I/C - ~415 GW

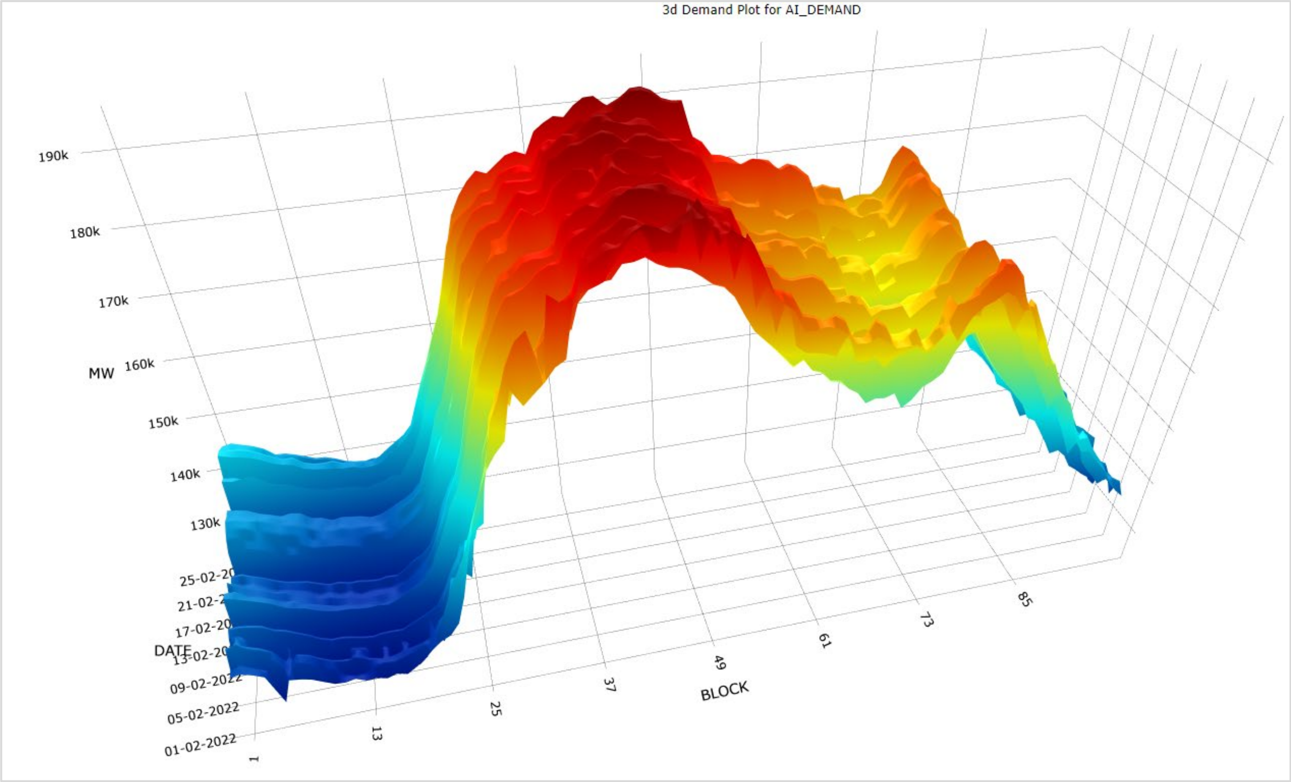


Total I/C - ~777 GW

*Excluding 2136 MW of Hydro imports from neighboring countries and 589 MW Diesel based capacity
**Excluding Hydro Imports of 5856 MW

Source: CEA Report On Optimal Generation Capacity Mix for 2030 (Ver 2.0)
https://cea.nic.in/wp-content/uploads/notification/2023/05/Optimal_mix_report__2029_30_Version_2.0__For_Uploading.pdf

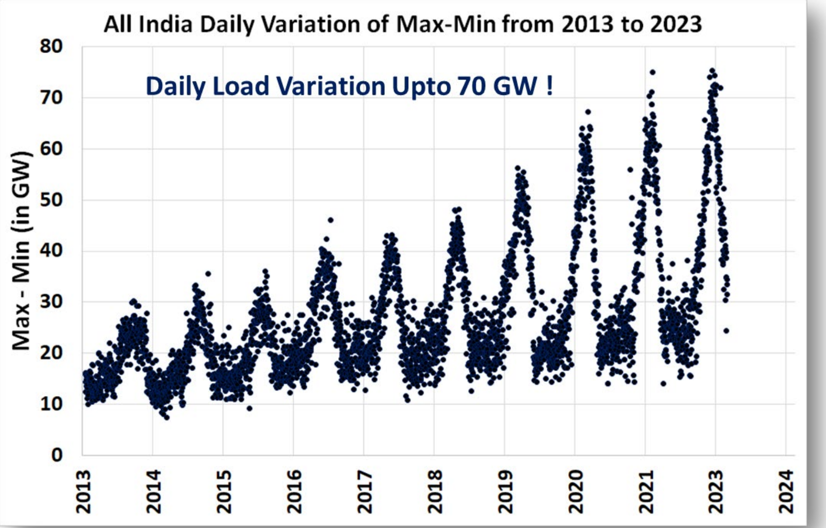
Growing Need for Flexibility – Increasing All India Demand Ramp

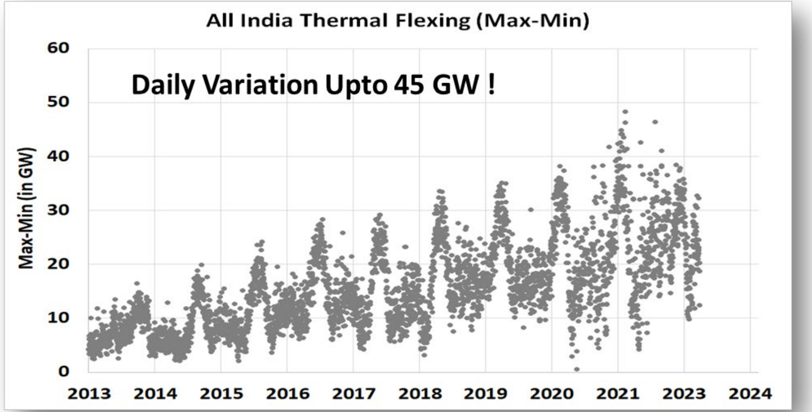


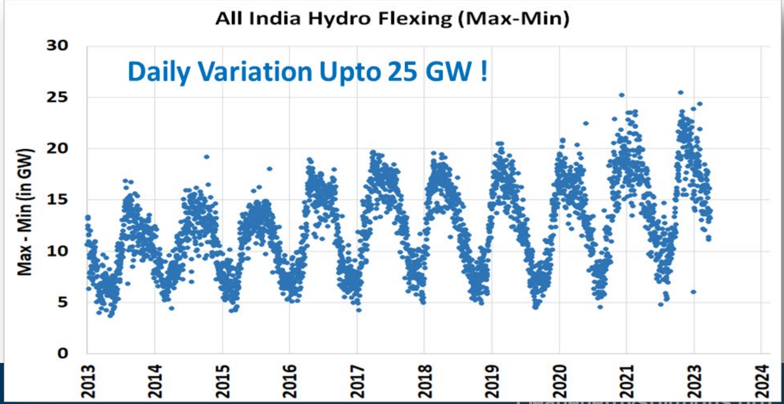
All India Demand

- Typical Ramp rate ~ 250 MW/min
- Special Days ~ 500 MW/min

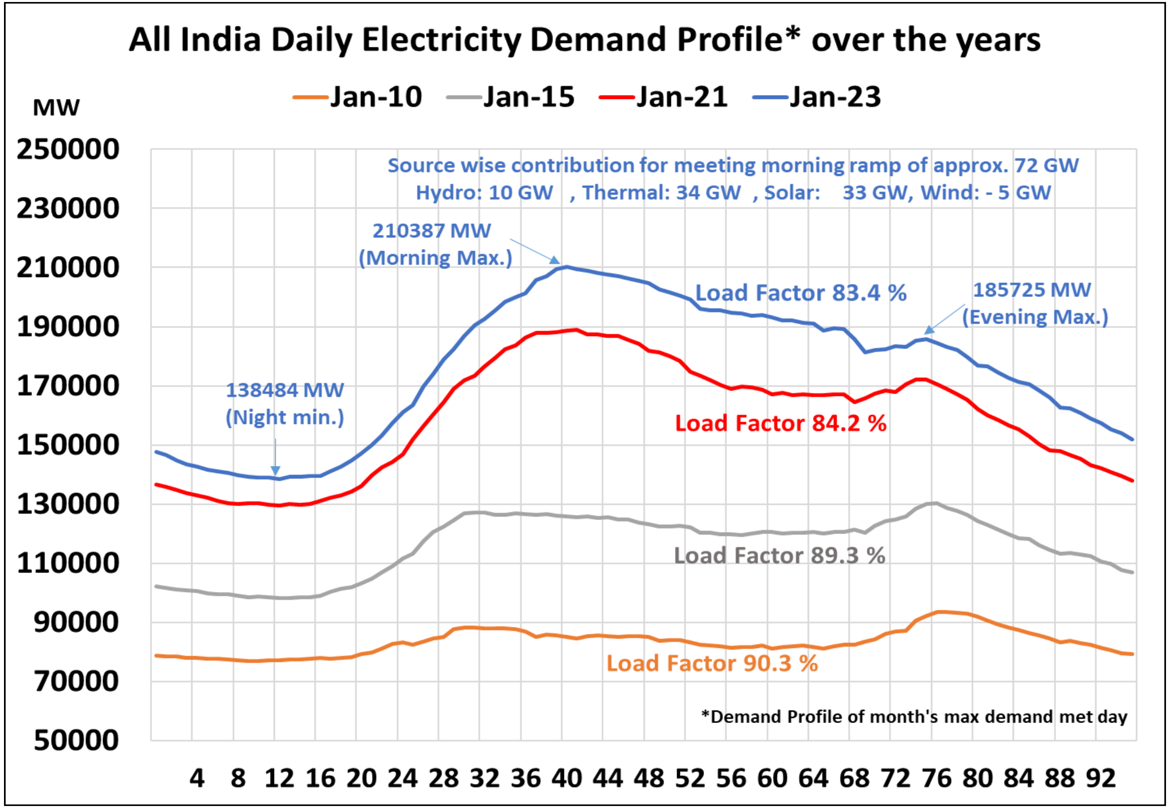
Growing Need for Flexibility – Increasing All India Demand Ramp





