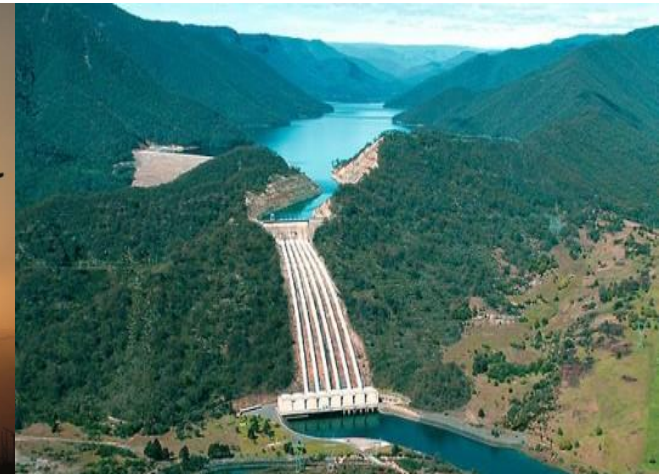


# Methodology for Capacity Credit of Generation Resources & Coincident Peak Requirement of Utilities under Resource Adequacy Framework



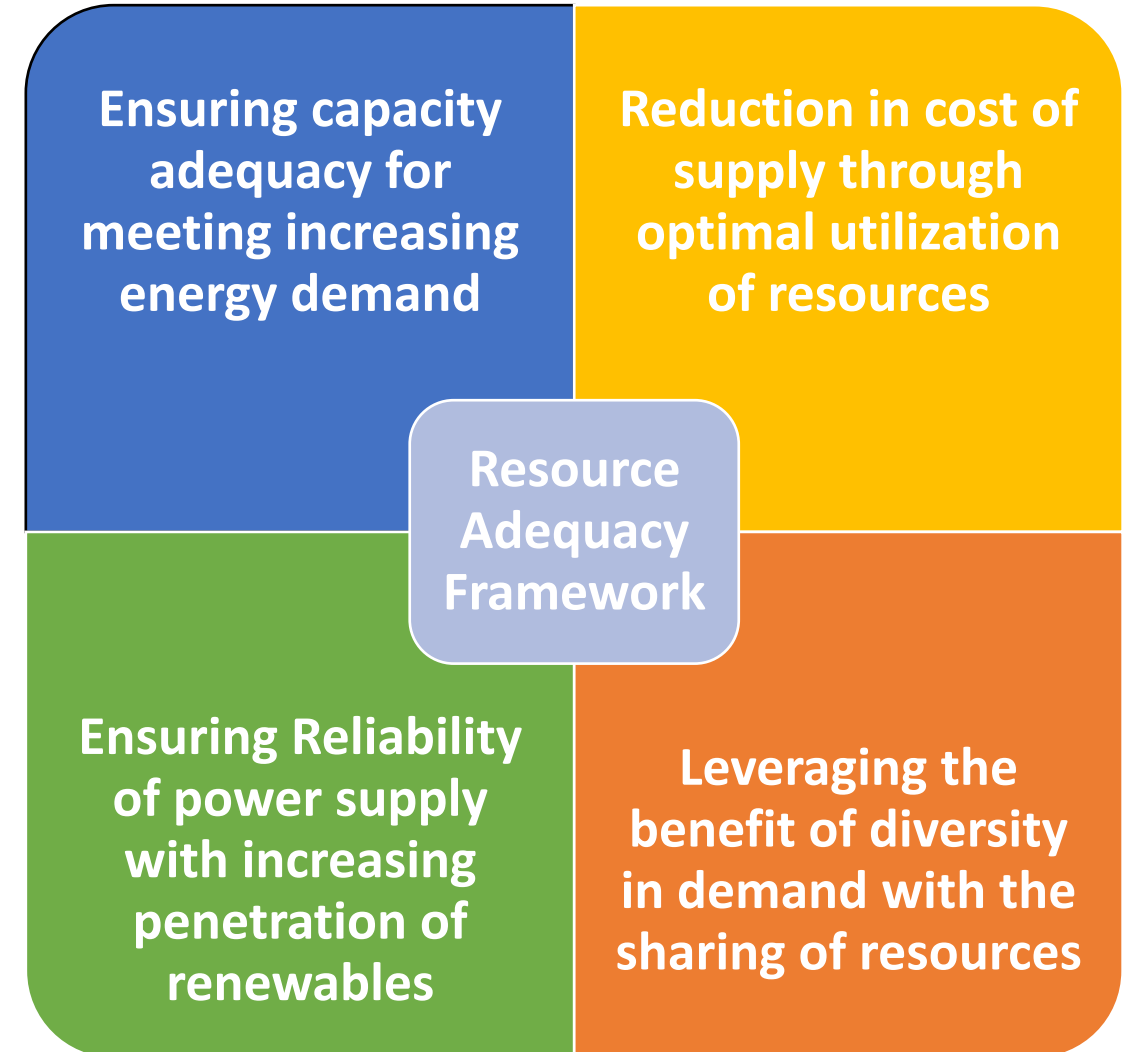
# Resource Adequacy guidelines, June 2023

- Published under Under Rule 16 of Electricity (Amendment) Rules, 2022
- Role of CEA, Discoms, SERCs, Grid India, SLDC defined.
- LT-NRAP, LT-DRAP, ST-DRAP
- PRM, LOLP, NENS, Coincident Peak, Capacity Credit
- **Benefits:**
  - Ensures optimal capacity development and utilization
  - Ensures adequacy in generation capacity to meet electricity demand at every instance
  - 24X7 uninterrupted supply of power to end consumers
  - Facilitates integration of variable Renewable Energy
  - Ensures system reliability and security

# Salient Features of Resource Adequacy Framework



# Benefits of Resource Adequacy Framework



# Role of Central Electricity Authority Under Resource Adequacy Framework

Publish Long-term National Resource Adequacy Plan (LT-NRAP) which shall determine the optimal Planning Reserve Margin (PRM) requirement at the All-India level conforming to the reliable supply targets(section 3.1)

Publish the capacity credits for different resource types on a regional basis. (Section 3.1)

## CENTRAL ELECTRICITY AUTHORITY

Specify the State/UT's contribution towards national peak. (Section 3.1)

Publish the national-level PRM as a guidance for all the States/UTs to consider while undertaking their RA exercises. (section3.1)

# Coincident Peak

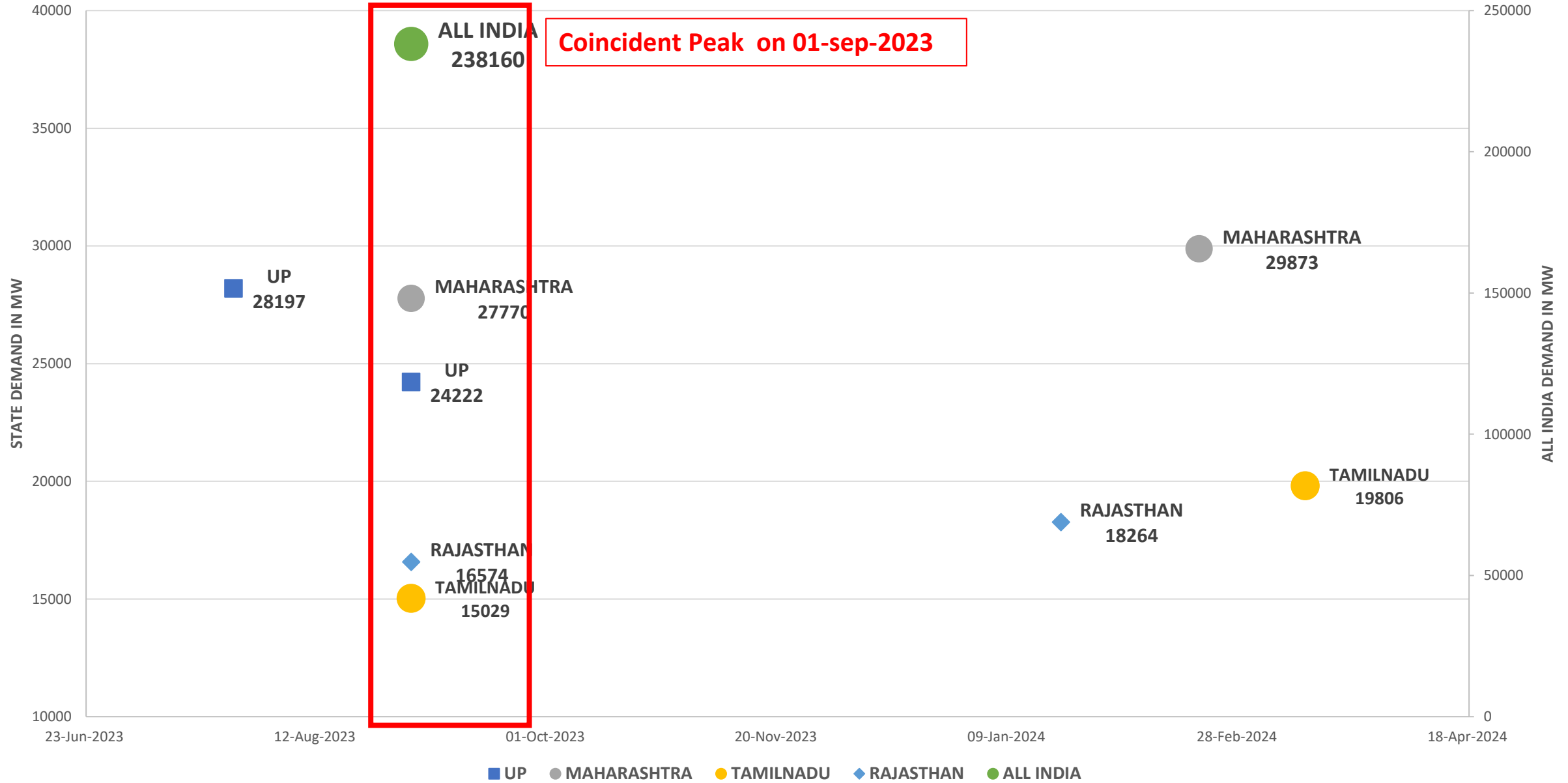
## What is Coincident Peak?

