FINAL REPORT ON RESOURCE ADEQUACY PLAN FOR THE STATE OF CHHATTISGARH

GOVERNMENT OF INDIA
MINISTRY OF POWER
CENTRAL ELECTRICITY AUTHORITY

Executive Summary

The electricity demand for the State of Chhattisgarh is increasing with a CAGR of 7.1 % from 2023-24 to 2029-30 as forecasted by 20th EPS. The projections of CSPDCL also indicate that electricity demand may increase with a CAGR of 5.0 % from 2023-24 to 2029-30. For satisfying resource adequacy i.e., meeting the electricity demand reliably and at affordable cost, the State need to methodically plan its capacity expansion either by investing or by procuring power. In view of the reduction in cost of solar panels and newer technology options like battery energy storage systems, planning for long term optimal generation capacity mix gains tremendous importance so as the future generation capacity mix is cost effective as well as environment friendly.

The electricity demand during the months of February, March and April is higher compared to rest of the year. The lowest electricity demand month is generally in the month of November. The peak electricity load is generally observed during morning hours during winter season and around flat load during summer season.

Ministry of Power had notified Electricity (Amendment) Rules in December, 2022. As per Rule 16 of the Electricity (Amendment) Rules, Ministry of Power has notified Resource Adequacy guidelines. As per the Resource Adequacy (RA) Guidelines, Central Electricity Authority is entrusted to prepare Long Term-National Resource Adequacy Plan (LT-NRAP). Further Distribution Utility need to carry out LTDRAP (Long term Discoms Resource Adequacy Plan) to meet the utility peak and energy requirement reliably.

The government of India has notified new RPO till 2029-30 which ensure certain amount of energy consumption to be met from renewable energy sources. However, while carrying out studies RPO Trajectory as per MOP order dated 22.07.2022 were considered.

The resource adequacy studies to assess the hourly generation dispatch with the existing and planned capacity have been carried out to assess the hourly demand supply gap till 2029-30 for Chhattisgarh based on inputs received from CSPDCL. It was found that the state's likely contracted capacity alone is not sufficient to meet projected demand.

To find out the least cost option for generation capacity expansion for the period 2023-24 to 2029-30, long-term study for the State of Chhattisgarh was carried with an objective to minimize the total system cost of generation including the cost of anticipated future investments while fulfilling all the technical/financial constraints associated with various power generation technologies.

The study was carried out considering existing capacity, planned capacity & capacity required to fulfil the Renewable Purchase Obligations (RPO). It was observed that in the year 2029-30 no additional capacity is required other that existing, planned and capacity required to fulfil the Renewable Purchase Obligations (RPO). The Resource adequacy studies have projected likely optimal capacity mix for future years till 2030 which is able to meet anticipated demand reliably at every instance.

Generation capacity expansion pathways have been considered for the long-term study based on the yearly capacity addition plans of the state along with RPO constraints for solar and wind technologies. The Renewable capacities have been assessed in view of adherence to RPO notified by Ministry of power considering the fungibility among different sources.

No additional capacity expansion from renewable capacities have been considered other than required for meeting RPO requirements in the studies. No capacity addition other than the planned addition in nuclear capacity has been considered in the studies.

1.0 Introduction

Ministry of Power has notified Electricity (Amendment) Rules, 2022 in December 2022. Rule 16 (I) of the said rules stipulates that "A guideline for assessment of resource adequacy during the generation planning stage (one year or beyond) as well as during the operational planning stage (up to one year) shall be issued by the Central Government in consultation with the Authority". Accordingly, the Resource Adequacy Guidelines have been notified in June, 2023 by Ministry of Power in consultation with Central Electricity Authority.

Resource Adequacy is generally defined as a mechanism to ensure that there is an adequate supply of generation resources to serve expected demand reliably at least cost. A key aspect of resource adequacy planning is to ensure that adequate generation capacities are available, round-the-clock, to reliably serve demand, under various scenarios. This naturally translates into the need for ensuring adequate reserve margin, which could cater to varying levels of demand and supply conditions in the grid. In the wake of high RE generation, it is important to understand demand-supply situation in the grid precisely due to high seasonality and intermittency in RE generation. Resource Adequacy exercise may also help in assessment of capacity requirement to be tied up or contracted on long term, medium term, and short-term basis.

Further, Ministry of Power vide order dated 22nd July 2022 had notified the RPO trajectory for the states. Based on the trajectory specified the hydro, wind and other (solar, biomass etc.) RPO quantum in million units (MUs) has been calculated to find additional quantum of renewable capacity that the states have to contract in addition to its existing/planned capacity to meet their RPO targets.

Resource Adequacy studies has been carried out for Chhattisgarh based on the inputs received from CSPDCL and fulfilling the RPO trajectory. The study suggests the optimal resource mix till 2030 taking into account all technical and financial parameters associated with capacities. The study optimizes power purchase on a long-term basis while evaluating resource adequacy for meeting the demand 24 X 7 considering variation in demand, RE generation and forced outages of thermal capacities. The study has also assessed the requirement of Planning Reserve margin for Chhattisgarh for catering to above highlighted uncertainties so that demand can be met reliably throughout the year.

2.0 Chhattisgarh RA Study

2.1 Present Power Scenario in Chhattisgarh

As of March 2023, the total contracted capacity for Chhattisgarh is 7,858 MW. Out of the total contracted capacity (CC), the share of non-fossil fuel-based CC is 20 %.

The fuel-wise contracted capacity as on March 2023 is given in Table and Figure below:

Table 1 Fuel-wise Contracted Capacity as on Mar 2023

Source	Contracted Capacity (MW)	Percentage
Coal	6284	80%
Nuclear	48	1%
Biomass	182	2%
Hydro	427	5%
Solar	517	7%
Hybrid	400	5%
Wind	0	0%
Total	**7858**	**100**

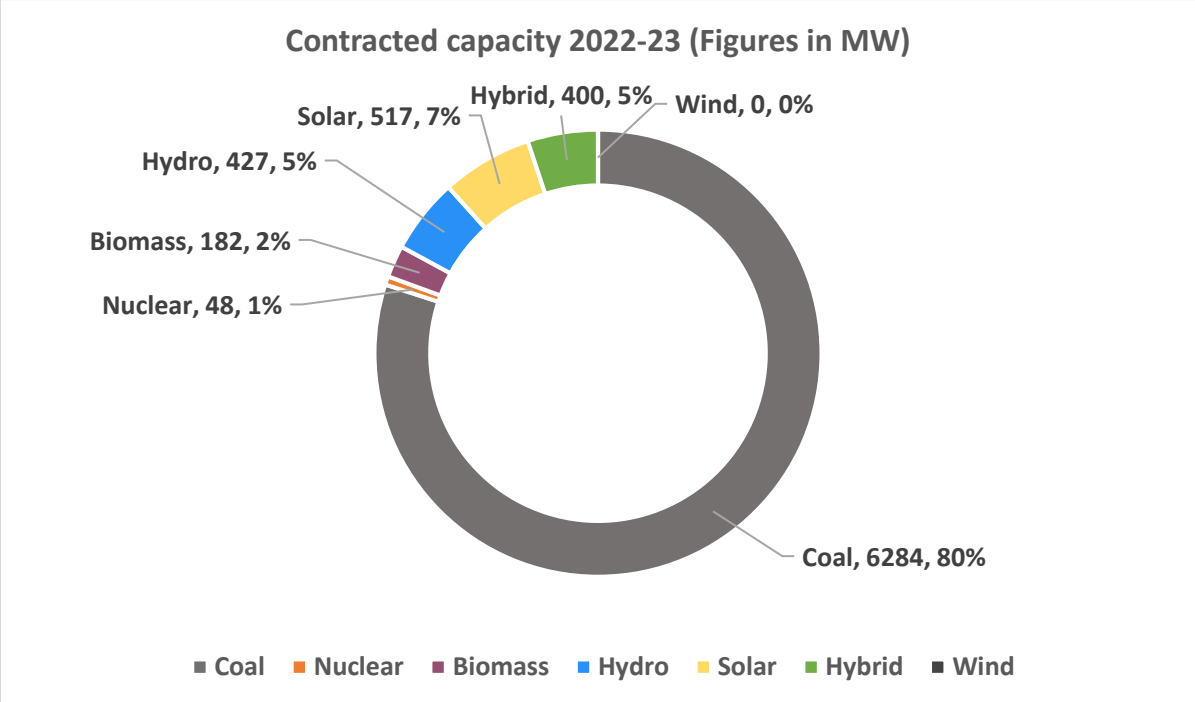


Figure 1 Fuel-wise Contracted Capacity (in MW) as on March 2023

2.2 Present Demand Analysis (2022-23)

The hourly demand pattern of Chhattisgarh was analyzed in detail and it was observed that the peak demand of Chhattisgarh is almost similar during day and night and peak is observed during February and March months.