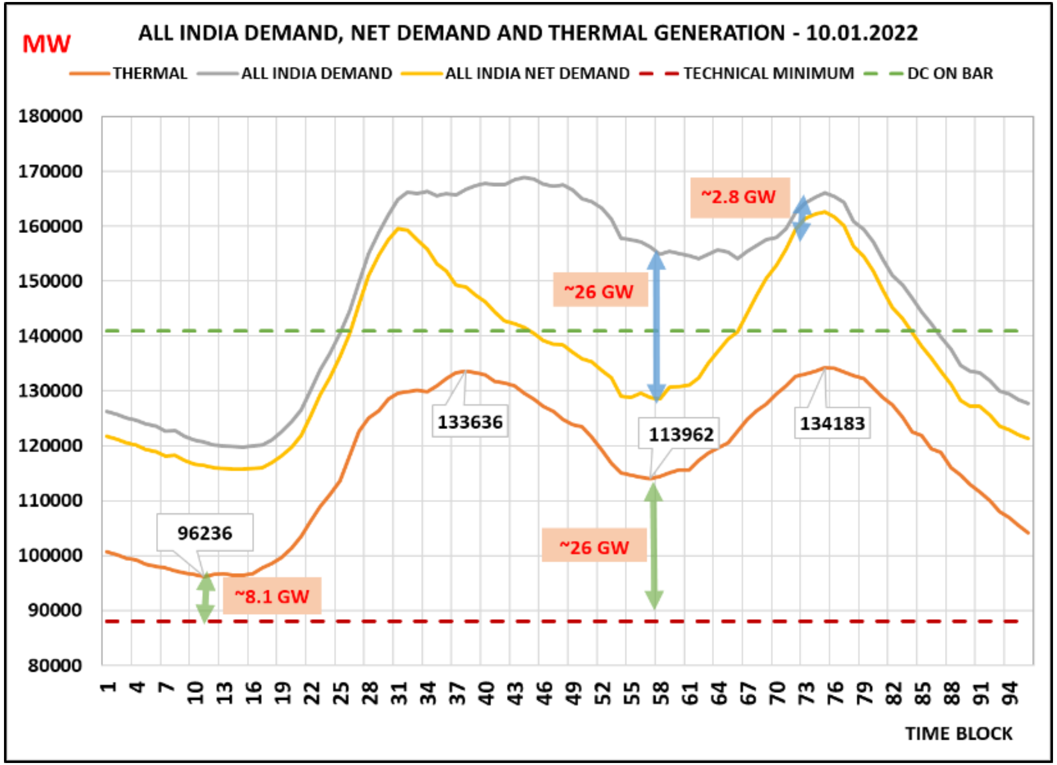


Growing Need for Flexibility – Change in Load Shape



Change in Load Shape Over the Years !!

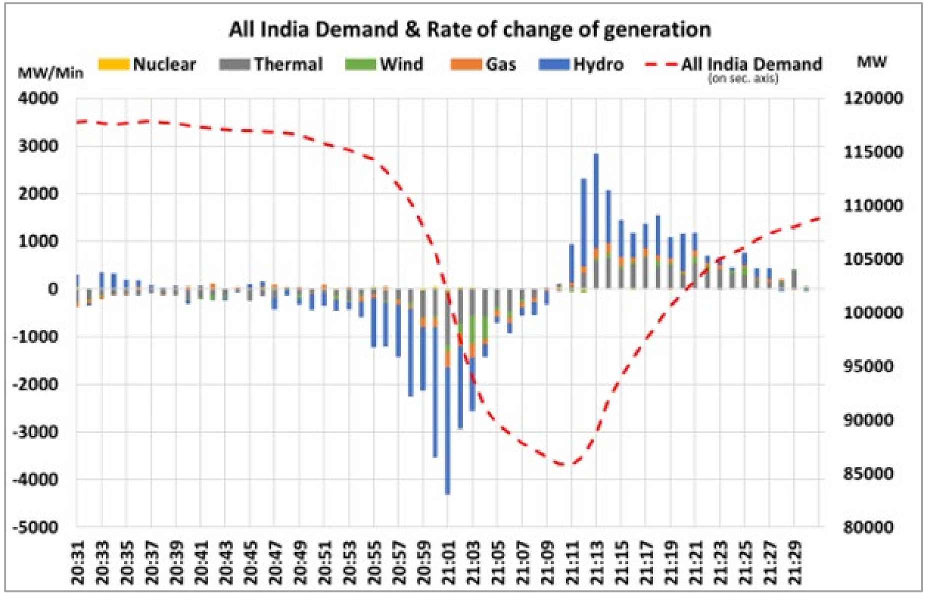
Growing Need for Flexibility – Increasing Duck Curve Belly



- Increasing "Duck Curve" Belly
- Issues in absorbing additional RE (solar) beyond a certain quantum

Growing Need for Flexibility – HILF Events

5th April 9PM9Min Event – Demand Reduction of ~31000 MW within 25 minutes

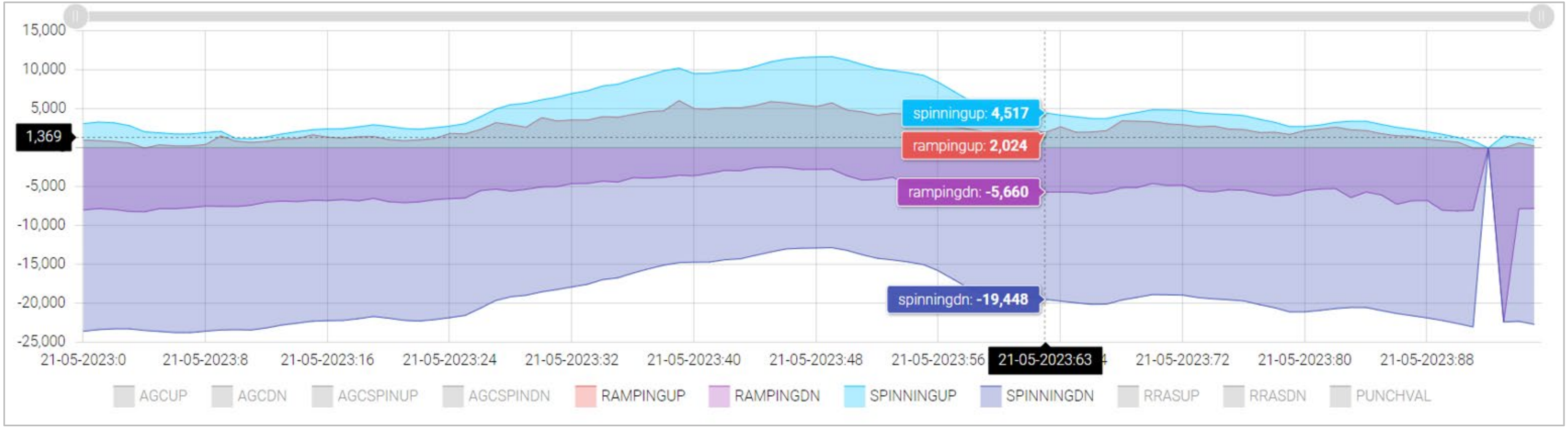


Type of Gen. / Demand	Generation/Demand (MW)			Delta A to B (MW)	Delta B to C (MW)	Max. Ramp (MW/Min) A to B
	20:45 hrs (A)	21:10 hrs (B)	21:30 hrs (C)			
Hydro	25559	8016	18923	17543	10907	2728
Thermal	75277	68037	75661	7240	7624	1109
Gas	7305	5355	7175	1950	1820	339
Wind	3564	1566	2527	1998	961	580
All India Demand	116887	85799	108808	31089	23009	4197