- Contribution of State/UT or Distribution Utilities during National Peak
- Top 5% of National Peak instead of Single Peak
- May or May not be same as own peak of State/UT

## Resource Adequacy framework

- The utilities must ensure sufficient tied-up capacity from long-term, medium-term, and short-term (Bilateral only) as per their contribution to National Peak demand +PRM
- Share of Capacity tie-up
  - Long term- 75-80%**
  - Medium-term- 10-20%**
  - Short-term- 5-10%**
- 100% tie-up for the first year and a minimum 90% tie-up for the second year to meet the requirement of their contribution towards meeting national peak to SERCs/JERCs

# Coincident Peak vs Own Peak(FY 2023-24)



# Methodology for calculation of Coincident Peak

## Top 5% methodology

- Average State/Distribution Utilities Demand During the Top 5% of National Demand.

### PROS:

- Easier to calculate.

### CONS:

- Doesn't take into account time of day( Solar ,Non Solar).
- Average value may not be adequate during high-demand hours.
- States with Solar Capacity tied up may face challenges in meeting their coincident peak demand during Non-Solar Hours

## Solar vs. NonSolar Hours

- Top 5 % of demand during Solar and Non-Solar Hours.
- 80<sup>th</sup> percentile Instead of Maximum

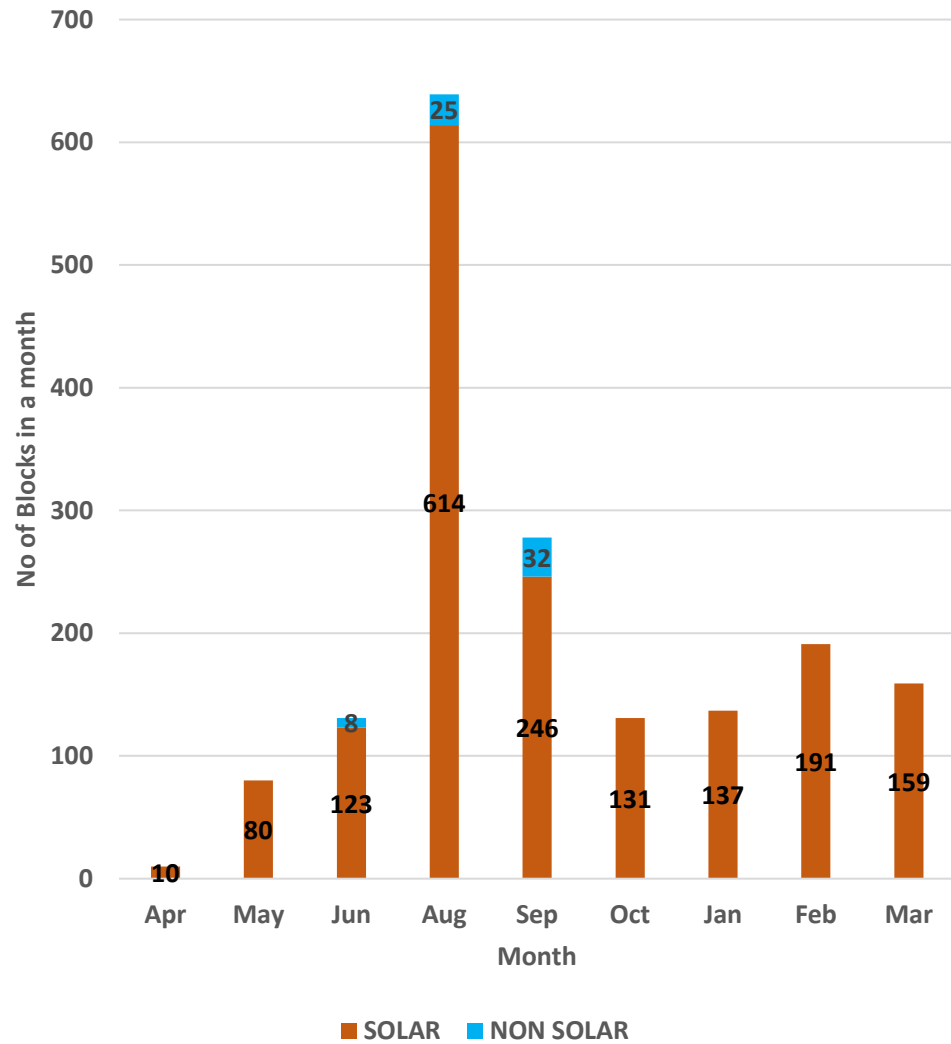
### PROS:

- Impact of Solar, Non-Solar hours considered
- Different Coincident Peak requirements for Solar and Non-Solar Hours

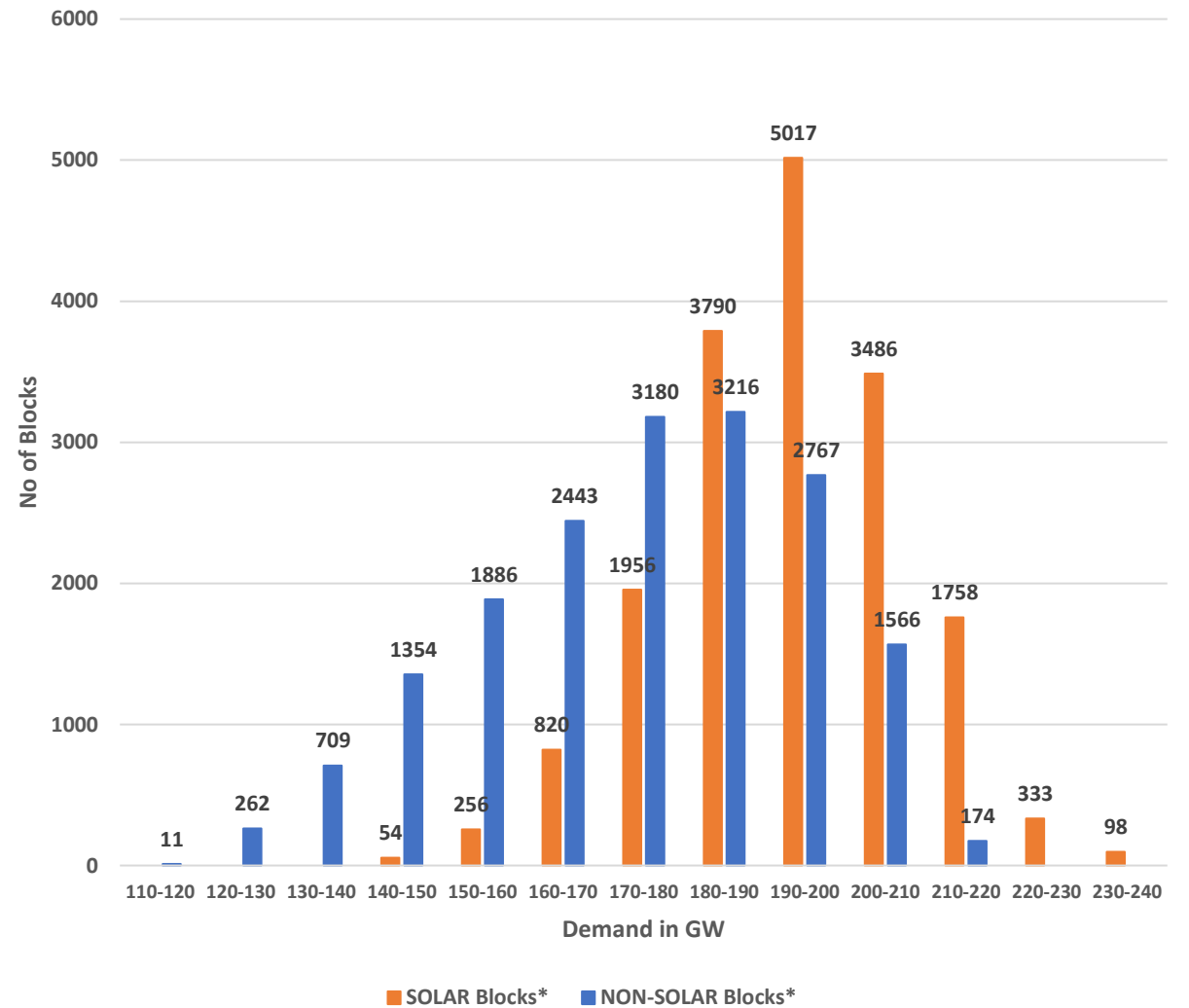
### CONS:

- States with higher coincident peak demand during non-solar periods compared to solar periods may need to acquire additional conventional power capacity (like coal or gas) to meet their resource adequacy requirements

Month wise Distribution of Demand blocks during Top 5% National Demand Hours in FY 2023-24

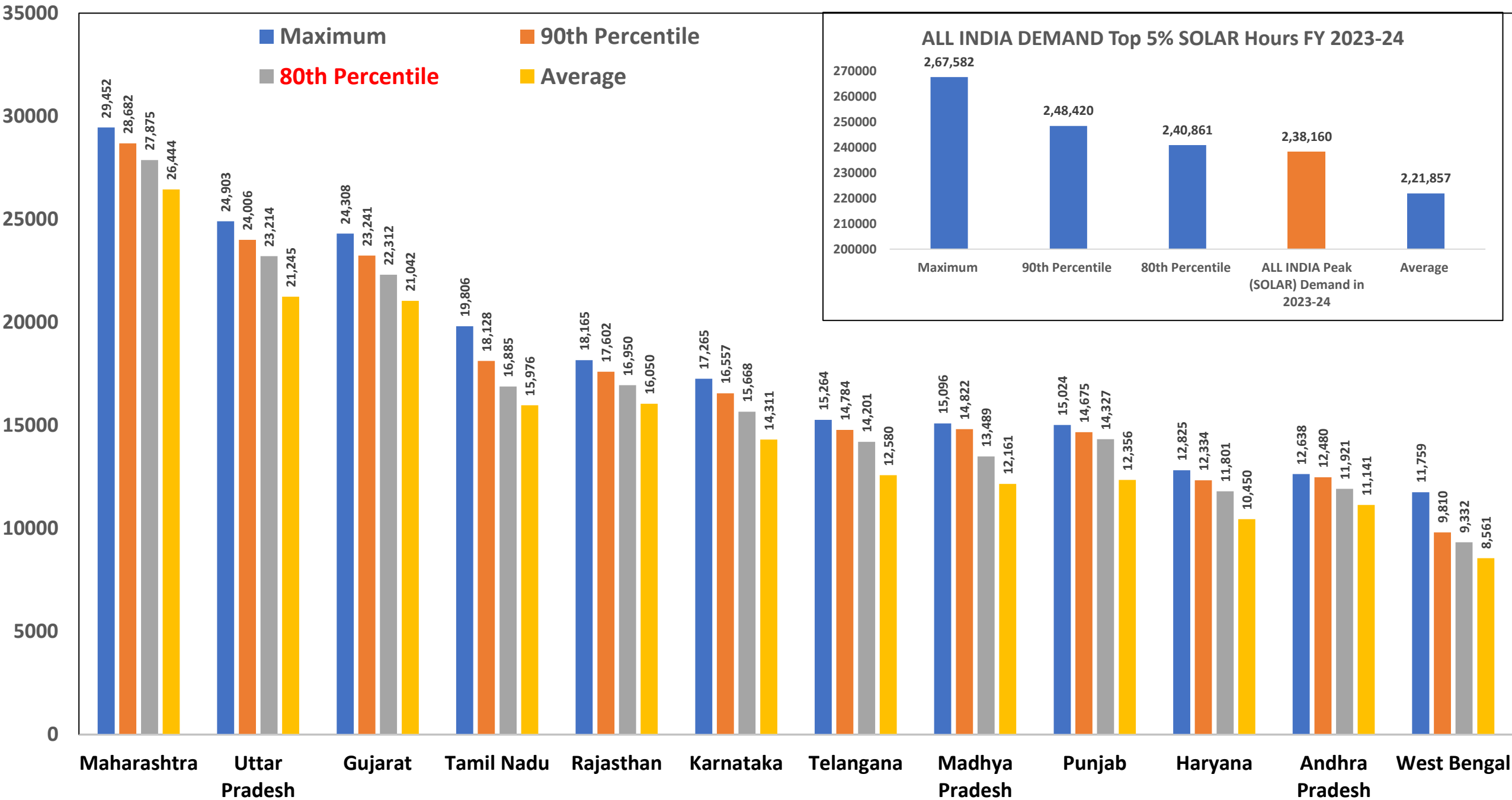


National Demand Distribution During Solar and Non-Solar Hours in FY 2023-24

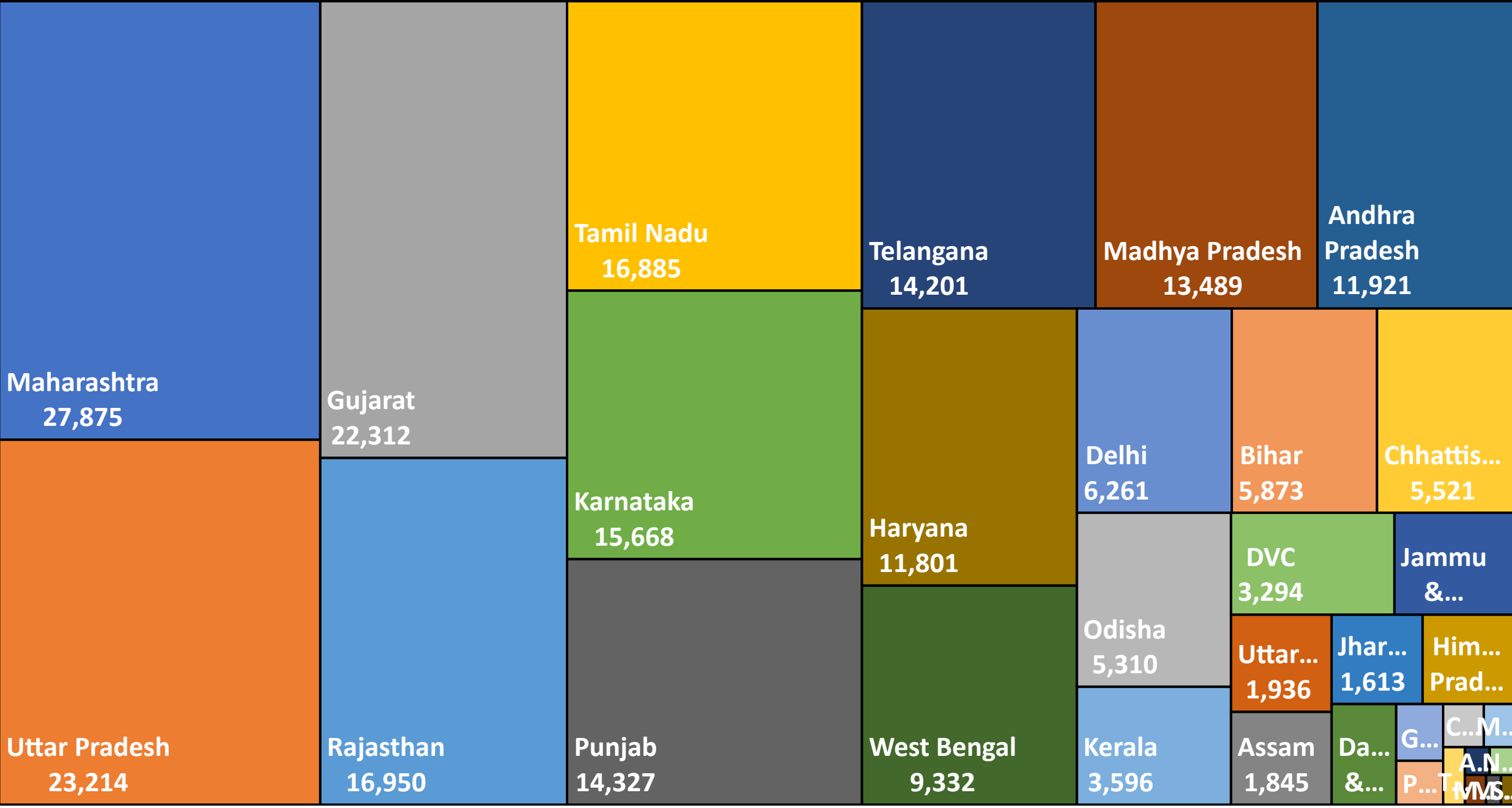




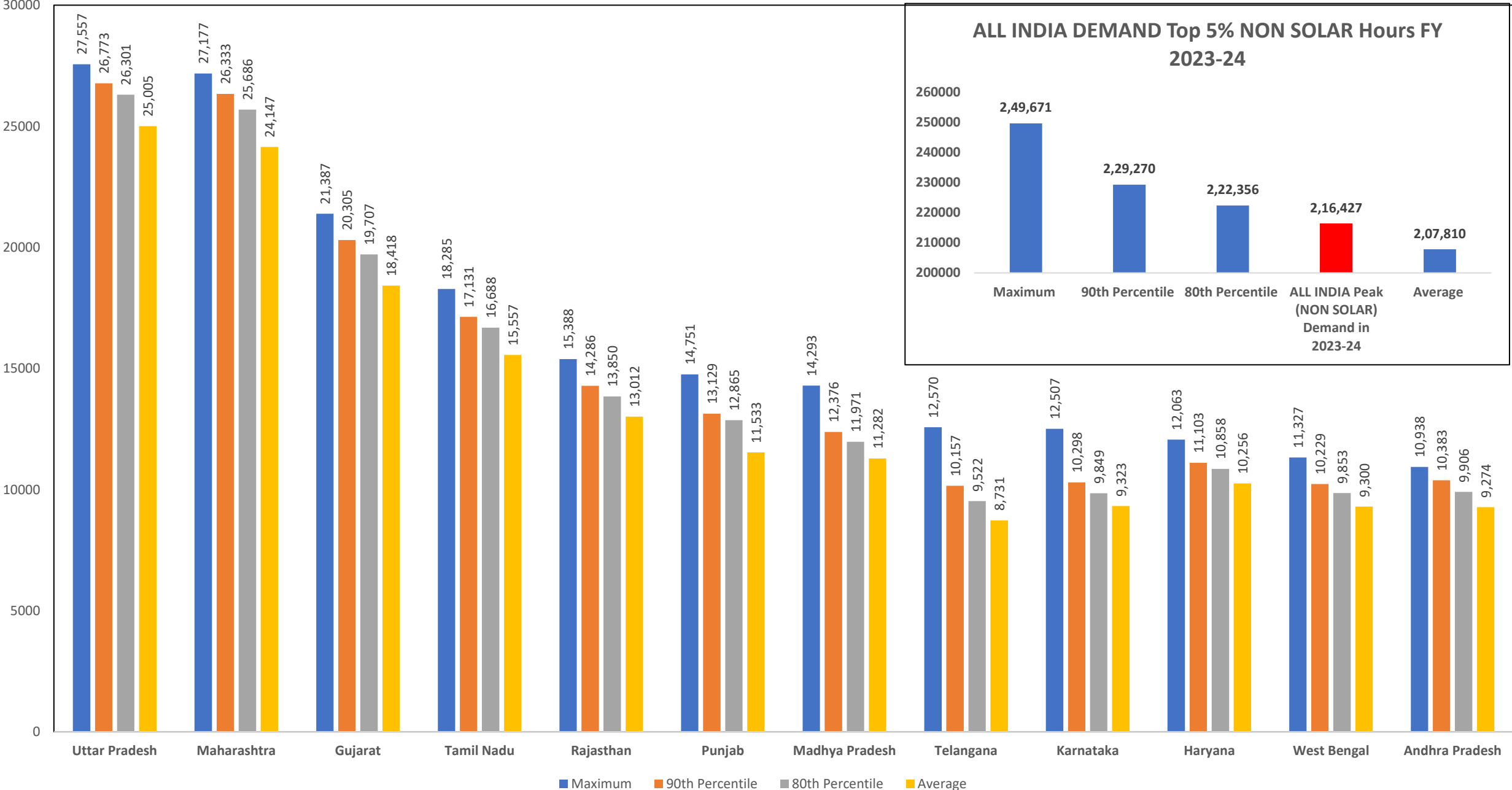
Maximum ,90th Percentile, 80th Percentile, Average Demand of Top 5 % Demand of Top 12 States (Solar Hours)