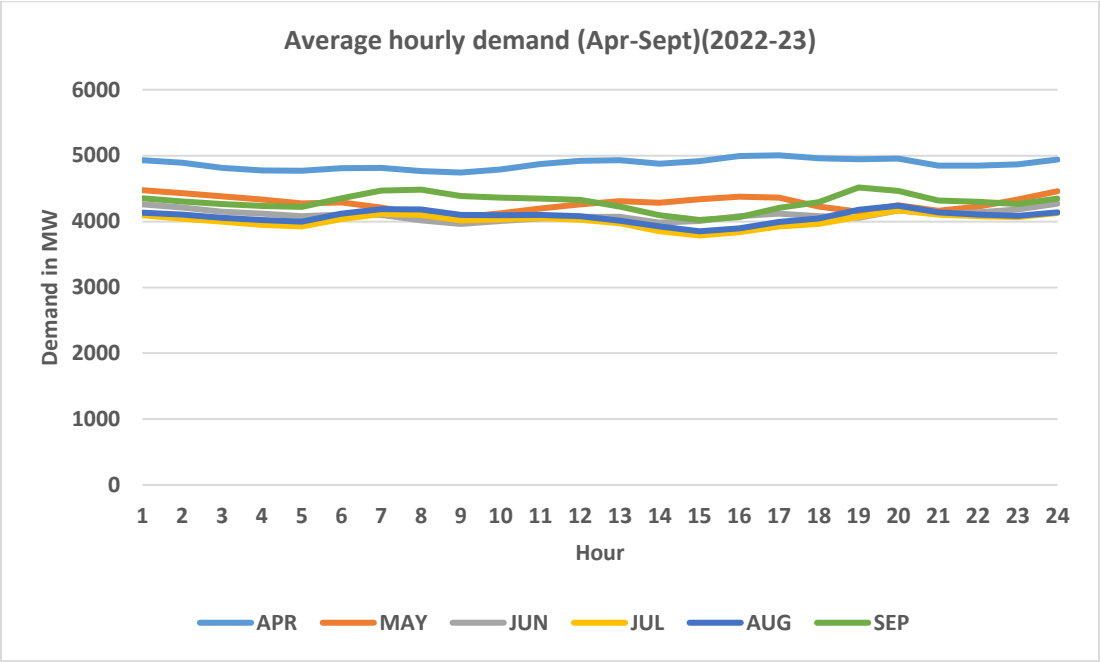


Figure 1 Month-wise hourly demand pattern for Chhattisgarh (Apr-Sept)

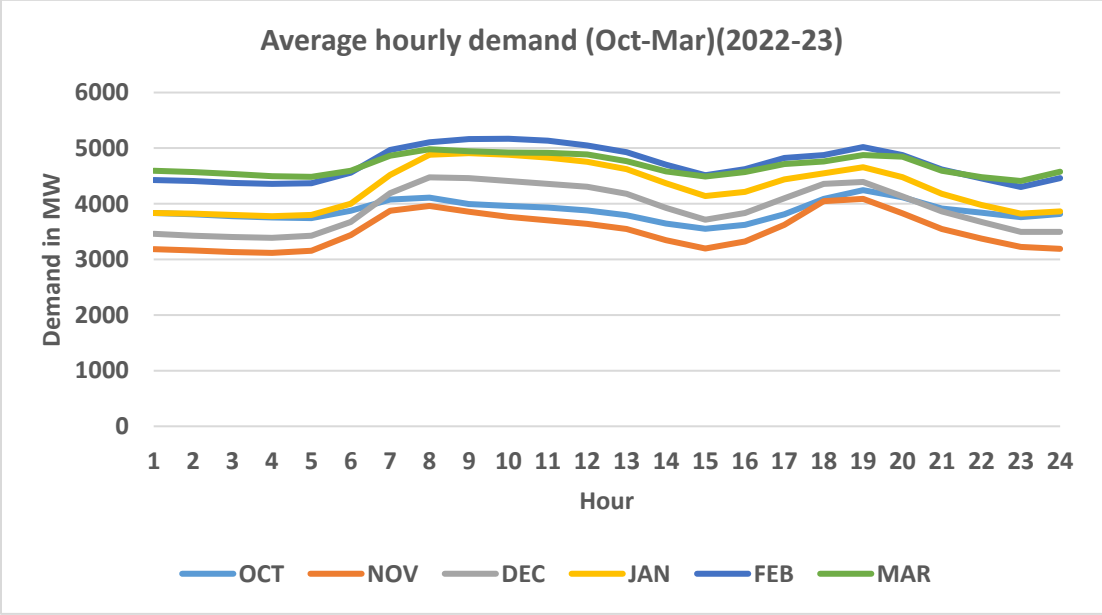


Figure 1 Month-wise hourly demand pattern for Chhattisgarh (Oct-Mar)

From the above pattern, it can be seen that there is almost flat demand curve during Apr-Sept and there is day and night peak during Oct-Mar.

The solar and non-solar hours peak demand for the year is plotted and shown in the figure below. It can be observed that the day and night peak demand are almost the same for the summer months i.e., April-September. However, for rest of the months day peak is relatively higher. The same can be seen in the figure below. In such cases, potential for shifting of demand/load from non-solar hours to solar hours may be explored and encouraged by the utility.

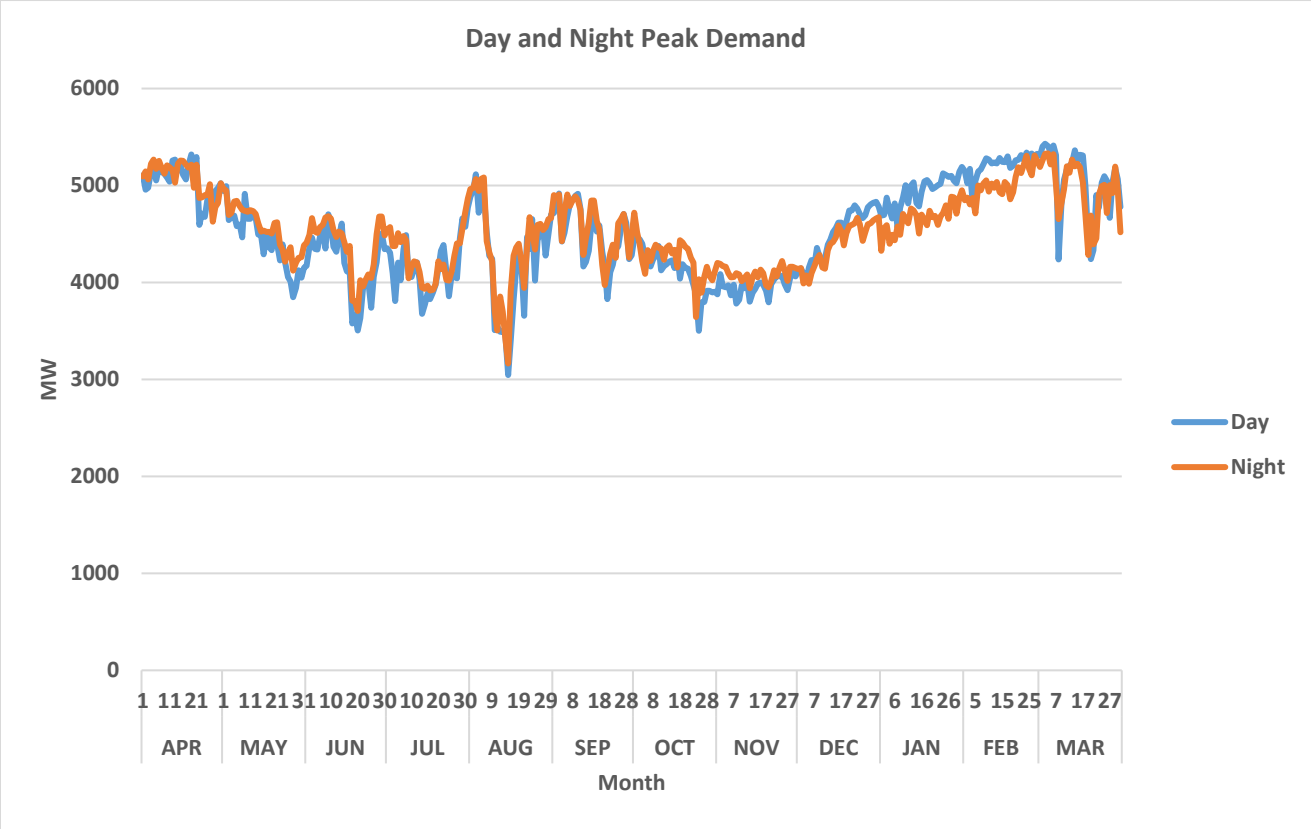


Figure 3 Day and Night Peak in MW of Chhattisgarh (2022-23)

3.0 Inputs/Assumptions for the Study

i) Peak and Energy Demand for the state of Chhattisgarh has been taken as per 20th EPS (Electric Power Survey) report, as the actual peak demand and energy requirements are closer to the projections made by 20th EPS. This can be seen from Table 1 below, which show the actual energy requirement and peak demand of Chhattisgarh and the projections as per 20th EPS.