Flexibility provided primarily by Hydro and Thermal Generation

Growing Need for Flexibility – Availability of Reserves

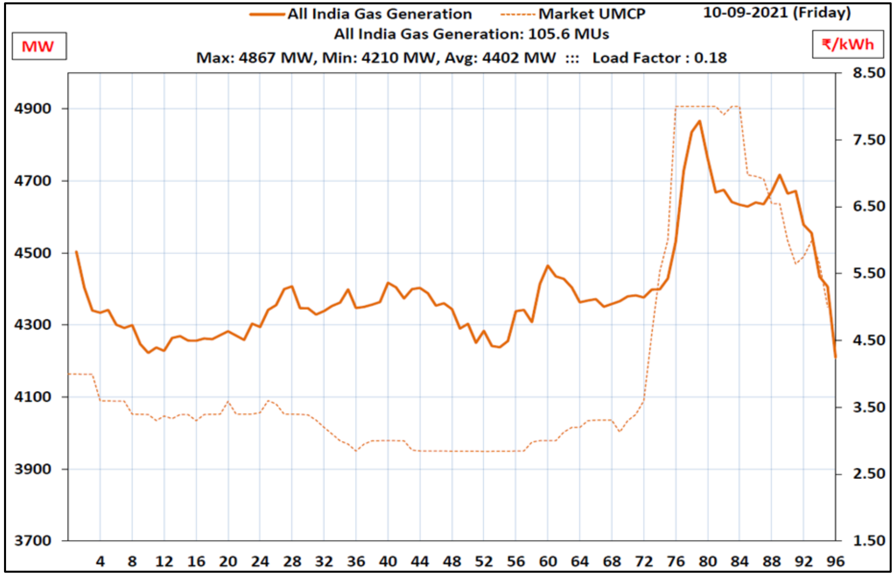
Availability of Ramp Limited Reserves

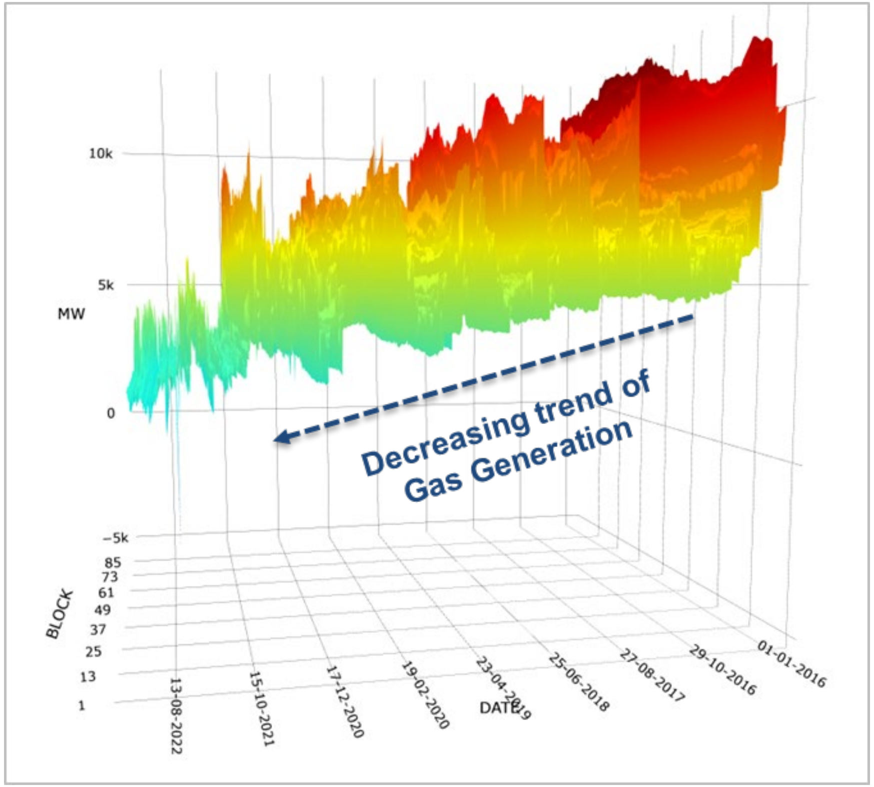


Source: Grid-India, RRAS Portal

Flexibility Providers – Gas Generation

All India Gas Generation

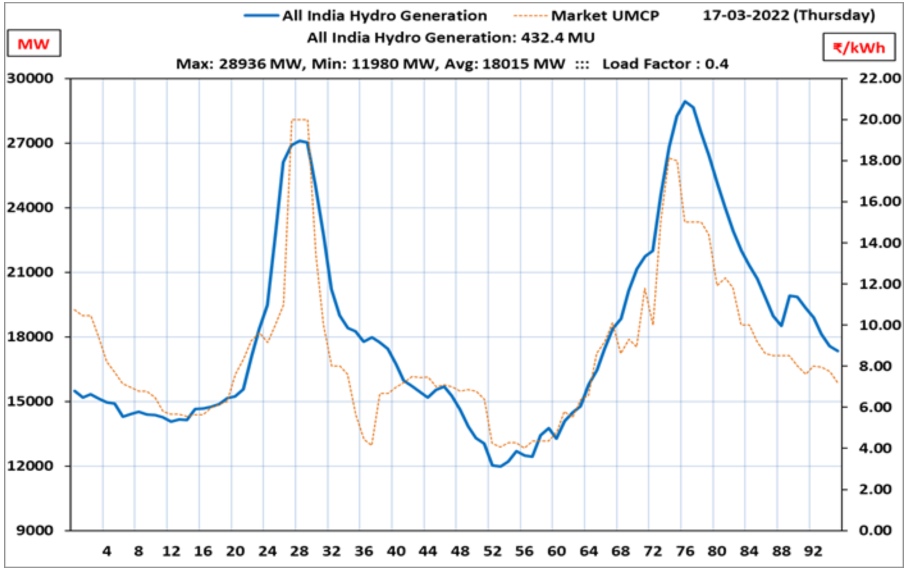




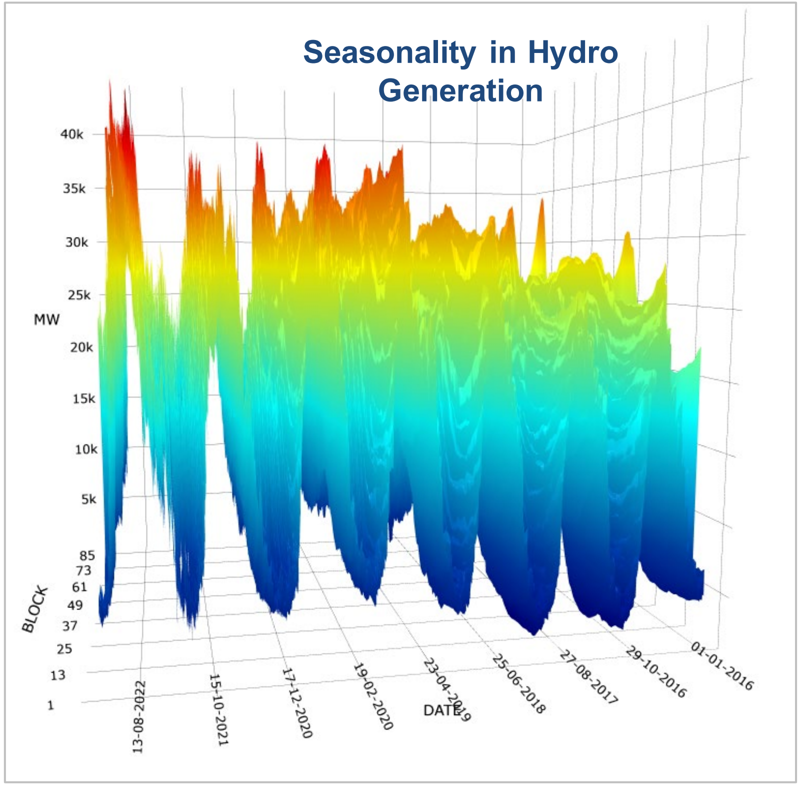
- Flexibility from Gas Generation constrained by availability of Gas !!