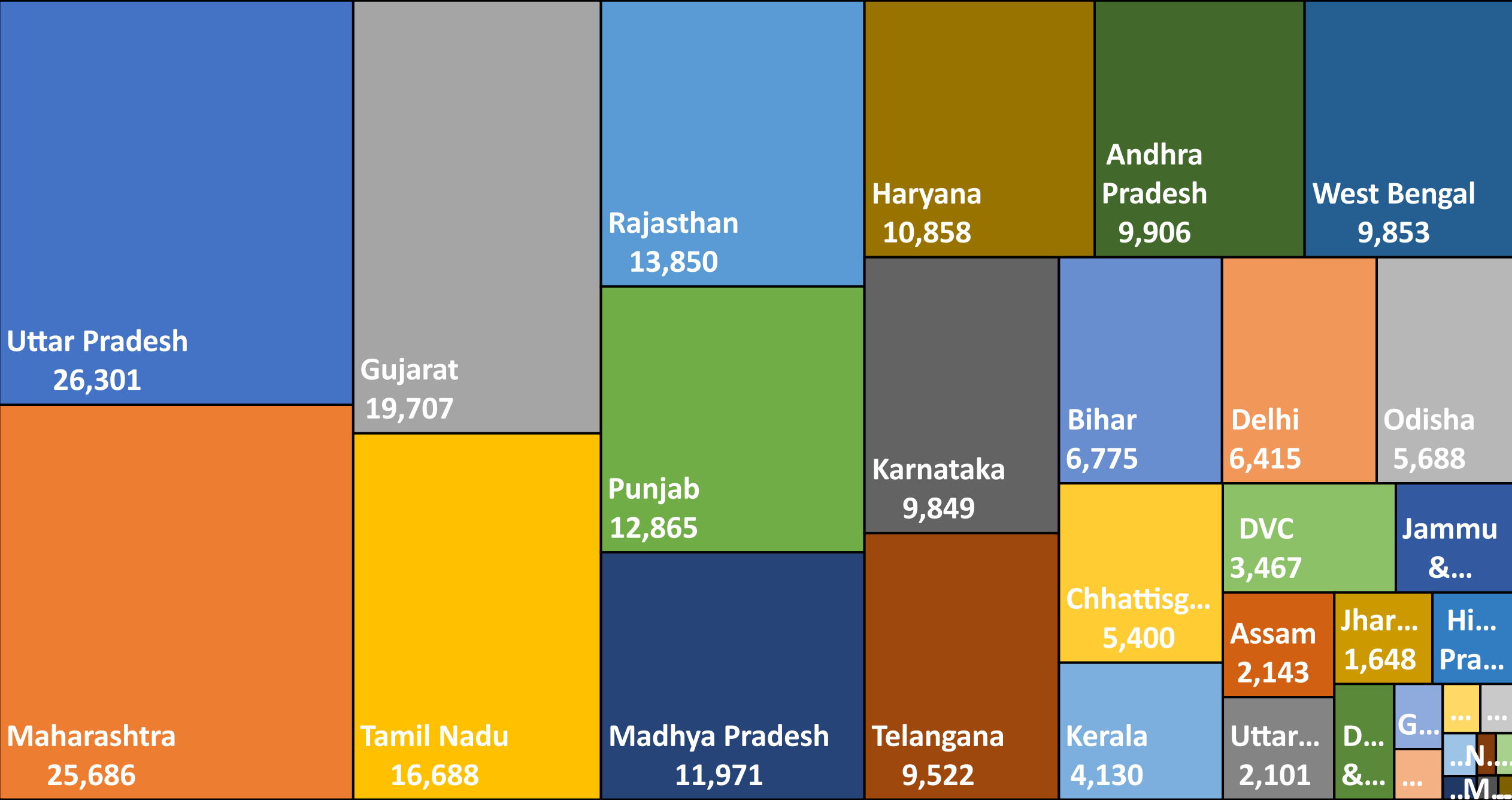
State Wise Coincident peak in MW(Solar)in FY 2023-24



Maximum ,90th Percentile, 80th Percentile, Average Demand of Top 5 % Demand of Top 12 States (NON Solar Hours)



State Wise Coincident peak in MW( Non Solar)



# Capacity Credit

## What is Capacity Credit?

- Capacity Credit refers to firm capacity available during peak demand period.
- Capacity Credit of Conventional Sources is based on availability.
- Capacity Credit of VRE Sources is calculated using Statistical analysis.