Table 1 Peak Demand and Energy Requirement as per Actuals and 20th EPS

Year	Actual Peak Demand (in MW)	Peak Demand projected in 20th EPS (in MW)	Actual Energy Requirement (in MU)	Energy requirement projected in 20th EPS (in MU)
2021-22	5,019	5,029	31,908	31,948
2022-23	5,399	5,358	39,051	36,260

The year-wise Energy and Demand projections as per 20th Electric Power Survey and CSPDCL are given below:

Table 2 Energy Requirement (MU) and Peak Demand (MW) Projections as per 20th EPS

Energy Requirement (MU) and Peak Demand (MW) Projections							
	2023-24	**2024-25**	**2025-26**	**2026-27**	**2027-28**	**2028-29**	**2029-30**
Energy Projections (MU)	38528	41223	44130	47208	50475	53900	57983
Peak Demand Projections (MW)	5708	6132	6592	7081	7602	8152	8805
Year on Year Growth (Energy)		6.99 %	7.05 %	6.97 %	6.92 %	6.79 %	7.58 %
Year on Year Growth (Peak)		7.43 %	7.50 %	7.42 %	7.36 %	7.23 %	8.01 %

Table 31 Energy Requirement (MU) and Peak Demand (MW) Projections as per CSPDCL

Energy Requirement (MU) and Peak Demand (MW) Projections							
	2023-24	**2024-25**	**2025-26**	**2026-27**	**2027-28**	**2028-29**	**2029-30**
Energy Projections (MU)	39158	41115	43171	45330	47596	49976	52475
Peak Demand Projections (MW)	5824	6232	6668	7135	7634	8168	8740
Year on Year Growth (Energy)		5.0 %	5.0 %	5.0 %	5.0 %	5.0 %	5.0 %
Year on Year Growth (Peak)		7.00 %	7.00 %	7.00 %	7.00 %	7.00 %	7.00 %

From the above tables and the figures given below, it can be seen that the projections of CSPDCL energy projections are on the lower side but peak projections are almost similar as that of the 20th EPS.

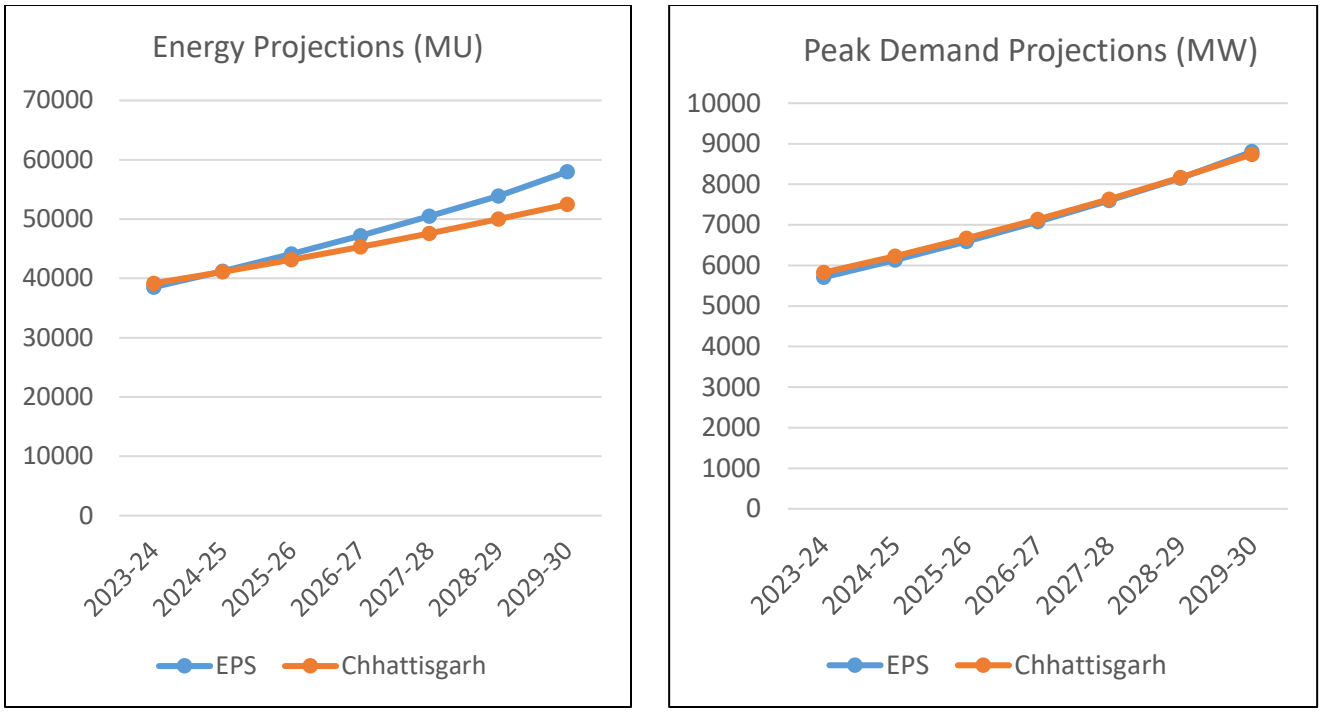


Figure 2 Comparison of Energy and Peak Demand Projections as per EPS and Chhattisgarh

From the comparison of the projections of 20th EPS and CSPDCL, it can be seen that the energy projections of CSPDCL are slightly on the lower side and peak projections are almost similar, and the projections of 20th EPS are closer to the actual energy requirement and peak demand for 2021-22 and 2022-23, and the growth trajectory considered in the 20th EPS is closer to actual. Hence, for the purpose of this study considering 20th EPS demand instead of CSPDCL demand is justified, as considering CSPDCL demand might lead to lower contracted capacity for meeting the demand in the future for Chhattisgarh.

ii) The demand profile for 8760 hours for the year 2029-30 has been projected using the demand profile for the year 2022-23.

iii) The Solar generation profile for solar plants located in western region has been taken as per RE generation provided for solar plants in Chhattisgarh state and for solar plants located in other regions has been taken as per National Electricity Plan Studies.

iv) The Wind generation profile of Western Region has been considered for generating wind generation profile for Chhattisgarh.

v) Capital cost of candidate plants for Coal, Wind, Solar and Battery has been referred from National Electricity Plan.

vi) The year-wise contracted/planned capacity addition (MW) as furnished by the State of Chhattisgarh is shown in table below:

Table 4 Planned contracted Capacity addition of state, based on existing and planned contracted capacity addition till 2029-30

FY/Technology	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30
Thermal	0	0	0	400	1200	1060	660
Nuclear	88	0	0	0	0	600	0
Solar	690	400	0	0	0	0	0
Wind	770	0	0	0	0	0	0
Hybrid	400	400	0	0	0	0	0
Hydro	155	300	550	100	0	150	0
Biomass	8	0	0	-13.5*	-64.15*	-7.2*	-17.82*
Total	**2111**	**1100**	**550**	**486.5**	**1135.85**	**1802.8**	**642.18**
Battery	**40 MW (3Hours)**	**0**	**0**	**0**	**0**	**0**	**0**

* -ve capacity is due to termination of PPAs in the respective years

vii) Ministry of Power vide order dated 22nd July 2022 had notified the RPO trajectory for the states. Based on the trajectory specified the hydro, wind and other (solar, biomass etc.) RPO quantum in million units (MUs) has been worked out to find additional quantum of renewable capacity that the state has to plan in addition to its existing/planned capacity to meet its RPO targets.

The table below shows the details of the hydro, wind and other RPO requirement as per the RPO trajectory notified by Ministry of Power for the state of Chhattisgarh.

Table 5 Hydro, wind and other RPO requirement as per the RPO trajectory notified by Ministry of Power for the state of Chhattisgarh

Source-wise total Energy required to meet various RPO (MU) as per MoP order dated 22.07.2022							
	2023-24	**2024-25**	**2025-26**	**2026-27**	**2027-28**	**2028-29**	**2029-30**
Hydro RPO	616	1014	1483	2025	2640	3320	4024
Wind RPO	254	445	653	850	1085	1353	1635
Other RPO	9559	10871	12431	14096	15864	17620	19465

viii) The generation eligible to meet the Hydro/Wind/other RPO (in MU) for the state of Chhattisgarh is given below.

Table 6 Generation eligible to meet the Hydro/Wind/other RPO (in MU) for the state of Chhattisgarh

Source-wise Generation eligible for various RPO (MU)							
	2023-24	**2024-25**	**2025-26**	**2026-27**	**2027-28**	**2028-29**	**2029-30**
Hydro Generation	888	1808	3494	3800	3800	4260	4260
Wind Generation	2415.57	2706.84	2706.84	2706.84	2706.84	2706.84	2706.84
Generation eligible for Other RPO	4063	5290	5290	5268	5167	5156	5128

ix) As per the Ministry of Power order dated 22nd July 2022 and corrigendum dated 19th September 2022, any shortfall in achievement of "Wind RPO" can be met from excess generation from hydro sources which are eligible for "Hydro RPO" and vice versa. Similarly, any shortfall in "Other RPO" in a particular year can be met with excess generation from hydro sources eligible for "Hydro RPO" or excess generation from wind sources eligible for "Wind RPO" or partly from both.

x) The table below provides the details of the shortage in various RPOs, after considering fungibility from the surplus hydro and Wind generation.