Flexibility Providers – Hydro Generation

Load Following / Peaking Support - Hydro

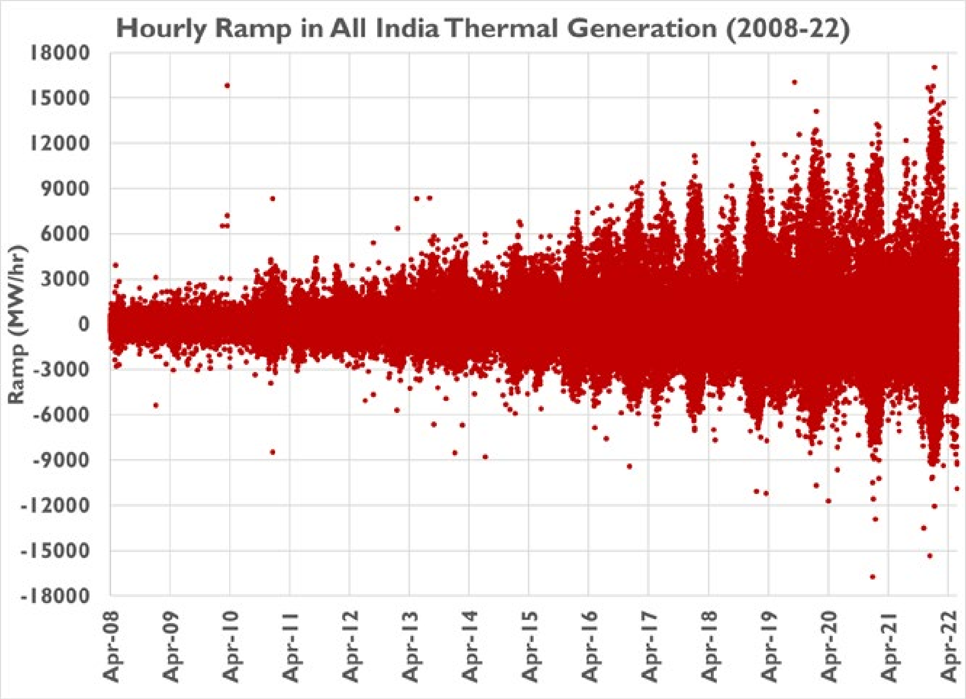


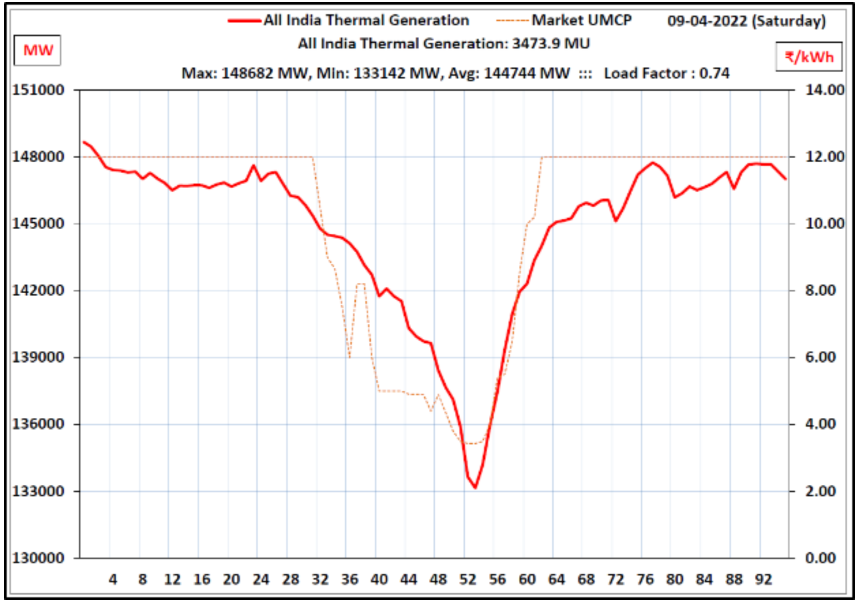
- Flexibility from Hydro Generation is highly seasonal !!



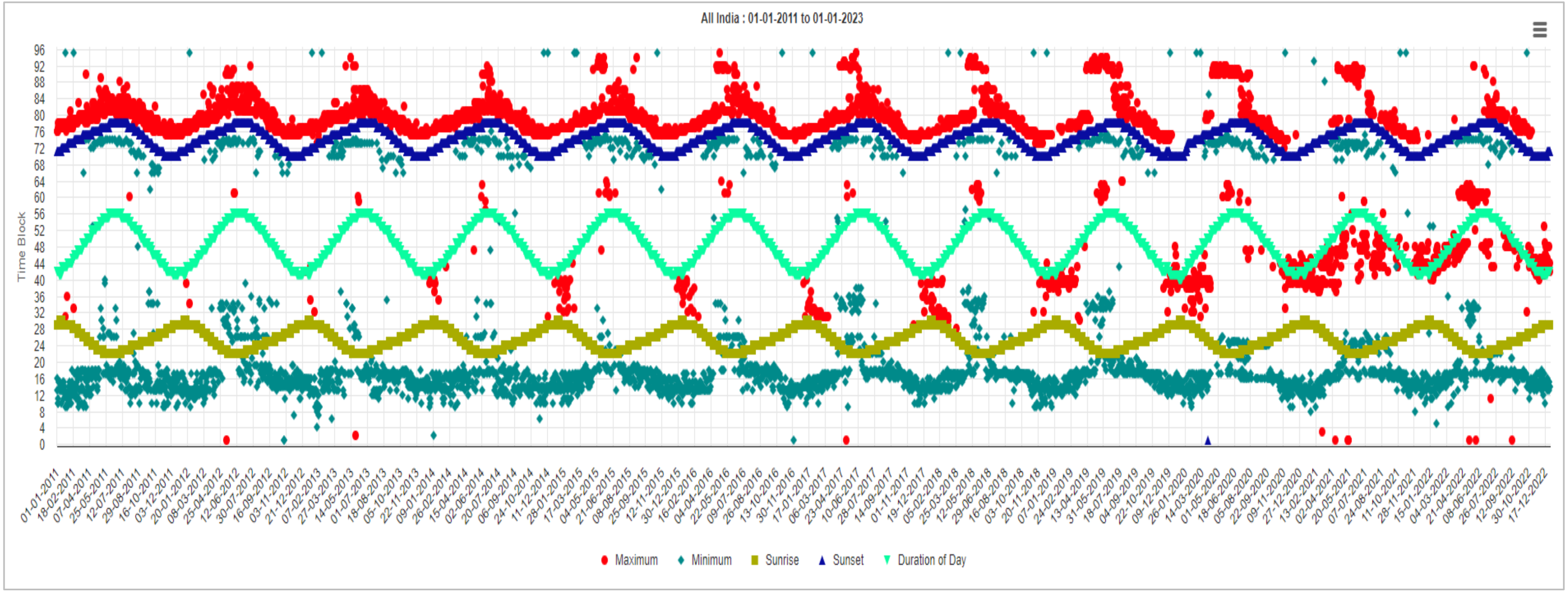
3D Plot – Hydro Generation (Jan 2016 – Jan 2023)

Flexibility Providers – Thermal Generation



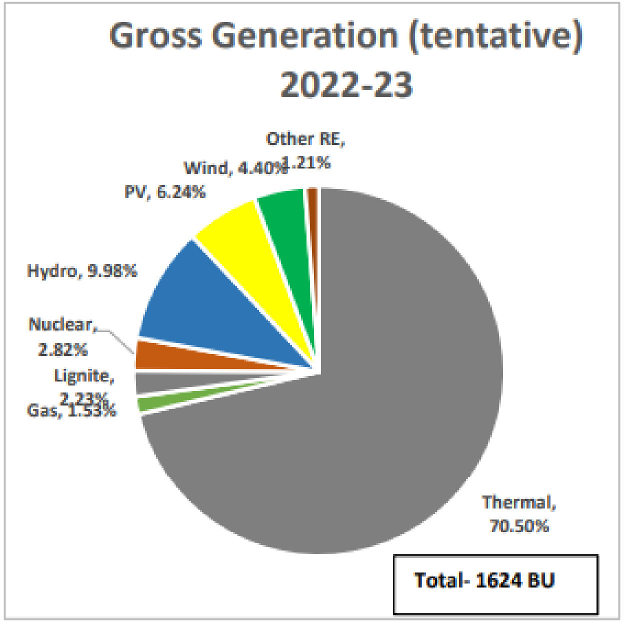


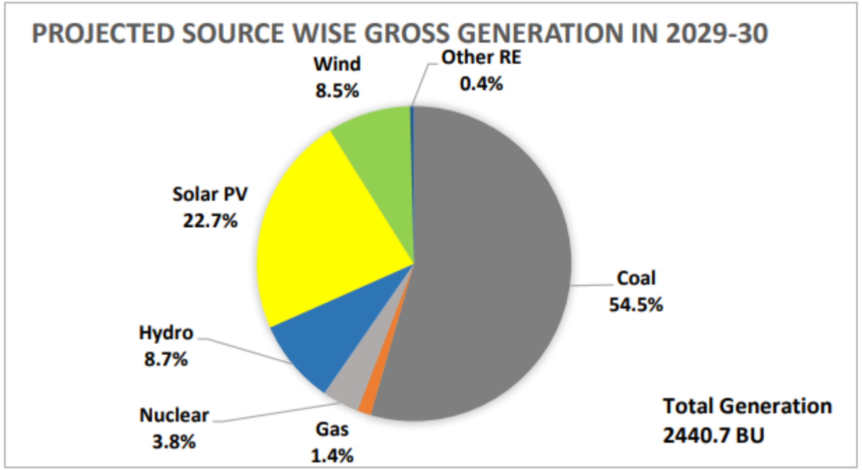
Harnessing Load Flexibility



Load shift to solar hours primarily due to catering of agricultural loads during this period

Role of Thermal Generation in providing Flexibility

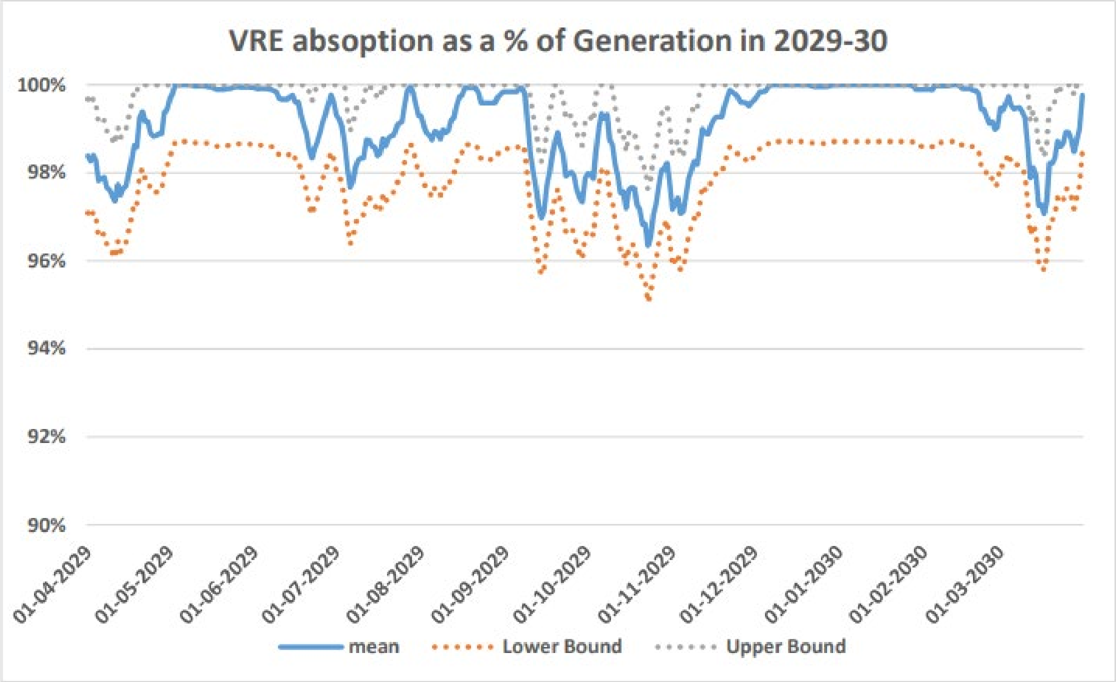




Thermal Generation to remain a major source of generation and therefore, of flexibility also in 2030 !!