## Resource Adequacy framework

### At National Level

**$\sum$  Source wise Installed capacity (ALL INDIA) \* Capacity Credit of the source = National Peak Demand \* (1 + National PRM)**

### For Distribution Licenses

**$\sum$  Source wise tied up capacity (Distribution licensee) \* Capacity Credit of the source = Contribution to National Peak \* (1 + National PRM)**

# Methodology for Determining Capacity Credit of Conventional Sources

- Capacity Credit (CC) of Conventional Sources (Coal, Gas, Nuclear) = Installed Capacity \*(1- Auxiliary Power) \*Availability
- CC of Hydro, Biomass, and geothermal energy=Seasonal Availability, Past generation data
- CC of PSP, BESS = Name Plate Capacity

Generation Sources	Capacity Credit(p.u.)
Coal	0.7-0.8
Nuclear	0.6-0.7
Gas	0.7-0.8
Hydro#	RoR- 0.25-0.3, With Storage- 0.6-0.7
Biomass#	0.3
PSP@	0.5-1
BESS@	0.5-1

***@ The availability of energy-limited sources is dependent on the duration of peak demand hours. For example, the availability of a BESS of 2h is only 50% during high demand period of 4h in a day***

***# Highly Seasonal in Nature***

# Methodology for calculation of Capacity Credit for VRE Sources

## Top 10% Demand methodology

- Median of VRE Profile during Top 10% demand Hours.
- Easier to calculate
- Doesn't take into account time of day( Solar ,Non Solar).

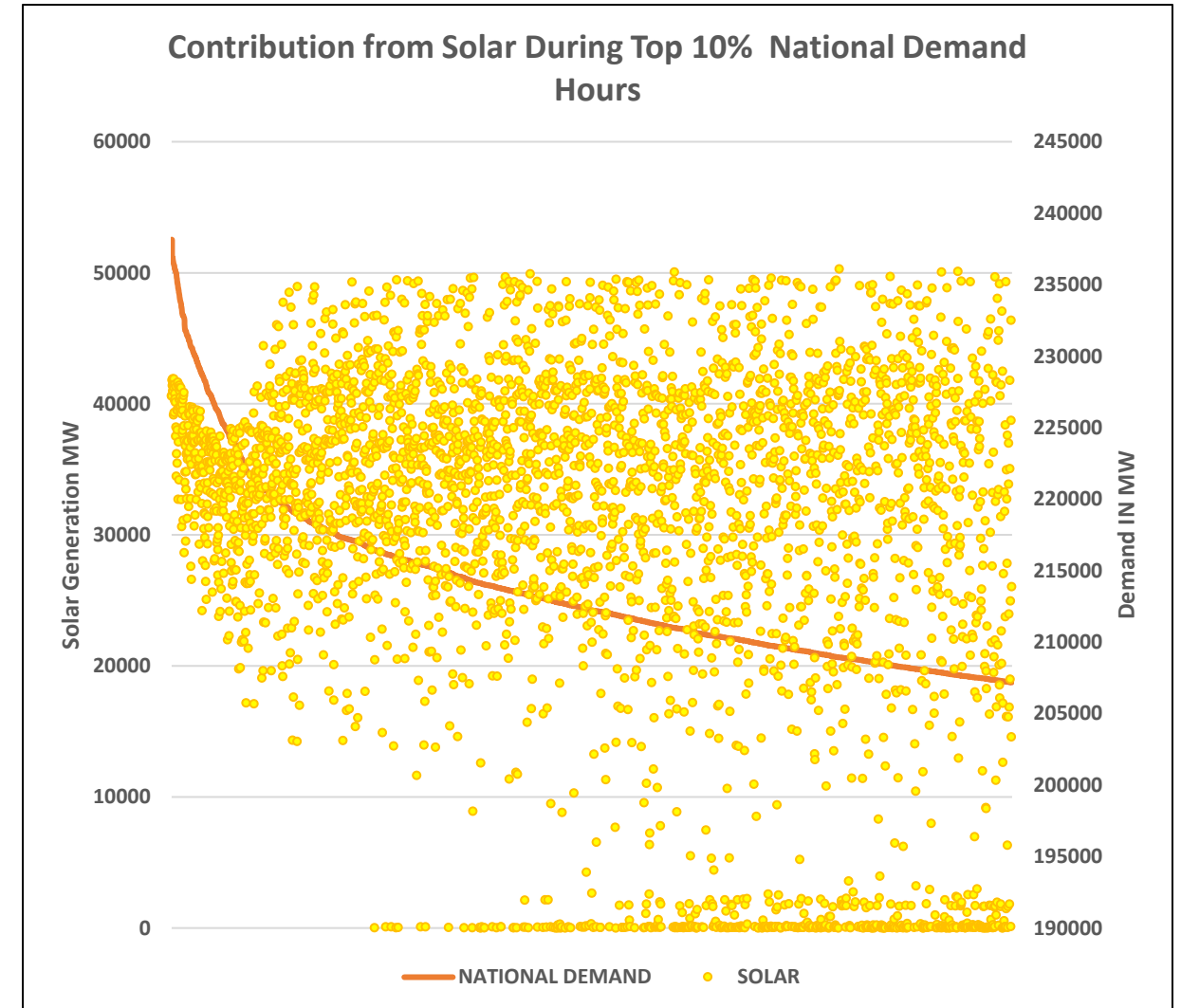
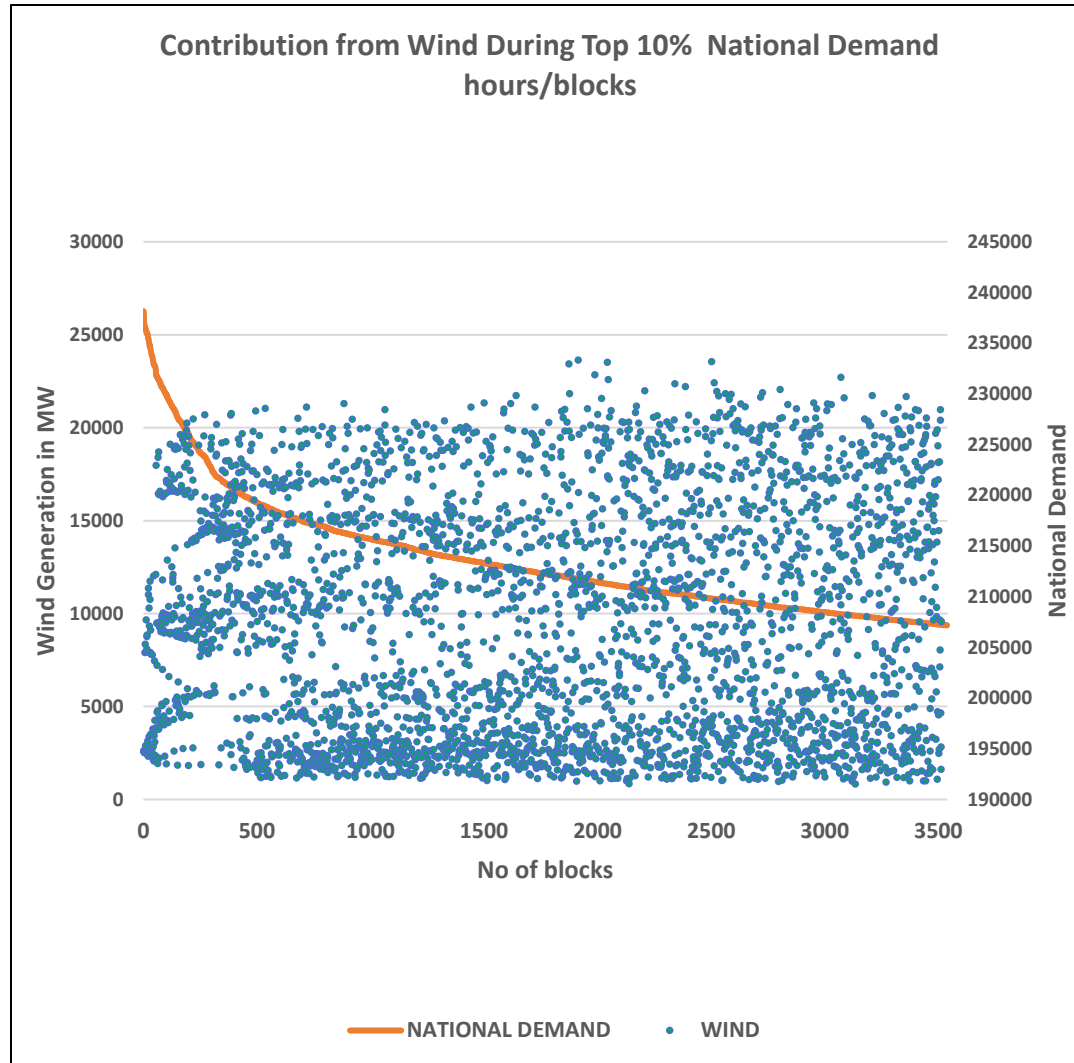
## Solar Vs Non-Solar Hours