Table 7 Shortage in various RPOs, after considering fungibility from the surplus hydro and Wind generation.

Shortfall (-) in various RPO after considering fungibility from Hydro and wind RPO (MU)							
	2023-24	**2024-25**	**2025-26**	**2026-27**	**2027-28**	**2028-29**	**2029-30**
Hydro RPO	0	0	0	0	0	0	0
Wind RPO	0	0	0	0	0	0	0
Other RPO	-3064	-2526	-3077	-5196	-7915	-10170	-13029

xi) It can be seen from the above table that existing and planned wind capacity is completely meeting the Wind RPO every year except for the years 2028-29 and 2029-30. The shortfall in wind RPO in year 2028-29 and 2029-30 is fulfilled by considering fungibility from the excess

hydro generation. The surplus hydro generation after meeting wind RPO till 2027-28 is considered for fungibility for Other RPO.

xii) In order to meet its Renewable Purchase Obligation (RPO), as per RPO trajectory notified by the Ministry vide order dated 22nd July, 2022, Chhattisgarh needs to add/contract following additional capacity (MW) apart from the planned capacity, based on the calculations shown in the tables above:

Table 8 Additional Capacity (MW) required to be added/contracted for meeting the year-wise RPO

Additional Capacity (MW) required to be added/contracted for meeting the year-wise RPO								
	2023-24	**2024-25**	**2025-26**	**2026-27**	**2027-28**	**2028-29**	**2029-30**	**Total**
Wind	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Small and large Hydro	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Solar and other RE	1665.35	0.00	7.28	1151.69	1478.16	1225.89	1554.19	**7082.56**
Total	**1665.35**	**0.00**	**7.28**	**1151.69**	**1478.16**	**1225.89**	**1554.19**	**7082.56**

4.0 Reliability Analysis

One of the main criteria of resource adequacy studies is to determine the reliability of the system to meet the demand adequately at very instance of time. This reliability is measured via two indices (i.e.) LOLP (Loss of Load Probability) and EENS (Expected Energy Not Served). These indices have been defined in resource adequacy guidelines as below:

- **Loss of Load Probability (LOLP)**: Measure of the probability that a system's load may exceed the generation and firm power contracts available to meet that load in a year. E.g., 0.0274 % probability of load being lost.
- **Expected Energy Not Served (EENS):** Expected amount of energy (MWh) that may not be served for each year within the planning period under study. It is a summation of the expected number of megawatt hours of demand that may not be served for the year. This is an energy-centric metric that considers the magnitude and duration of energy being not served, calculated in Mega Watt hours (MWh). The metric can be normalized (i.e., divided by total system load) to create a Normalized Energy Not Served (NENS) metric.

Monte Carlo /Stochastic simulation has been used to factor-in the uncertainty associated with various generation resources and demand. It is an approach which is used to predict the probability of a variety of outcomes when the potential for random variables is present as compared to deterministic modelling of economic dispatch model. Monte Carlo simulation helps in analysing the randomness associated with RE energy resource, demand pattern changes and forced outages of plant. A large no of random samples of these variables are simultaneously simulated to ascertain system reliability indices (i.e. Loss of load probability LOLP & Energy Not Served (ENS)) & the system robustness in case of above variation of system parameters.

Planning Reserve Margin (PRM): To meet the prescribed standard of LOLP / NENS conditions, sufficient reserve margins need to be maintained in the system for adequately addressing the demand and supply variations. Planning Reserve Margin (PRM) is the predominant metric used to ensure adequacy of generation resources in the system. PRM in a power system is expressed as a certain % of peak load forecast of the system.

4.1 Demand variation:

The variation in demand pattern of CSPDCL for last 5 years has been analyzed. The hourly demand variation for consecutive years (i.e., 2021-22 and 2022-23) has been analyzed.

The Demand pattern variation of 2021-22 and 2022-23 is shown below.

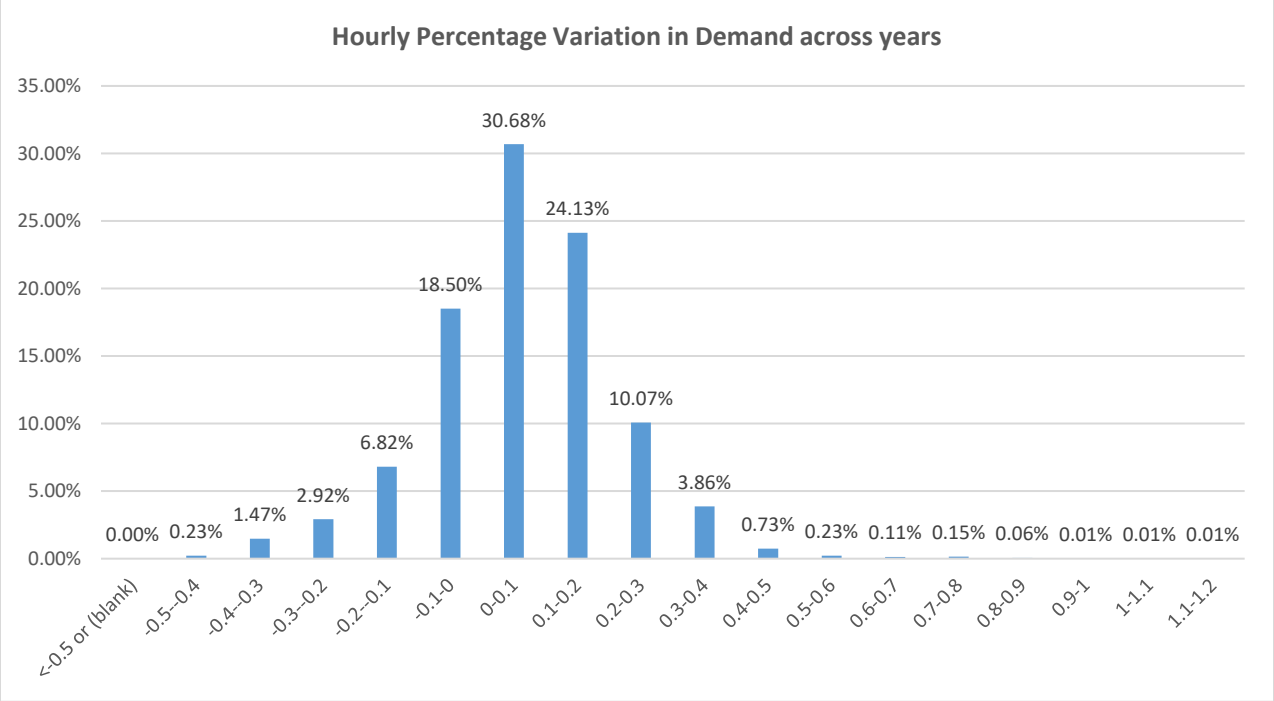


Figure 5 Hourly Percentage Variation in Demand across years

It can be observed that the hourly demand typically varies ±10% for 73% of instances from corresponding hour in previous years (Normalized figure). This variation is primarily due to temperature, weather parameter or any random outages of transmission line and generation units etc. This variation has been captured in the reliability study by varying the projected hourly demand for the future years by varying ±10% by introducing a random variable (with normal distribution) for demand as per the observed behavior over the years.

4.2 RE variation

In the Long-term capacity expansion planning studies, a particular profile for Solar and Wind Plants are considered based on the observed solar and wind generation data to determine the optimal capacity mix. However due to intermittent nature of these sources the generation from these non-dispatchable sources may vary across years. As per the analyses carried out based on historical generation data, solar generation and wind generation has been varied by 5% and 50% respectively to incorporate the variation in these generation sources and plan for requisite measures to mitigate such behavior.

4.3 Forced Outage of Thermal Generators

The forced outage rate of thermal generators of CSPDCL were observed for previous years and it was observed that average forced outage rate is typically at 10% with ±5% variation. The same has been incorporated in the model.

Based on the variation reliability studies are carried out to ascertain robustness of the system. The LOLP & EENS of the system is within specified range.

5.0 Results of the study

5.1 Capacity Mix Projection

Studies were carried out by considering the inputs received from the state by using the Ordena software. Studies results showed that after considering existing generation capacity, the planned capacity of the state (provided by CSPDCL) and the capacity required for meeting RPO requirements, there was no unserved energy till year 2029-30.

As per studies, the total projected Capacity for the year 2029-30 is 22768 MW which consists of 9604 MW from Coal, 736 MW from Nuclear, 1682 MW from Hydro (including small Hydro), 770

MW from Wind, 8689 MW from Solar, 1200 MW from Hybrid and 87 MW from Biomass, also 40 MW (3 Hour) of Battery is required to meet the projected demand. The share of non-fossil fuel based IC is 57.8 %.

The Reliability studies have been carried out to adhere to the reliability criteria of LOLP and NENS as provided in NEP (0.2% and 0.05% respectively). The PRM for the state of Chhattisgarh has been assessed as 5%. In addition, the projected/contracted capacity fulfils the stipulated Renewable Purchase Obligation.