Source: CEA Report On Optimal Generation Capacity Mix for 2030 (Ver 2.0)
https://cea.nic.in/wp-content/uploads/notification/2023/05/Optimal_mix_report__2029_30_Version_2.0__For_Uploading.pdf

Role of Flexible Thermal Generation in facilitating RE Integration



Optimal Generation Capacity Mix Studies for 2030 (Ver 2.0)

- During high RE period, RE absorption is likely to decrease to as low as **95%** on some days during 2029-30
- Minimum power level constraint of thermal generators (55% in studies) one of the major reasons for the same
- Additional BESS to absorb this power not found to be economical
- ~0.78% RE curtailment in 2029-30 with Min power level of 55%
- Decreases to 0.25% at 40% Min Power level

Source: CEA Report On Optimal Generation Capacity Mix for 2030 (Ver 2.0)
https://cea.nic.in/wp-content/uploads/notification/2023/05/Optimal_mix_report__2029_30_Version_2.0__For_Uploading.pdf

Thermal Flexibilization – Regulatory Initiatives

- CERC Grid Code – 4th Amendment, Regulations 2016
  - ❑ Reduction of conventional thermal generation to the 55% levels

  Following incentivization for operation of thermal plants at Lower Operational Levels also introduced

  - ❑ Compensation for the Increase in Heat Rate Degradation
  - ❑ Compensation for Auxiliary Energy Consumption Degradation
  - ❑ Start-up fuel cost over and above seven (7) start / stop in a year

- CERC (Terms and Conditions of Tariff) Regulations, 2019
  - ❑ Incentivized generators to provide ramping capability beyond the threshold of 1%

- Central Electricity Authority (Technical Standard for Construction of Electrical Plant and Electrical Lines), 2022

Thermal Flexibilization – Policy Initiatives

- Central Electricity Authority (Flexible Operation of Coal based Thermal Power Generating Units) Regulations, 2023
  - ❑ Specify **Minimum Power Level of 40%** for Thermal Generating Units
  - ❑ Requires thermal generators to be **capable of providing 1%–3% ramp rate**

*"The coal based thermal power generating units shall have flexible operation capability with **minimum power level of forty percent**.*

*Provided that the generating units which are not capable of achieving minimum power level of **fifty-five percent, shall achieve the same within one year of the notification of these regulations.***

Provided further that the generating units which are not capable of achieving minimum power level of forty percent, shall achieve the same as per phasing plan mentioned in the sub-regulation (2) of regulation 5 of these regulations."

*7(1) "..The coal based thermal power generating units shall have ramp rate capability of **minimum three percent per minute for their operation between seventy percent to hundred percent of maximum continuous power rating** and **shall have ramp rate capability of minimum two percent per minute for their operation between fifty-five percent to seventy percent of maximum continuous power rating.***

*Provided that the generating units which are not capable to comply with this regulation, shall comply with the same **within one year** of the notification of these regulations…"*

*7(2) "…The coal based thermal power generating units shall achieve ramp rate capability of **minimum one percent per minute for their operation between forty percent to fifty-five percent of maximum continuous power rating** as per phasing plan mentioned in the sub-regulation (2) of regulation 5 of these regulations.."*

Thermal Flexibilization – Policy Initiatives

- Central Electricity Authority – Phasing Plan (draft) for Implementation of 40% Technical Minimum Level, May 2023

- ❑ Pilot Phase (May 2023 - Dec 2023)
- ❑ 1st Phase (July 2024 - Jun 2026)
- ❑ 2nd Phase (July 2026 – Jun 2028)
- ❑ 3rd Phase (July 2028 – Dec 2029)
- ❑ 4th Phase (Jan 2030 - Dec 2030)

- 11 units of central/state/pvt. sector to be considered in Pilot Phase
- Units commissioned between Jan 2016 and Dec 2022 in 1st Phase
- Units commissioned between Jan 2011 and Dec 2015 in 2nd Phase
- Unit commissioned between Jan 2001 and Dec 2010 in 3rd Phase
- Remaining units commissioned up to Dec 2000 in 4th Phase

Draft Phasing Plan for achieving 40% Technical Minimum Load (TML)

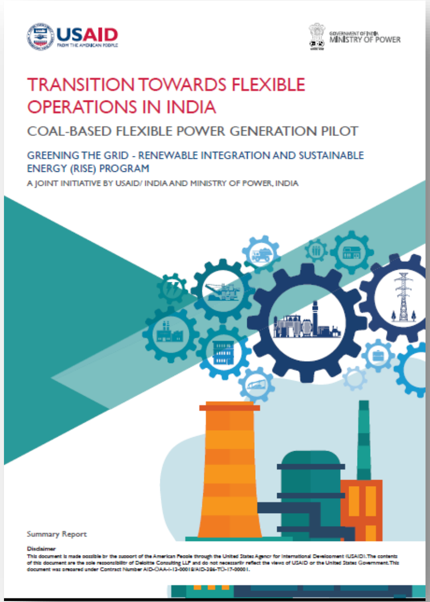
The inconsistency and intermittency of solar & wind power has to be managed by flexible power from other sources in order to ensure security, reliability and stability of electricity grids. Coal-fired power plants are capable to provide comparatively cheaper flexible power in the grid. Thus, flexible operation of coal fired unit is essential for handling the instability of renewable generation by tuning of control system or few retrofitting.

The flexibilisation of coal fired units shall have to be done in phased manner looking at 597 units of 213.55 GW capacity to be refurbished. The preliminary phasing has been worked out in the **CEA report "Flexibilisation of coal fired power plant - A road map for achieving 40% technical minimum load" published in Feb 2023.** Wherein, it was proposed to be accomplished in four phases based on the date of commissioning of the units. Before first phase there is a *pilot phase* which shall be an experience gaining phase, in which few thermal units from central/state/pvt utilities shall be considered for refurbishment. The subsequent phases shall have to be fine-tuned considering the above mentioned aspects. The comprehensive phasing plan has been prepared considering various factors as mentioned below:

Source: https://cea.nic.in/wp-content/uploads/news_live/2023/05/Draft_phasing_plan_merged_letter.pdf

Recent Pilot Initiatives

- USAID-GTG-RISE Pilot on Coal based Flexible Generation in Gujarat
  - Two (2) units of Gujarat State Electricity Corporation Limited (GSECL) Ukai thermal power station (Unit # 4, 200 MW and Unit #6, 500 MW).
  - Unit Flexibility Assessment Tests were conducted in March, 2020 to study the response pattern of the units for:
    - Different load ramping rates [at 1%/minute and 3%/minute]
    - Low load operation [test was conducted at 40% Technical Minimum)