- Top 5 % of demand during Solar and Non-Solar Hours.
- Median of Profile during Top 10% demand Hours
- Variation of Wind CC during Solar vs non-Solar Hours

## Critical Day Analysis

- Critical days instead of Critical blocks
- Both Demand & RE generation instead of only high Demand period
- High Demand- Low RE, Medium Demand-LOW RE days
- K means clustering algorithm
- Computationally complex

# Top 10% Demand Hours Methodology

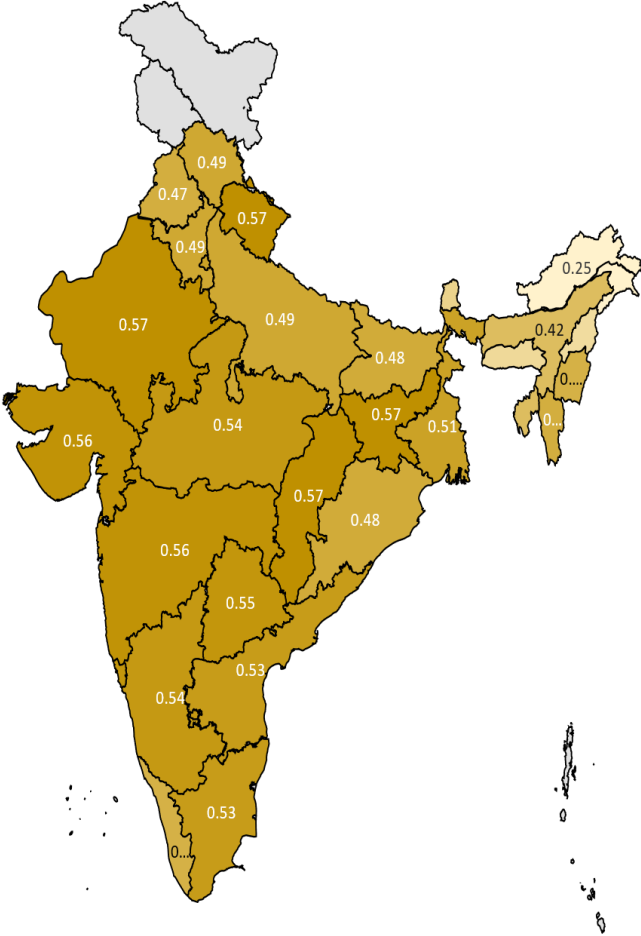




# Capacity Credit Using Top 10% (demand) Methodology

## SOLAR

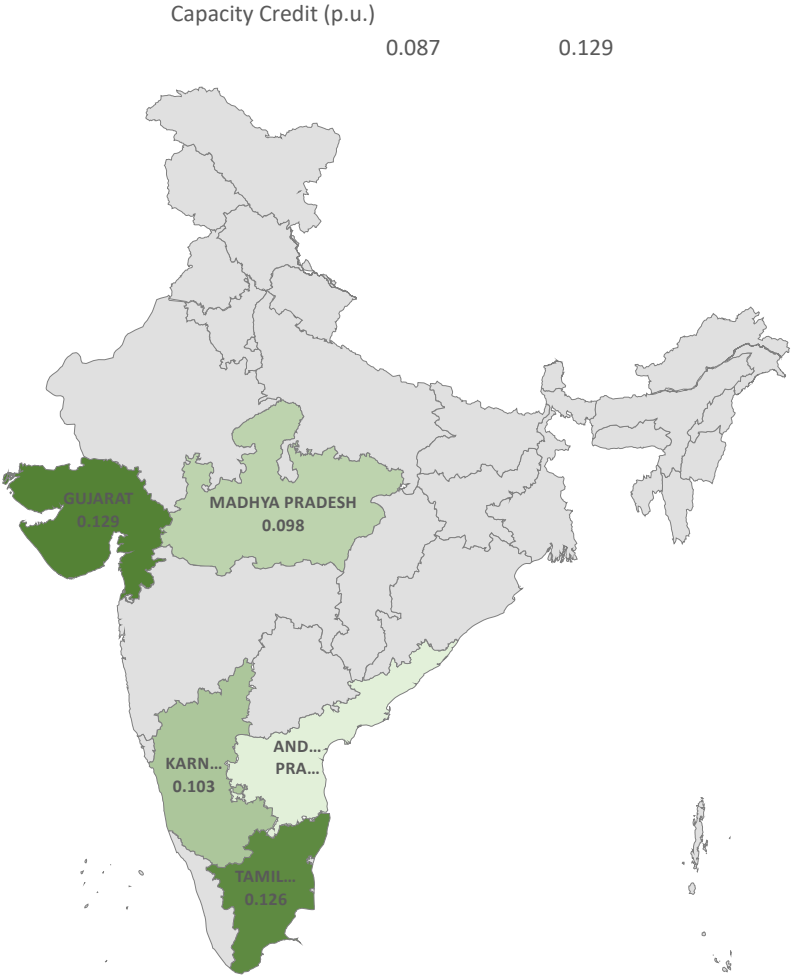
State Wise Capacity Credit of Solar



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## WIND

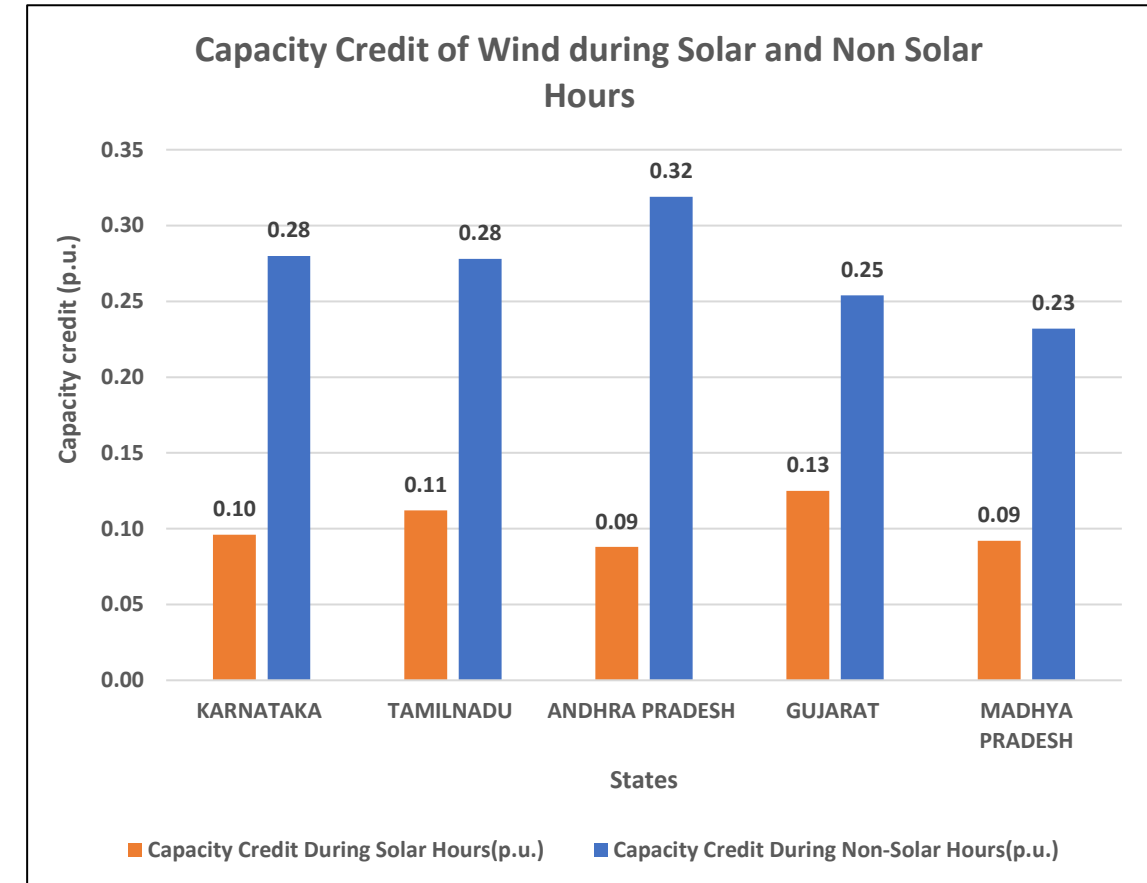
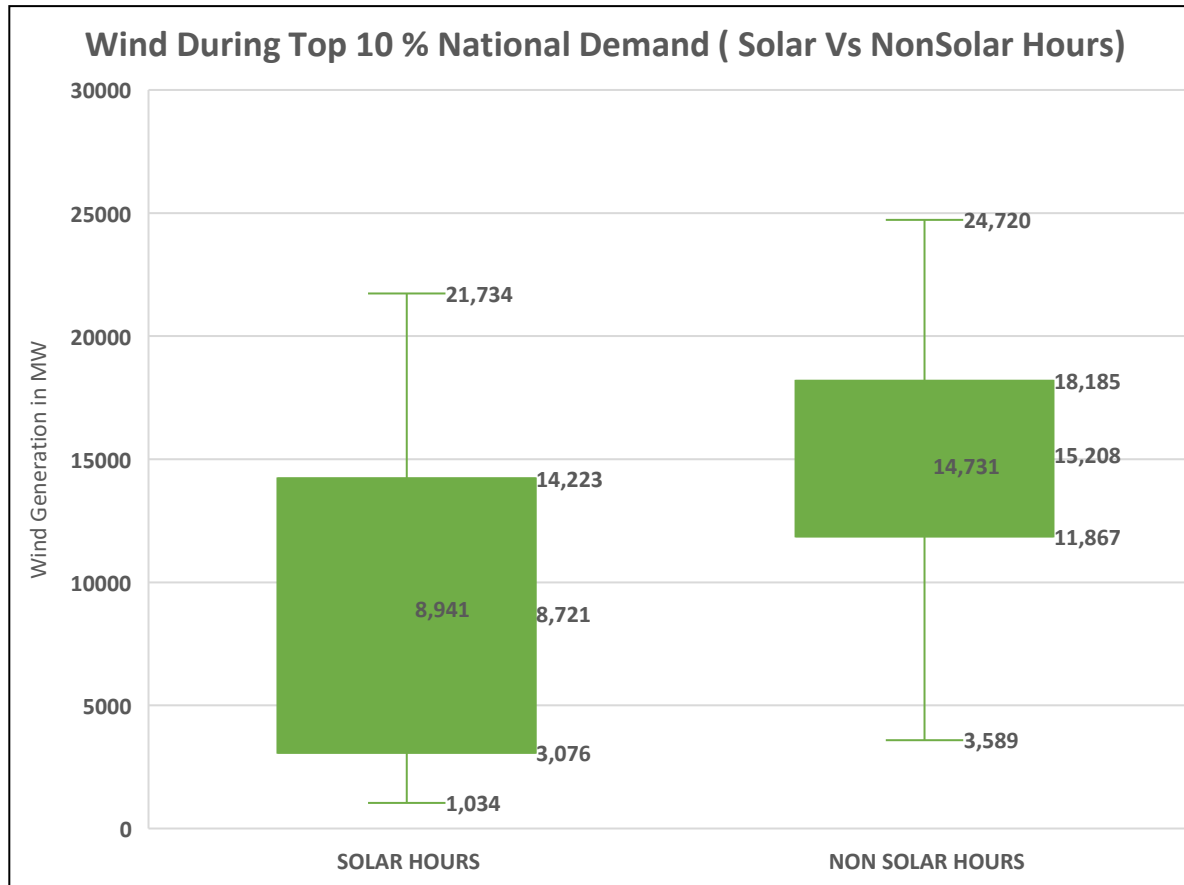
State wise Capacity Credit of Wind