The capacity projections for Chhattisgarh are given below:

Table 9 Year-wise capacity projections (in MW)

	COAL	NUCLEAR	BIO-MASS	HYDRO	WIND	SOLAR	HYBRID	TOTAL	Storage (Battery 3 Hours)
2023-24	6284	136	190	582	770	2872	800	11634	40
2024-25	6284	136	190	882	770	3272	1200	12734	40
2025-26	6284	136	190	1432	770	3279	1200	13291	40
2026/27	6684	136	177	1532	770	4431	1200	14930	40
2027/28	7884	136	112	1532	770	5909	1200	17543	40
2028/29	8944	736	105	1682	770	7135	1200	20572	40
2029/30	9604	736	87	1682	770	8689	1200	22768	40

The projected capacity mix, year-wise is given in the figure below:

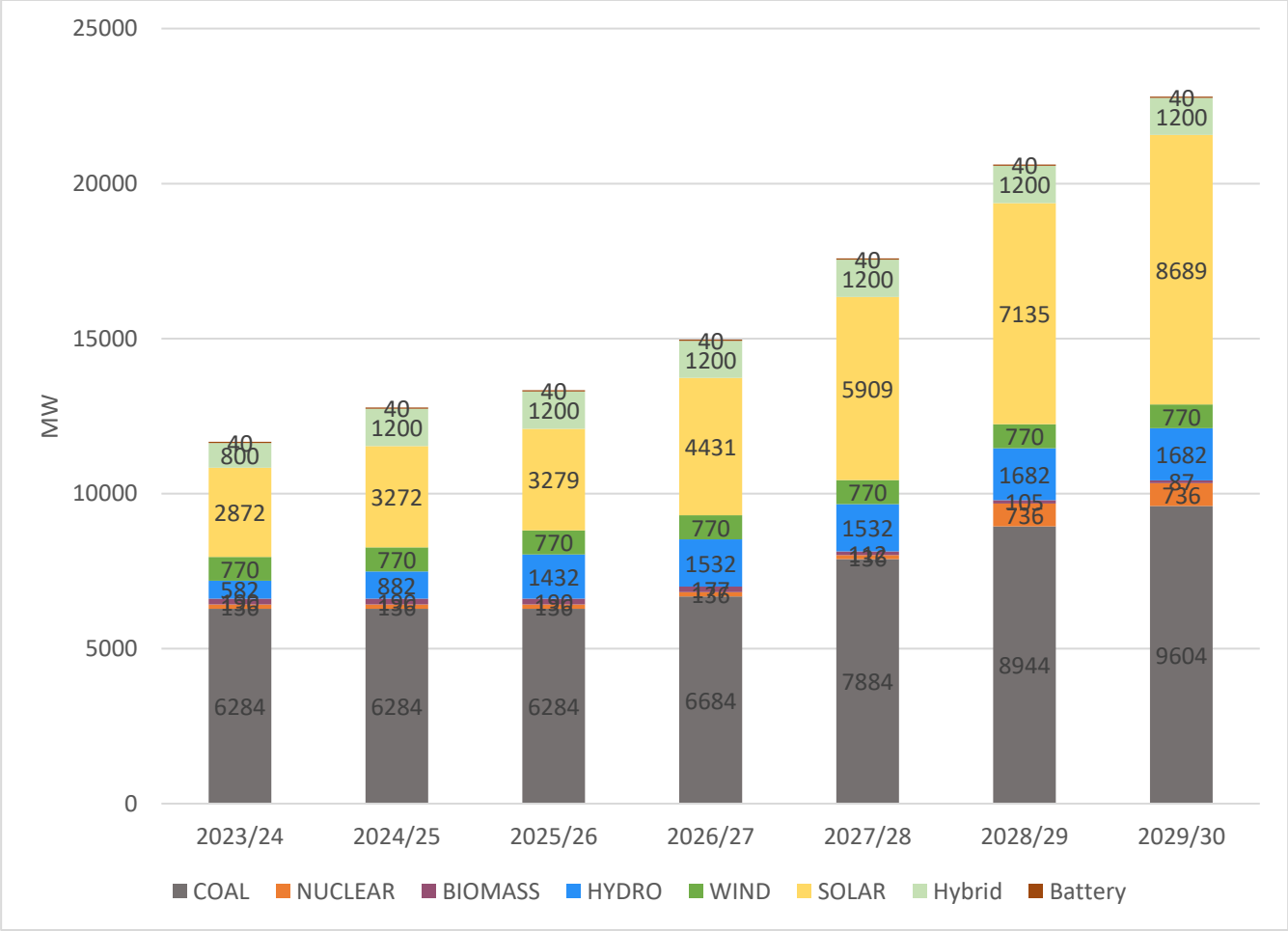


Figure 6 Projected Contracted Capacity of Chhattisgarh 2023-30 (5 % PRM)