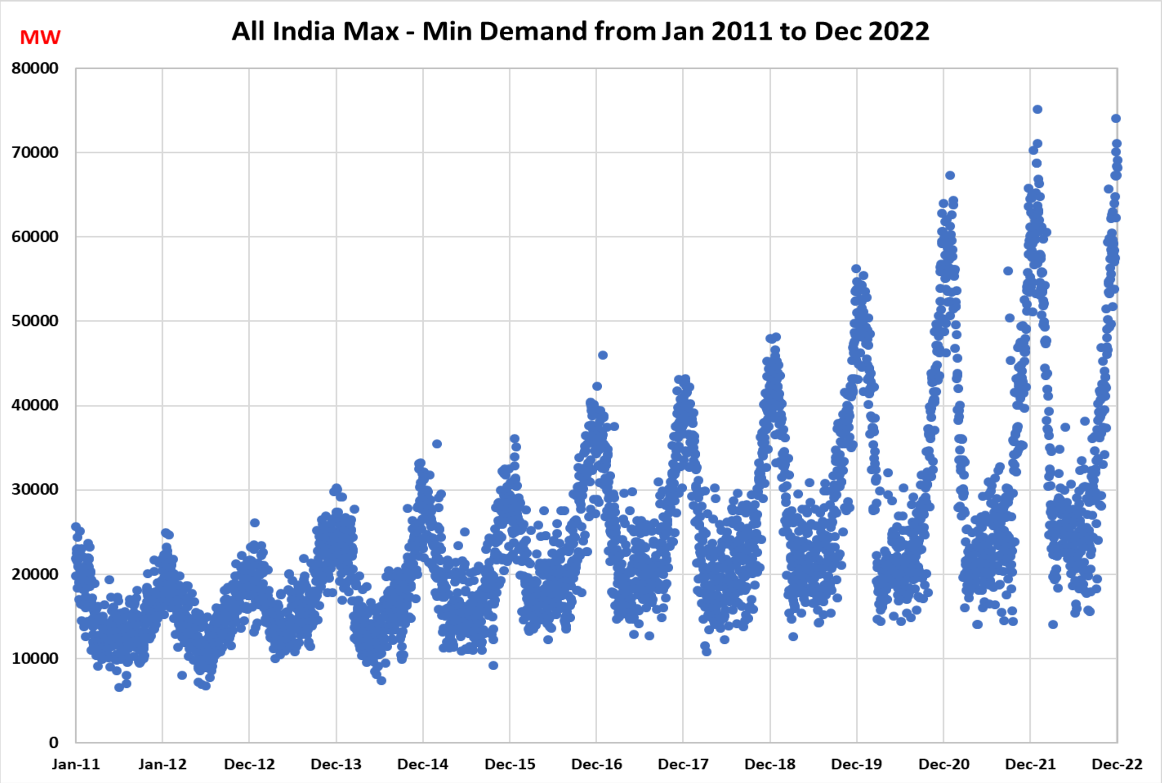


https://www.gtg-india.com/wp-content/uploads/2020/10/USAID-GTG-RISE-Pilot-on-Coal-based-Flexible-Generation_Summary-Report-Revised.pdf

Way Forward

- Selection and Incentivization of thermal stations and units for flexible operations
  - Size, make of main components, age, coal quality, location, design and variable cost
- Implementation of 40% Technical Minimum Level as per Phasing Plan
- Incremental costs due to flexibilization to be factored in (especially at state level)
  - Low load and cyclic operations
  - Life cycle damage costs and increased operational expenditures
- Adaptability and willingness of generation utilities to embrace and prepare for future as more units are subjected to low load and cyclic operations.
  - Capacity building, knowledge dissemination and executive exchanges

Growing Need for Flexibility – Difference b/w Max. and Min. Demand



Increasing difference between Max. and Min Demand !!

Thermal Flexibilization – Regulatory Initiatives

- CERC Grid Code – 4th Amendment, Regulations 2016
  - *"…The technical minimum for operation in respect of a unit or units of a Central Generating Station of inter-State Generating Station shall be 55% of MCR loading or installed capacity of the unit of at generating station…."*
  - Beneficiaries (DISCOMs) compensate for the Heat rate degradation

S. No.	Unit loading as a percentage % of installed capacity of the unit	Increase in SHR for supercritical units (%)	Increase in SHR for sub – critical units (%)
1	85-100	Nil	Nil
2	75-84.99	1.25	2.25
3	65 -74.99	2	4
4	55-64.99	3	6

Thermal Flexibilization – Regulatory Initiatives

- CERC Grid Code – 4th Amendment, Regulations 2016
  - *"… In case of coal / lignite based generating stations, the following Auxiliary Energy Consumption degradation or actual, whichever is lower, shall be considered for the purpose of compensation…."*
  - Beneficiaries (DISCOMs) compensate for the Heat rate degradation

Sl. No	Unit Loading (% of MCR)	% Degradation in AEC admissible
1.	85 – 100	NIL
2.	75 – 84.99	0.35
3.	65 – 74.99	0.65
4.	55 - 64.99	1.00

Thermal Flexibilization – Regulatory Initiatives

- CERC Grid Code – 4th Amendment, Regulations 2016

  - *"…Where the scheduled generation falls below the technical minimum schedule, the concerned CGS or ISGS shall have the option to go for reserve shut down and in such cases, start-up fuel cost over and above* ***seven (7) start / stop in a year*** *shall be considered as additional compensation based on following norms or actual, whichever is lower.."*

Unit Size (MW)	Oil Consumption per start up (Kl)		
	Hot	Warm	Cold
200/210/250 MW	20	30	50
500 MW	30	50	90
660 MW	40	60	110

Monthly Heat Rate Compensation Accounts

Northern Regional Power Committee

Compensation Calculation

Calculation period from 01-04-2021 to 31-5-2021

ECR & Cumulative Energy Report

Station	Cumulative Energy(MWh)	ECR(SE) (Rs/kWh)	ECR(DC) (Rs/kWh)	ECR(A) (Rs/kWh)	ECR(N) (Rs/kWh)	Final Compensation (Rs Lakh)
DADRI TPS	3955.003767	3.051	2.973	3.026	2.973	193.23304
DADRI-II TPS	6613.756648	3.198	3.054	3.160	3.054	718.63814
IGSTPS-JHAJJAR	8955.133314	3.507	3.350	3.556	3.350	1501.21385
UNCHAHAR-I TPS	3132.541747	3.337	3.186	3.369	3.186	
UNCHAHAR-II TPS	3503.062797	3.392	3.239	3.441	3.239	
UNCHAHAR-III TPS	1413.057179	3.383	3.230	3.428	3.230	
UNCHAHAR-IV TPS	4747.228589	3.169	3.027	3.097	3.027	

ECR (SE): Energy Charge Rate in rupees/kWh based on degraded SHR and AEC as per regulation considering average unit loading of generating station during the

ECR (DC): Energy Charge Rate in rupees/kWh based on degraded SHR and AEC as per regulation considering average declared capacity as average unit loading d

ECR (A): Energy Charge Rate in rupees/kWh based on actual parameters SHR and AEC during the calculation period

ECR (N): Energy Charge Rate in rupees/kWh based on normative parameters of SHR and AEC during the calculation period

6 Compensation for Degradation of Heat Rate(SHR) and Auxiliary Energy Consumption (AEC)

As per Detailed Operating Procedure on Reserve Shutdown and Compensation Mechanism issued on 05-05-2017 by Hon'ble CERC.

From Date: 2021-04-01 , To Date: 2021-09-30

6.1 Information used for ECR calculation

Entity	Normative SHR or Net SHR (kCal/kWh)	Normative SFC (ml/kWh)	CVSF (kCal/ml)	LPPF (Rs./MT)	LPSFi (Rs./KL)	Normative LC (kg/kWh)	LPL (Rs./kg)	Normative Aux. Cons (%)	CVPF (kCal/kg)	Actual GHR / SHR (kCal/kWh)	Actual SFC (ml/kWh)	Actual LC (kg/kWh)	Actual Aux. Cons (%)
KudgiSTPS1	2221.240	0.500	9.388	5266.290	50007.810	0.000	0.000	6.250	3591.040	2259.000	2.011	0.000	7.690
NLC1EXPN	2720.000	1.000	9.673	2132.240	42128.660	0.000	0.000	8.500	2675.000	2718.000	0.456	0.000	8.590
NLC21	2890.000	1.000	10.112	2132.239	44274.000	0.000	0.000	10.000	2628.000	2883.000	0.481	0.000	9.320
NLC22	2890.000	1.000	10.117	2132.239	43323.000	0.000	0.000	10.000	2627.000	2885.000	0.621	0.000	9.510
NLC2EXPN	2559.940	1.000	10.018	2132.239	46094.886	0.046	4.077	10.000	2635.361	2561.140	1.257	0.046	15.011
NNTPP	2481.725	1.000	9.783	2132.240	44013.460	0.000	0.000	6.250	2621.740	2634.020	1.090	0.000	6.870
NTECLVallurSTPS	2358.840	0.500	9.322	3904.244	49776.291	0.000	0.000	6.250	3193.118	2304.170	0.457	0.000	7.770
NTPL	2358.840	0.500	9.774	4472.313	43679.000	0.000	0.000	5.750	3762.447	2523.843	0.392	0.000	7.431
RamagundamSTPS12	2401.300	0.500	9.939	3829.848	39144.210	0.000	0.000	7.040	3736.000	2387.000	0.040	0.000	7.010
RamagundamSTPS3	2390.000	0.500	9.939	3829.848	39144.210	0.000	0.000	6.250	3736.000	2385.000	0.000	0.000	6.430
SimhadriSTPS1	2390.000	0.500	9.332	3567.700	49247.190	0.000	0.000	5.750	3125.940	2471.327	0.472	0.000	6.308
SimhadriSTPS2	2359.450	0.500	9.318	3561.910	50984.160	0.000	0.000	5.750	3120.810	2452.803	0.839	0.000	6.358
TalcherSTPS2	2390.000	0.500	9.997	1945.270	41096.391	0.000	0.000	6.250	3090.000	2403.000	0.350	0.000	6.060

Thermal Flexibilization – Regulatory Initiatives

- CERC (Terms and Conditions of Tariff) Regulations, 2019
  - Financially incentivize generators to provide ramping capability beyond the threshold of 1% and to penalize in case of failure to provide 1%, in terms of return on equity.

"…Proviso (iii)to regulation 30(2) of CERC (Terms and Conditions of Tariff) Regulations, 2019 (applicable to generators whose tariff is determined by CERC) "in case of thermal generating stations with effect from 1.4.2020:

a) Rate of return on equity shall be reduced by 0.25% in case of failure to achieve the ramp rate of 1% per minute;

b) An additional rate of return on equity of 0.25% shall be allowed for every incremental ramp rate of 1% per minute achieved over and above the ramp rate of 1% per minute, subject to ceiling of additional rate of return on equity of 1%..."