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# Capacity Credit using Solar Vs Non-Solar Hours

- Capacity credit of Solar is Similar to the 1<sup>st</sup> method
- Capacity Credit of Wind is different in Solar and Non-Solar Hours



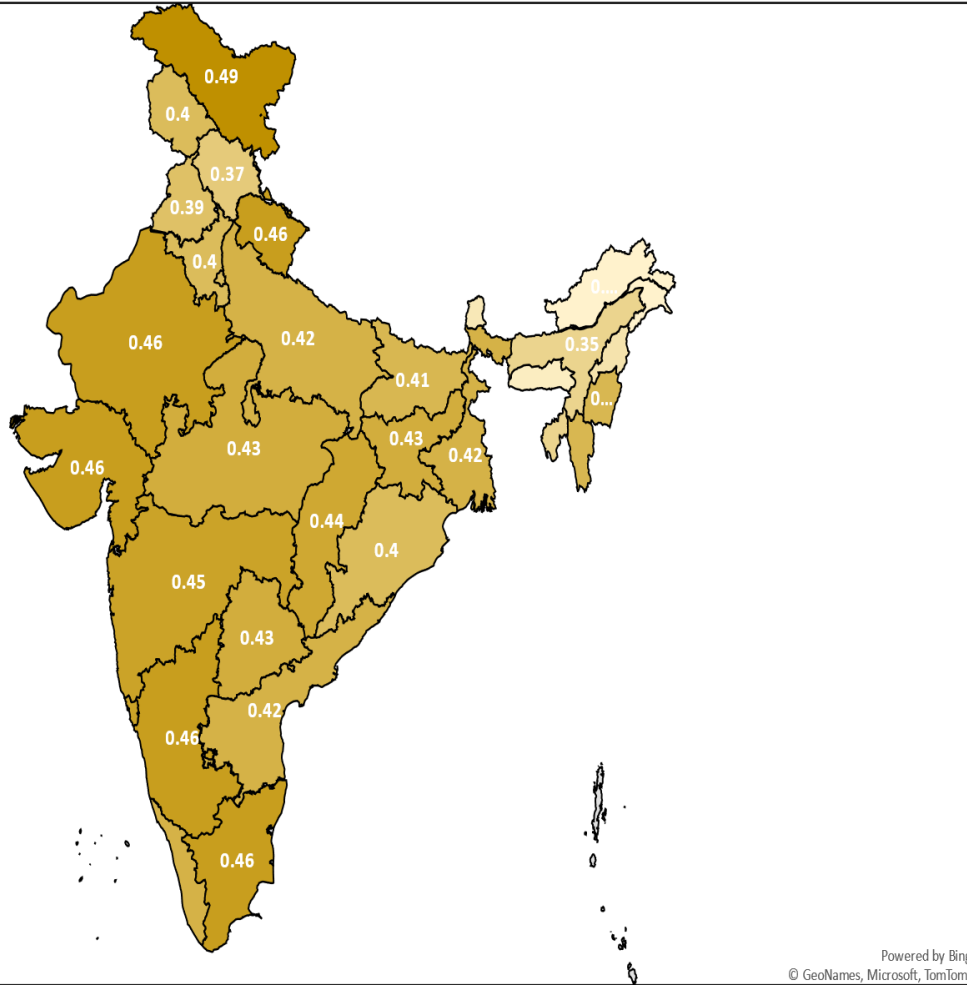
## Capacity Credit using Critical days analysis

<b>HIGH RE-Low Demand</b>	<b>High RE-Medium Demand</b>	<b>High RE-High Demand</b>
<b>Medium RE-Low Demand</b>	<b>Medium RE-Medium Demand</b>	<b>Medium RE-High Demand</b>
<b>Low RE-Low Demand</b>	<b>Low RE-Medium Demand</b>	<b>Low RE- High Demand</b>

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# Capacity Credit of VRE Sources(Critical Days)

## Capacity Credit of Solar(State Wise)(Critical Days)



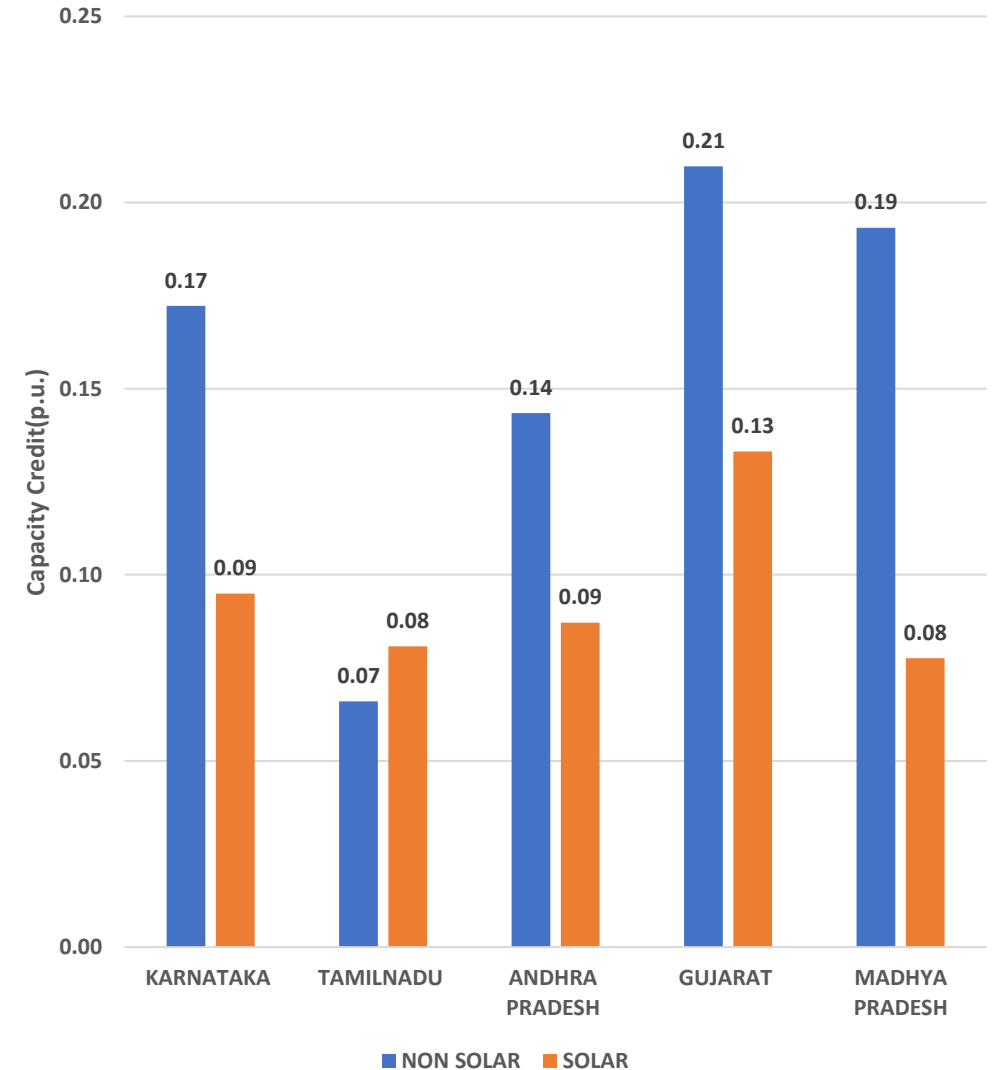
Capacity Credit (p.u.) (Solar)