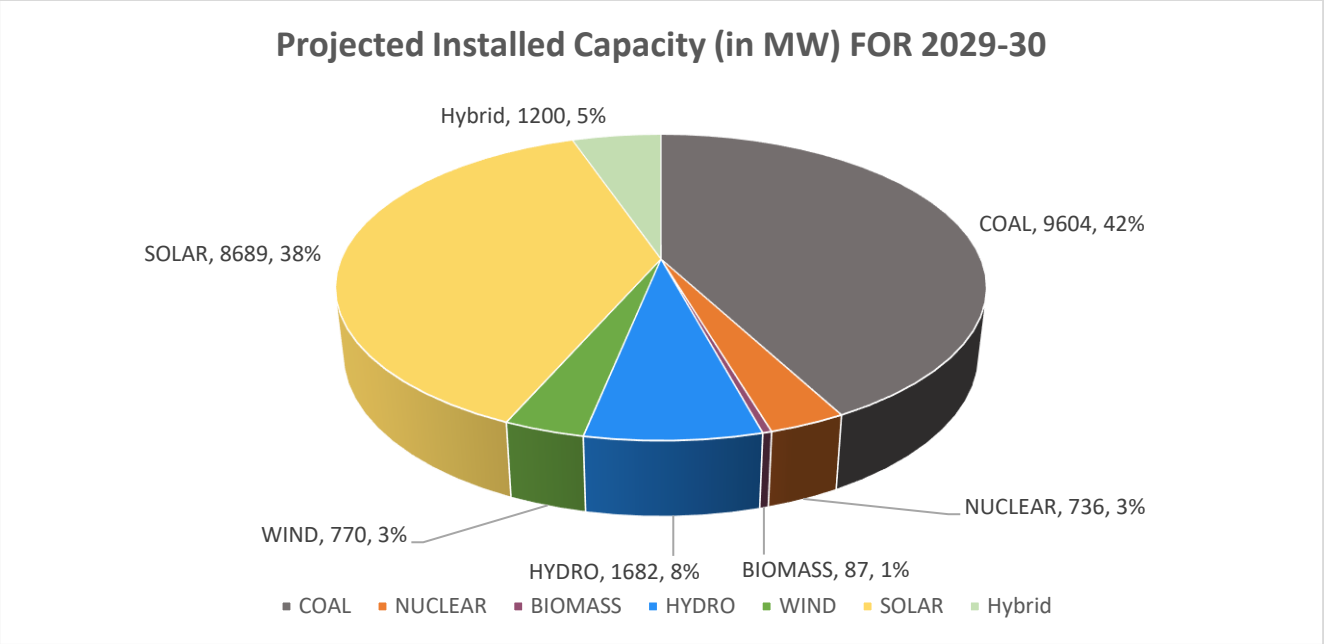
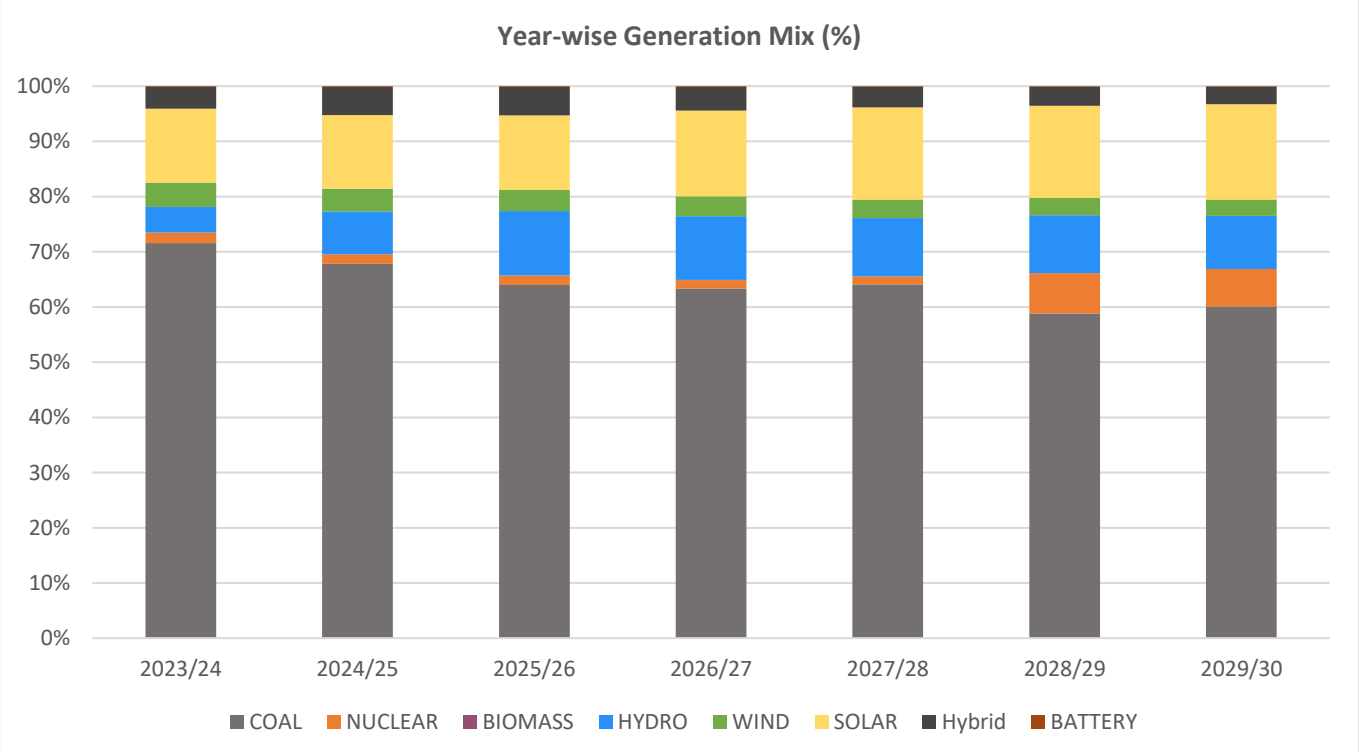
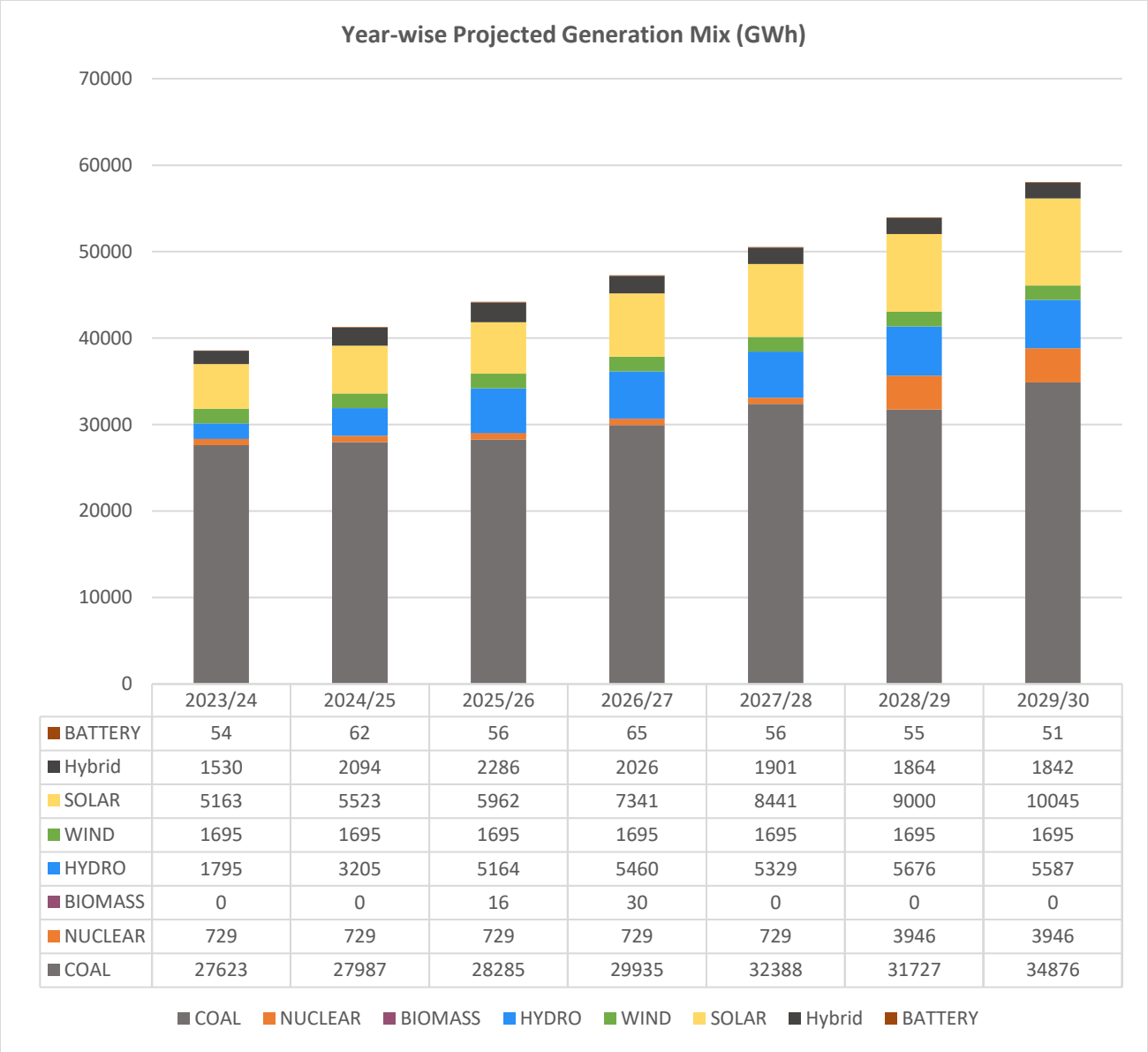


Figure 7 Projected Installed Capacity (MW) for 2029-30





	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30
BATTERY	54	62	56	65	56	55	51
Hybrid	1530	2094	2286	2026	1901	1864	1842
SOLAR	5163	5523	5962	7341	8441	9000	10045
WIND	1695	1695	1695	1695	1695	1695	1695
HYDRO	1795	3205	5164	5460	5329	5676	5587
BIOMASS	0	0	16	30	0	0	0
NUCLEAR	729	729	729	729	729	3946	3946
COAL	27623	27987	28285	29935	32388	31727	34876

Figure 8 Year-wise projected generation mix (in % and GWh)

5.2 Capacity contract requirement for future

It has been found out in the studies that Chhattisgarh needs to contract following capacities (planned and additional) per year till to meet its demand reliably along with fulfilment of its RPO as notified by MoP.

Year-wise capacity addition required to meet the projected demand while fulfilling RPO obligation are as below:

Table 10 Year wise, Source Wise Capacity Addition (in MW)

Year	Coal	Nuclear	Hydro	Solar		Wind	Hybrid	Biomass	Total		Battery
	Planned	Planned	Planned	Planned	Addition	Planned	Planned	Planned	Planned	Addition	Planned
2023/24	0	88	155	690	1665	770	400	8	**2111**	**1665**	40
2024/25	0	0	300	400	0	0	400	0	**1100**	**0**	0
2025/26	0	0	550	0	7	0	0	0	**550**	**7**	0
2026/27	400	0	100	0	1152	0	0	0	**486.5**	**1152**	0
2027/28	1200	0	0	0	1478	0	0	0	**1135.85**	**1478**	0
2028/29	1060	600	150	0	1226	0	0	0	**1802.8**	**1226**	0
2029/30	660	0	0	0	1554	0	0	0	**642.18**	**1554**	0

Note: No additional storage is required, 40 MW (3 hour) Battery planned in year 2023-24 is sufficient till 2029-30

5.3 Coal Capacity Performance

The coal capacity PLF is expected to remain in the range of 43%- 56% for the years till 2030 ensuring higher absorption of higher renewable energy.