Thermal Flexibilization – Policy Initiatives

Central Electricity Authority (**Technical Standard for Construction of Electrical Plant and Electrical Lines, 2022**) requires:

*"…The steam turbine shall be designed for a minimum of **four thousand hot starts**, **one thousand warm starts** and **one hundred fifty cold starts** during its life…"*

a. Hot starts (less than 10 hours of unit shutdown): **4000**
b. Warm starts (between 10 and 72 hours of unit shutdown): **1000**
c. Cold starts (greater than 72 hours of unit shutdown): **150**…"

Thermal Flexibilization – Regulatory Initiatives

Central Electricity Authority (**Flexible Operation of Coal based Thermal Power Generating Units**) Regulations, 2023 requires thermal generators to be **capable of providing 1%–3% ramp rate**

7(1) "..The coal based thermal power generating units shall have ramp rate capability of ***minimum three percent per minute for their operation between seventy percent to hundred percent of maximum continuous power rating*** *and* ***shall have ramp rate capability of minimum two percent per minute for their operation between fifty-five percent to seventy percent of maximum continuous power rating.***

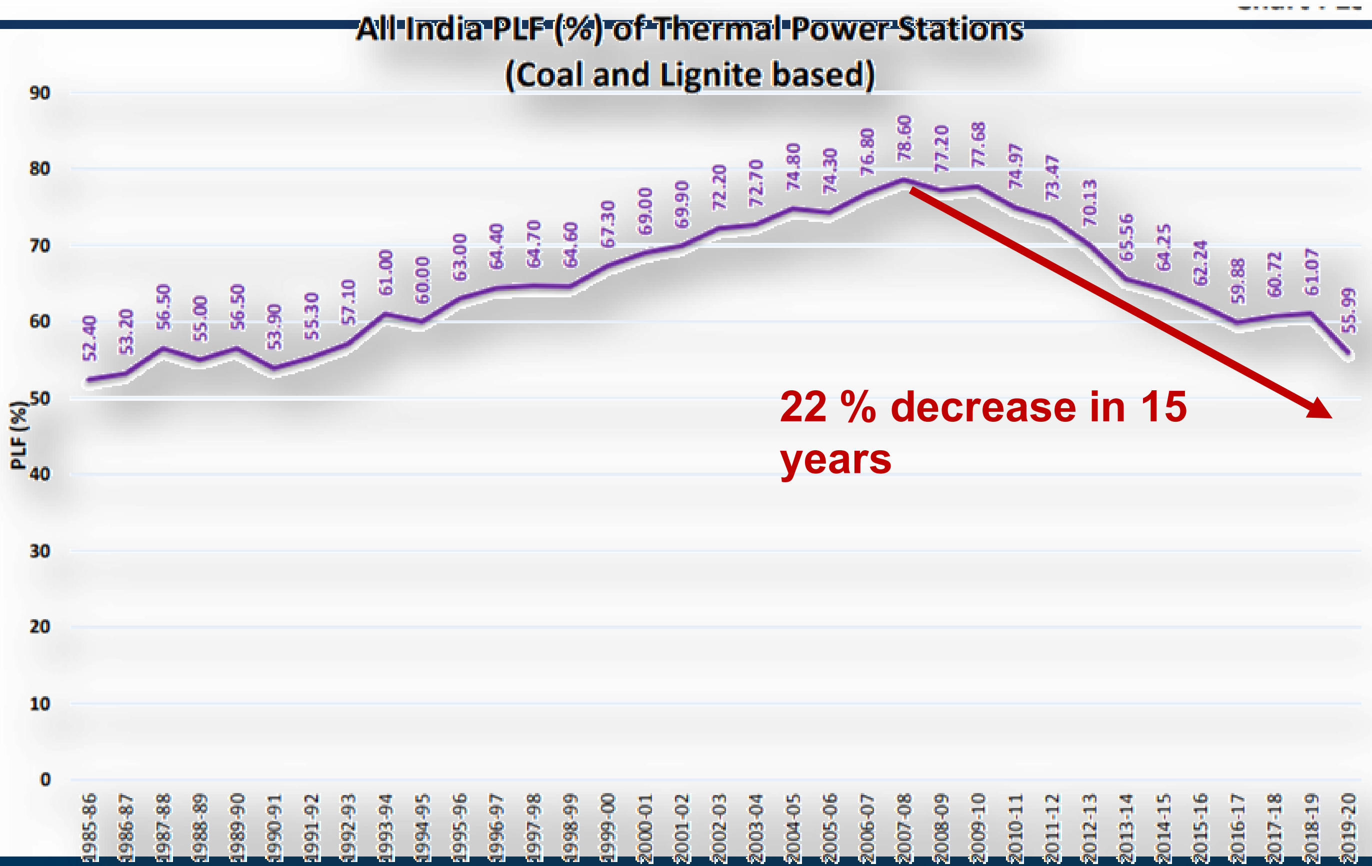
Provided that the generating units which are not capable to comply with this regulation, shall comply with the same ***within one year*** *of the notification of these regulations…"*

Thermal Flexibilization – Regulatory Initiatives

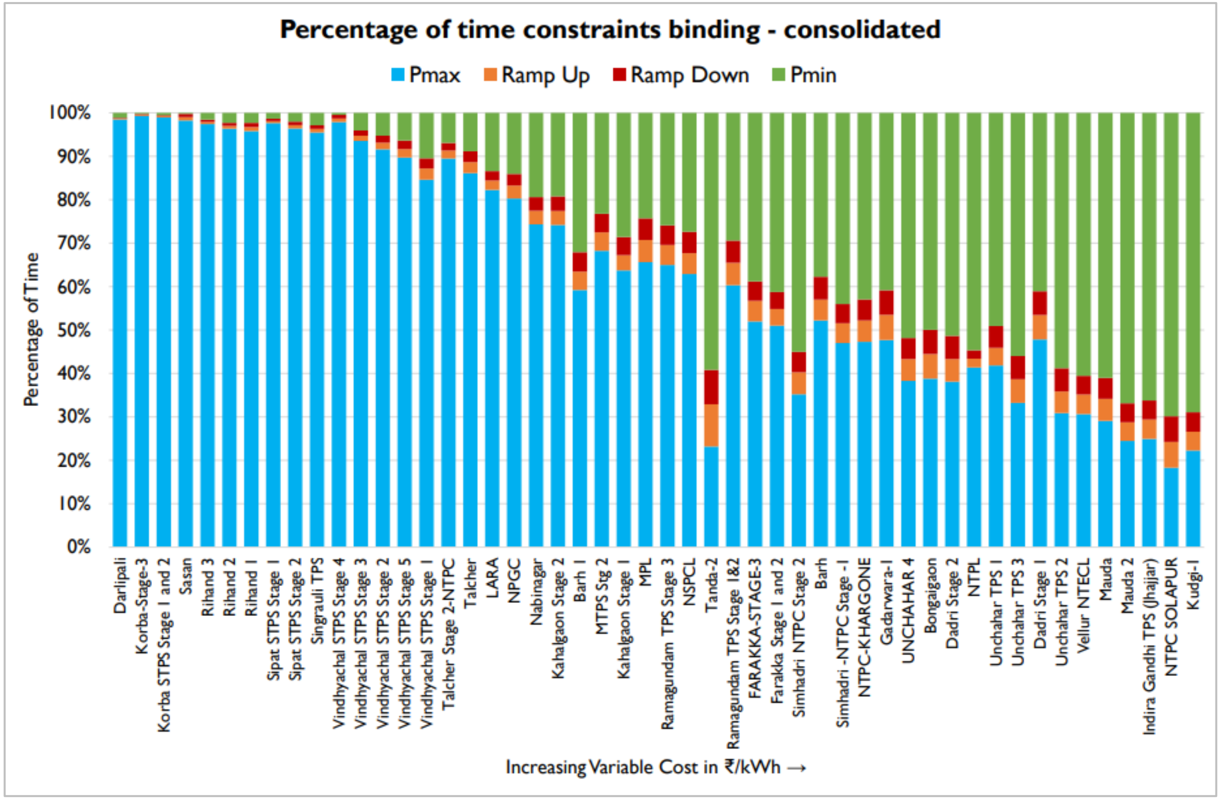
Central Electricity Authority (**Flexible Operation of Coal based Thermal Power Generating Units**) Regulations, 2023 requires thermal generators to be **capable of providing 1%–3% ramp rate**

7(2) "…The coal based thermal power generating units shall achieve ramp rate capability of ***minimum one percent per minute for their operation between forty percent to fifty-five percent of maximum continuous power rating*** *as per phasing plan mentioned in the sub-regulation (2) of regulation 5 of these regulations.."*