0.29

0.49

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## Capacity Credit of Wind( State Wise)(Critical Days)



## Conclusion

- For Coincident Peak -The solar vs. non-solar(Top 5% demand hours) methodology
- For Capacity Credit- The critical day's analysis

# Coincident Peak During Solar Hours(FY 2023-24)

State/UT	Maximum of Coincident Peak (top 5%) _SOLAR Hours	90 <sup>th</sup> Percentile of Coincident Peak (top 5%) SOLAR Hours	80 <sup>th</sup> Percentile of Coincident Peak (top 5%) SOLAR Hours	Average of Coincident Peak (top 5%) SOLAR Hours	Own Peak(Solar Hours)
Chandigarh	399.0	373.6	346.2	296.3	399.0
Delhi	7433.2	6708.7	6260.8	5595.2	7433.2
Haryana	12825.3	12334.0	11800.8	10449.8	12825.3
Himachal Pradesh	2057.1	1875.2	1609.0	1477.0	2151.0
Jammu & Kashmir	3037.8	2562.8	2402.9	2280.1	3179.0
Punjab	15023.5	14674.9	14326.6	12355.8	15297.3
Rajasthan	18165.4	17602.3	16950.0	16049.8	18264.2
Uttar Pradesh	24903.1	24005.7	23214.0	21245.2	25230.3
Uttarakhand	2399.2	2095.0	1935.8	1816.9	2519.6
Chhattisgarh	5940.4	5782.7	5521.1	5098.9	6247.1
Dadra & Nagar Haveli	1334.0	1309.7	1288.8	1246.9	1336.2
Gujarat	24308.2	23240.7	22312.1	21041.9	24308.2
Goa	631.3	569.7	526.2	500.7	686.1
Madhya Pradesh	15095.5	14821.6	13489.3	12161.2	15099.2
Maharashtra	29452.0	28681.9	27874.8	26444.0	29873.0
Andhra Pradesh	12638.3	12480.1	11921.3	11140.5	12668.0
Karnataka	17264.8	16556.8	15667.8	14310.8	17889.4
Kerala	4420.2	3898.3	3596.3	3453.7	4635.8
Puducherry	479.7	433.3	407.6	384.4	504.7
Tamil Nadu	19806.4	18128.3	16885.2	15975.9	19806.4
Telangana	15264.4	14783.5	14200.9	12579.7	15421.4
Bihar	6774.8	6220.0	5873.2	5259.1	7544.0
DVC	4060.6	3478.0	3293.9	3186.9	4060.6
Jharkhand	1898.2	1693.1	1613.4	1495.1	1968.3
Odisha	6713.5	6232.8	5310.2	4862.0	6911.5
Sikkim	109.5	97.9	74.1	66.3	127.5
West Bengal	11758.7	9809.5	9332.3	8560.6	11758.7
Arunachal Pradesh	162.3	141.7	136.5	125.4	223.5
Assam	2133.5	1996.5	1844.6	1637.6	2377.3
Manipur	161.4	135.4	123.8	111.2	240.8
Meghalaya	298.6	279.3	253.0	230.6	436.0
Mizoram	116.0	98.8	87.8	79.2	158.7
Nagaland	163.2	150.5	131.4	117.3	172.3
Tripura	353.3	278.4	249.5	220.6	417.8
Sum Total	267582.4	248419.5	240861.2	221856.8	272171
ALL INDIA Peak (SOLAR) Demand in 2023-24	238160.4				

# Coincident Peak During Non Solar Hours(FY 2023-24)

State/UT	Maximum of Coincident Peak (top 5%) NON-SOLAR Hours	90th Percentile of Coincident Peak (top 5%) NON-SOLAR Hours	80th Percentile of Coincident Peak (top 5%) NON-SOLAR Hours	Average of Coincident Peak (top 5%) NON-SOLAR Hours	Own Peak(Non Solar Hours)
Chandigarh	375.9	347.9	339.5	307.6	381.3
Delhi	7122.8	6602.9	6414.8	5927.6	7164.1
Haryana	12063.1	11102.7	10857.6	10255.6	12166.9
Himachal Pradesh	1699.8	1476.9	1365.9	1219.5	2193.3
Jammu & Kashmir	2873.8	2444.6	2360.7	2171.9	3270.6
Punjab	14751.1	13129.0	12865.4	11532.6	14751.1
Rajasthan	15387.8	14285.9	13849.6	13012.0	15725.3
Uttar Pradesh	27557.4	26772.8	26300.6	25005.3	28197.1
Uttarakhand	2343.9	2153.1	2100.7	1940.4	2439.9
Chhattisgarh	5938.7	5498.2	5400.0	4936.5	6234.1
Dadra & Nagar Haveli	1324.6	1286.5	1275.5	1244.5	1324.6
Gujarat	21386.8	20305.3	19707.3	18418.1	21386.8
Goa	660.3	605.9	577.3	532.7	707.7
Madhya Pradesh	14292.9	12376.0	11971.0	11282.0	14741.5
Maharashtra	27176.8	26333.2	25685.7	24146.6	28167.0
Andhra Pradesh	10938.4	10382.6	9906.0	9273.6	10965.8
Karnataka	12506.5	10297.9	9848.8	9322.6	13546.2
Kerala	4956.9	4261.4	4129.5	3859.9	5277.1
Puducherry	508.9	468.9	450.3	422.4	521.4
Tamil Nadu	18285.2	17131.1	16687.9	15556.6	18526.5
Telangana	12570.3	10156.9	9521.7	8731.3	14658.9
Bihar	7270.1	6935.9	6774.8	6440.8	7544.5
DVC	3870.1	3624.5	3467.3	3352.6	3870.1
Jharkhand	1873.7	1694.1	1647.9	1523.5	1908.0
Odisha	6741.3	5910.5	5687.9	5197.1	7029.0
Sikkim	92.1	74.8	67.6	51.4	122.7
West Bengal	11326.5	10228.5	9852.8	9300.1	11326.5
Arunachal Pradesh	172.3	156.5	148.7	133.0	183.6
Assam	2393.7	2225.5	2143.0	1909.9	2399.8
Manipur	192.0	150.7	136.6	106.8	221.3
Meghalaya	321.2	281.0	268.6	226.2	399.0
Mizoram	116.3	102.6	96.2	75.4	153.2
Nagaland	163.5	151.7	147.6	121.8	180.0
Tripura	416.0	313.8	301.1	271.4	416.0
Sum Total	249670.8	229270.0	222355.8	207809.7	258101
ALL INDIA Peak (NON SOLAR) Demand in 2023-24	216427				



# Dispatch during Critical Blocks in FY 2023-24(in GW)

Critical Days	Time Stamp	GAS	HYDRO	NUCLEAR	THERMAL	WIND	SOLAR	TOTAL GENERATION
Maximum demand block (Solar Hours)	01-09-2023 12:45:00	9.0	26.8	5.0	158.1	2.6	40.6	241.9
Maximum Demand Block (Non-Solar Hours)	28-08-2023 19:45:00	6.8	35.6	4.8	152.6	20.1	0.0	219.9
Minimum Wind Generation Block	04-05-2023 10:45:00	2.5	10.2	5.1	115.4	0.2	39.1	172.4
Minimum VRE generation Block	01-05-2023 06:45:00	2.6	13.4	5.1	127.8	0.9	0.0	152.1
Maximum Coal Generation Block	30-03-2024 19:30:00	3.7	17.2	4.3	168.5	7.7	0.0	201.5