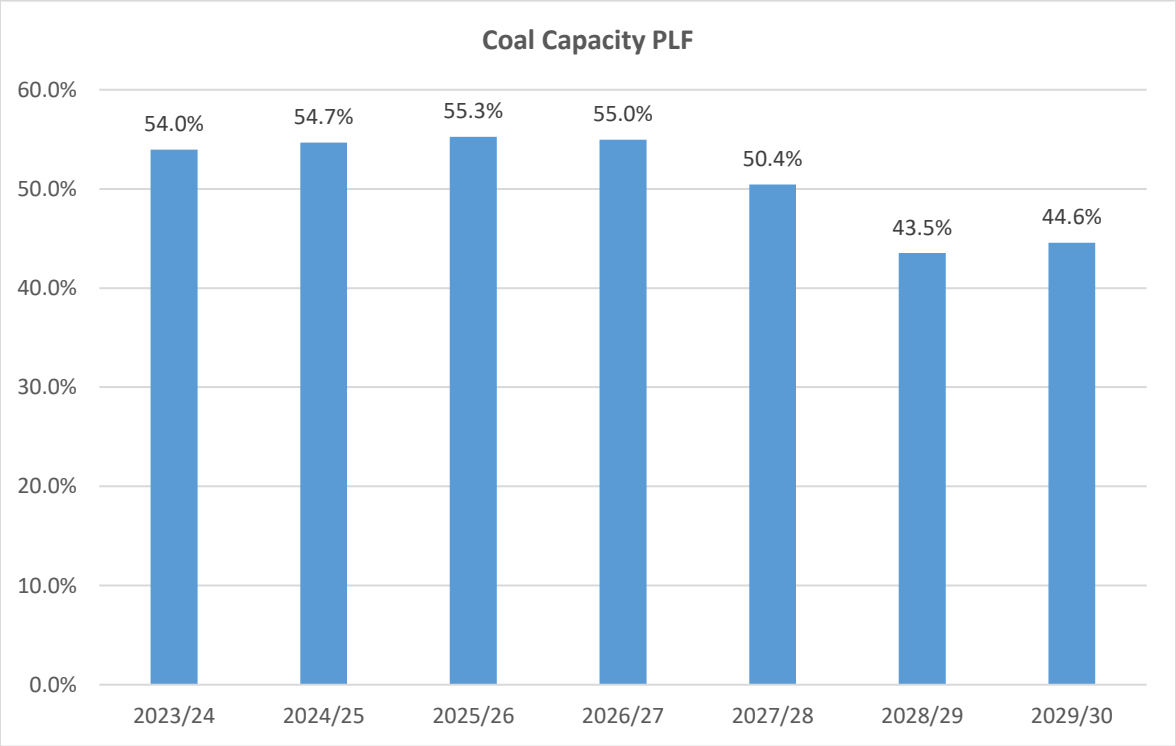


Figure 10 Year-wise coal capacity PLF for Chhattisgarh (in %)

5.4 Day-wise Surplus Capacity Chhattisgarh (MW)

Surplus capacity is available with states due to RE availability, Demand variation etc. The pattern of surplus capacities for Chhattisgarh has been observed as below. This capacity can be shared with other states and reduce the fixed cost burden on the utilities resulting in reduction in the cost for consumer. It can be seen from the above graph that the surplus coal capacity is available throughout the years except for month Feb, March and April, with the ranging from around 400-3400 MW for the year 2026-27.

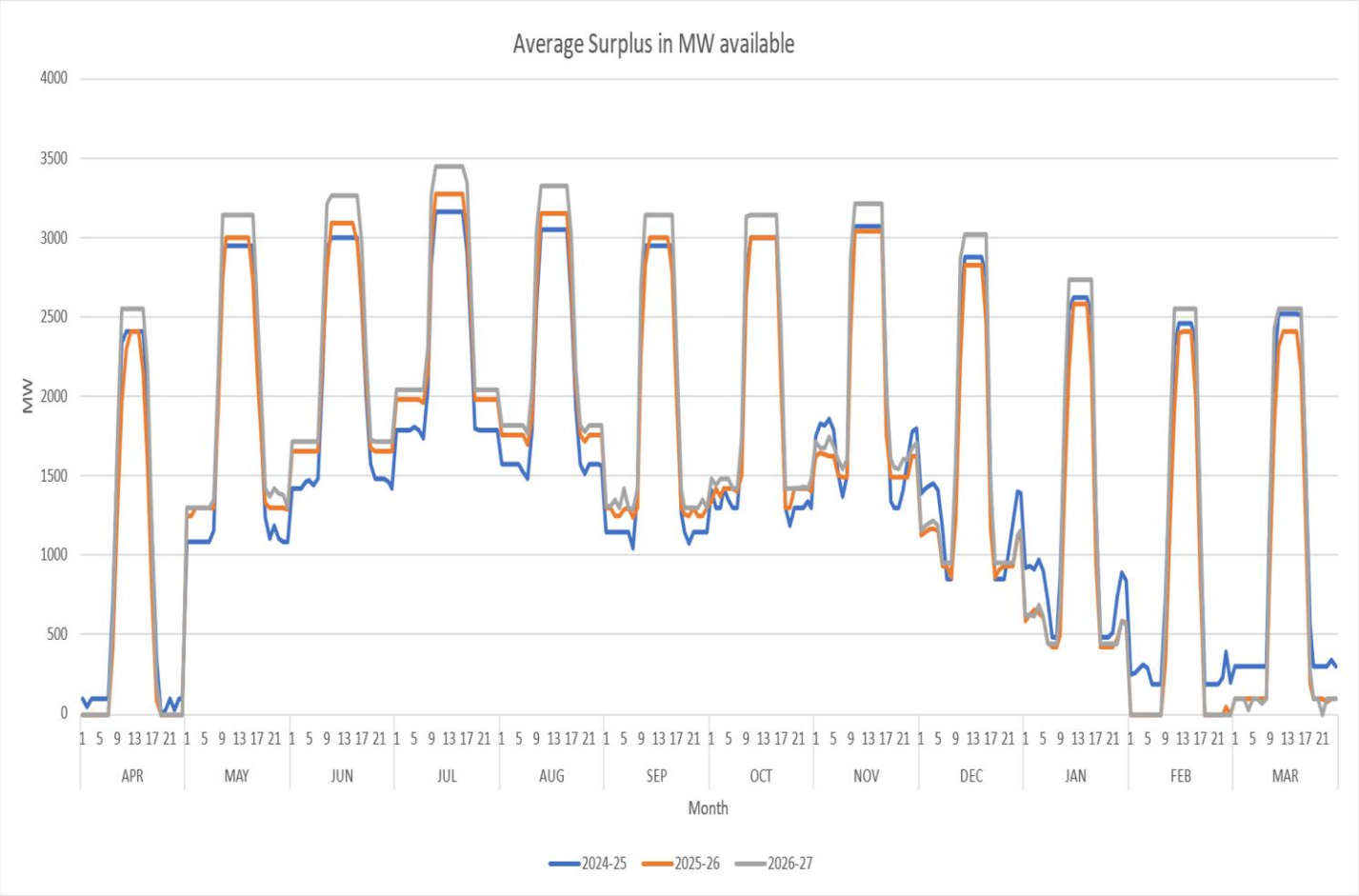


Figure 9 Surplus Coal Capacity Year-wise (MW)

6.0 Alternate Resilient Scenario Analysis

In view of the recent surge in Power demand during the year 2023-24 and capacity addition being delayed compared to the envisaged timelines, it was realized that stress scenario may be assessed to comprehend such situations arising in the future and prepare the utilities for

navigating such challenging situations optimally so as to fulfil their consumer end demand reliably.

The following cases were considered to occur simultaneously in the stress scenario:

- Peak and Energy Demand- 5% increase compared to the EPS demand
- Capacity Addition being delayed from their anticipated year as follows:

Table 11 Time Delay in commissioning of contracted capacity

Contracted Capacity Type	Years Delayed
Hydro	2
Nuclear	2
Renewable Energy Capacity	1
Coal	1

6.1 Year-wise RPO Requirement in Alternate Resilient Scenario:

Table 12 Year-wise capacity requirement (in MW) for RPO compliance in Alternate Resilient Scenario

Alternate Resilient Scenario Additional Capacity(MW) required to be added/contracted for meeting the Year-wise RPO (in MW)								
	2023-24	**2024-25**	**2025-26**	**2026-27**	**2027-28**	**2028-29**	**2029-30**	**Total**
Wind	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Small and large Hydro	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solar and other RE	3889	0	0	480	633	1383	1631	8015
Total	**3889**	**0**	**0**	**480**	**633**	**1383**	**1631**	**8015**