Declining PLF of Thermal Power



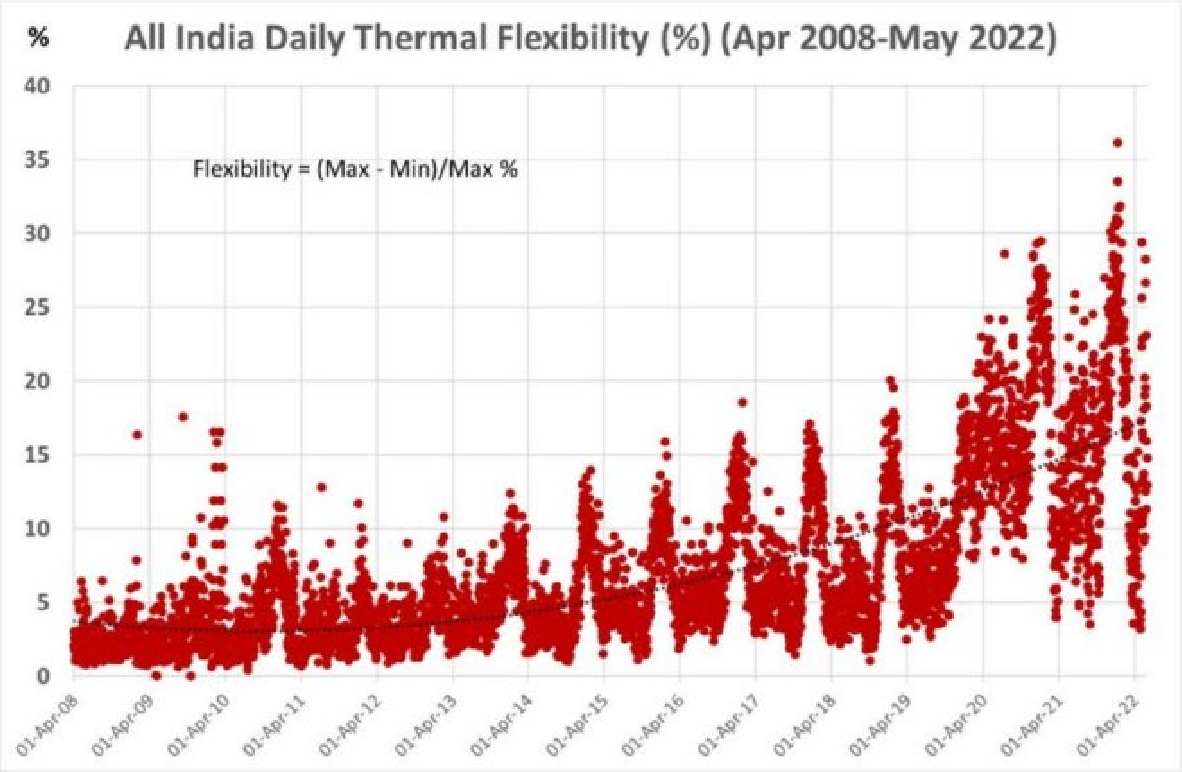
Other Advantages of Thermal Flexibilization



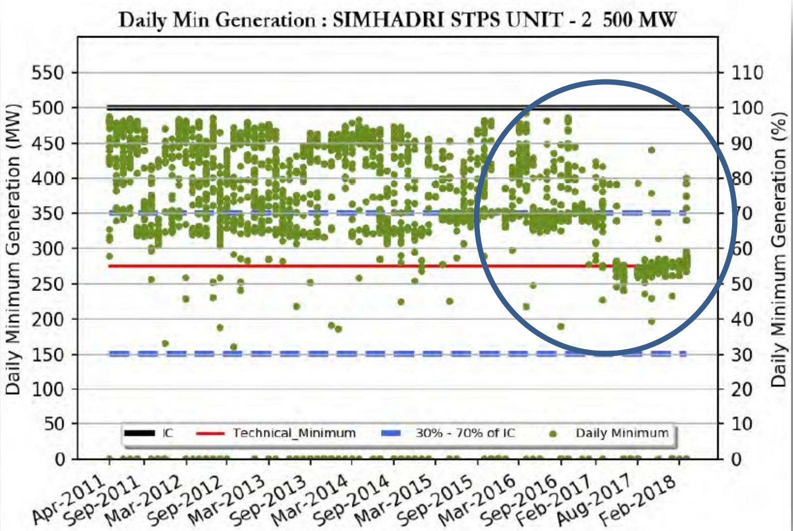
Facilitate Economic Scheduling and Dispatch

Source: SCED Detailed Feedback Report on Pilot, Mar 2022

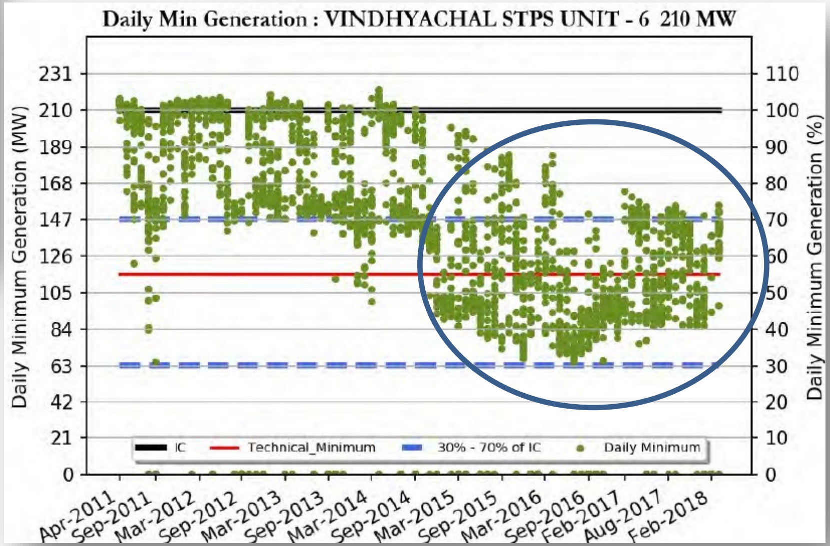
Thermal Generation Flexibility



Flexibility…Sample Generating Station

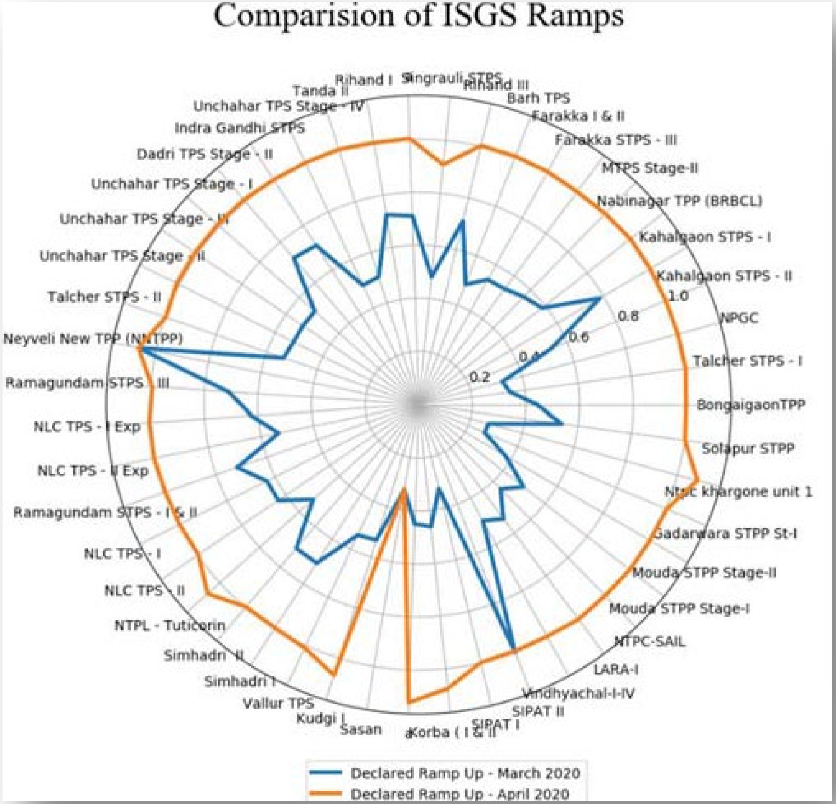


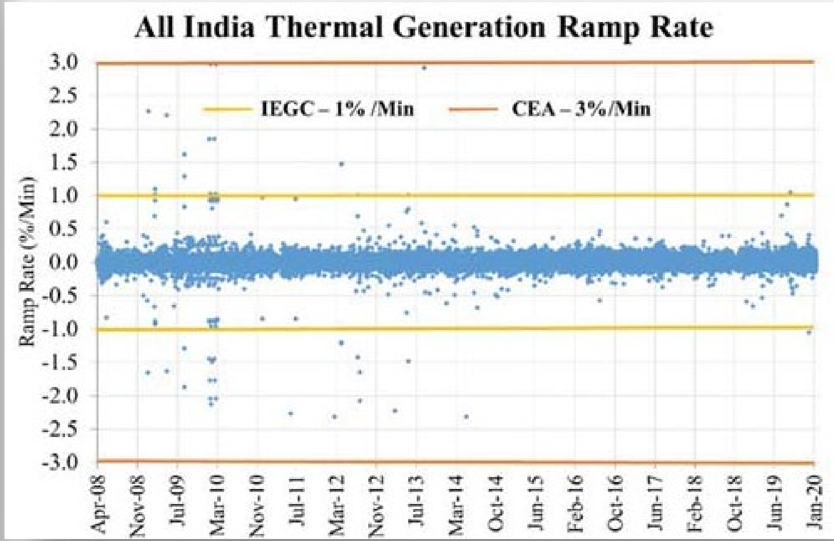
Generators responding to incentive for going upto 55 % technical minimum post 2016 !



Indian Electricity Grid Code, 2016 Amendment

Response to Incentivization





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Thank You!