6.2 Capacity Mix Projections

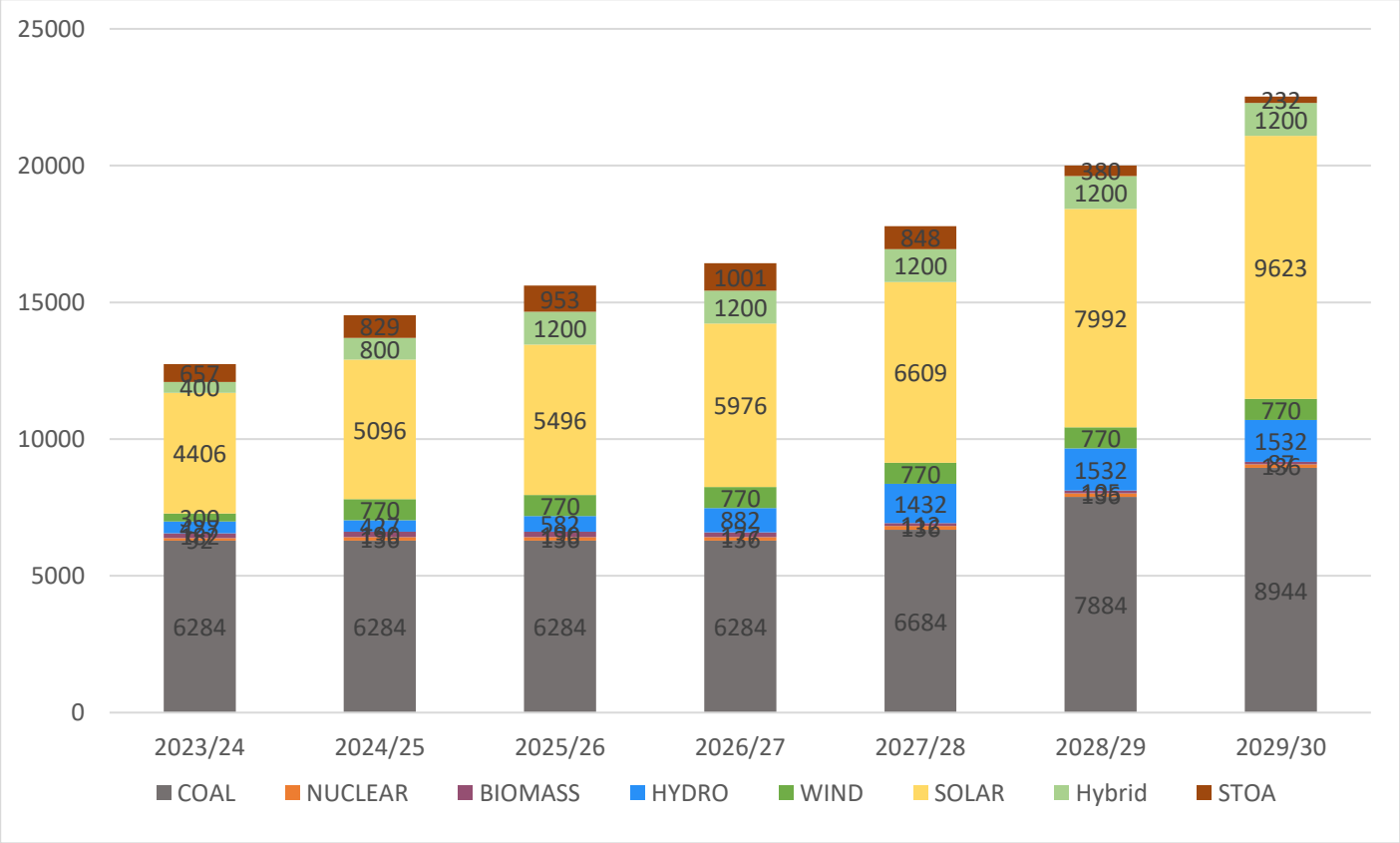


Figure 11: Year-wise capacity projections (in MW) for Alternate Resilient Scenario

In this scenario, Storage is required from year 2024/25 onwards ranging around 180 - 690 MW in different years. The dependence on short term open access (STOA) will increase from year 2023-24 ranging from 230-1100 MW.

If Additional Capacity required for meeting RPO in stress case is only 70% realized due to delay in commissioning of RE projects, then, STOA requirement gets further increased by 30 MW-70 MW starting from year 2024-25.

7.0 Conclusion

The study has considered two scenarios Base case and Alternate resilient scenario for assessing the resource adequacy of Chhattisgarh based on the demand projections by Electric Power Survey. The demand projections by CSPDCL are lower compared to the demand projections by 20th Electric Power Survey (EPS).

The current capacity mix in Chhattisgarh has 20% of IC from fossil fuel sources. The peak demand season is in months of February and March. The study is based on the hourly load pattern of the year 2022-23.

Chhattisgarh is deficit in fulfilment of its Renewable Purchase Obligations (RPO) and needs to contract renewable capacities for fulfilling them. The projected capacity and generation mix fulfils the RPO and ESO obligations by 2030 as specified by Ministry of Power. It requires to contract solar capacity from 2023/24 onwards.

In Base case scenario, Chhattisgarh does not require any additional capacities to be procured other than the capacity already planned and capacity required to fulfill RPO obligations. The quantum of solar capacity required to be contracted is about 7082 MW till year 2029-30.

Also, No additional storage requirement is required other than planned 40 MW (3 hours) in Base case scenario.

The coal capacity PLF is expected to remain in the range of 43%- 56% for the years till 2030 ensuring higher absorption of higher renewable energy.

It is likely that Chhattisgarh may have the surplus coal capacity available throughout the years except for month Feb, March and April, with the ranging from around 400-3400 MW for the year 2026-27.

The Alternate Resilient Scenario carried out for Chhattisgarh for possibility of higher demand than projected by 20th Electric Power Survey has revealed that the storage is required from year 2024/25 onwards ranging around 180 - 690 MW in different years. The dependency on STOA also increases compared to the base case scenario.

Assumption for Resource Adequacy Studies for the state of Chhattisgarh

1. Electricity Demand & peak requirement: As per 20th Electric Power Survey
2. Demand Profile: Based on hourly demand profile of 2022-23
3. Existing & Planned Capacity: As per the information received from CSPDCL
4. Future Capacity addition: based on RPO trajectory
5. Cost parameters: based on information in National Electricity Plan

RE CUF considered

Hydro PLF Existing & Planned	Bioenergy PLF	Solar CUF Existing & Planned	Wind CUF Existing & Planned	Small Hydro CUF
34% & 35%	18%	20% & 21%	25%	17.2%

RPO Trajectory

	RPO Target Trajectory (%)							
	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30
Wind RPO	0.81	1.60	2.46	3.36	4.29	5.23	6.16	6.94
Hydro RPO	0.35	0.66	1.08	1.48	1.80	2.15	2.51	2.82
Other RPO	23.44	24.81	26.37	28.17	29.86	31.43	32.69	33.57

Technical Parameters

Technology	Type	Availability (%)	Ramping (%/min)	Min. Technical. (%)	Start -up time (hr)		
					Hot	Warm	Cold
Coal/ Lignite	Existing/Planned	85	1	55	2	5	10
	Candidate	88	1	55	2	5	10

Gas	Existing	90	5	40	1.5	2	3
Nuclear	Existing/Planned	68	Const. Load	-	-	-	-
Biomass	Existing/Planned	60	2	50	2	4	8
Hydro	Existing/Planned/ Candidate	As per available hourly generation profile	100	-	-	-	-
Solar	Existing/Planned		-	-	-	-	-
	Candidate		-	-	-	-	-
Wind	Existing/Planned		-	-	-	-	-
	Candidate		-	-	-	-	-
Pumped storage	Existing/Planned	95	50	-	-	-	-
	Candidate		50	-	-	-	-
Battery Energy Storage	Candidate	98	NA	-	-	-	-

Technology	Type	Heat Rate (MCal/MWh)		Aux. Consum. (%)	Min. online time (hr)	Min. offline time (hr)	Start-up fuel consumption (MCal/MW)		
		At max loading	At min loading				Hot	Warm	Cold
Coal	Existing/ Planned	2300 to 2879	2438 to 3052	7.0	6	4	600	1000	1800
	Candidate (SC & USC)	2060 to 2125	2183 to 2253	6.5	6	4	600	1000	1800
Gas	Existing	2000 to 2900	2260 to 3277	2.5	4	3	30	50	90
	Existing/ Planned	2777	2777	10	6	4	-	-	-

Nuclear	Candidate	2777	2777	10	-	-	-	-	-
Biomass	Existing/ Planned	4200	4450	8	6	4	600	1000	1800
	Candidate	4200	4450	8	6	4	600	1000	1800
Hydro	Existing/ Planned	-	-	0.7	-	-	-	-	-
	Candidate	-	-	0.7	-	-	-	-	-
Pumped Storage	Existing/ Planned	-	-	pump efficiency	-	-	-	-	-
	Candidate	-	-	80 %	-	-	-	-	-
Battery Energy Storage	Candidate	-	-	Round trip losses 12%	-	-	-	-	-

Transmission Parameters

A single node has been considered for the purpose of study with all generating units and demand connected to the node. No transmission bottleneck has been considered for the study. Interstate ATC limit has not been considered in the study.

Financial Parameters

Following cost parameters have been assumed in the year 2021-2022:

Resource	Capex* (in ₹/MW)	O&M Fixed Cost (in ₹/MW)	Construction Time (in years)	Amortization /Life time (in years)
Coal	8.34 Cr	19.54 Lakh	4	25
Hydro~	6 Cr to 20 Cr	2.5% of Capex	5 to 8	40
Solar**	4.5 Cr to 4.1 Cr	1 % of Capex	0.5	25
Wind(Onshore)	6 Cr	1% of Capex	1.5	25
Wind(Offshore)	13.7 Cr	1% of Capex	1.5	25
Biomass	9 Cr	2% of Capex	3	20
Pumped Storage	3 Cr to 8 Cr	5 % of Capex	7	40
Battery Energy Storage	5.13 Cr to 3.13 Cr	1 % of Capex	0.5	14

(2-Hour)				
Battery Energy Storage (4-Hour)	8.22 Cr to 4.72 Cr	1 % of Capex	0.5	14
Battery Energy Storage (5-Hour)	9.77Cr to 5.51 Cr	1 % of Capex	0.5	14
Battery Energy Storage (6-Hour)	11.31 Cr to 6.30 Cr	1 % of Capex	0.5	14

* All the Capex figures are on actual basis at the cost level of 2021-22 i.e., inflation is not considered while calculating capex.

~ The Capex values of Hydro and PSS candidates are considered as per the project cost details furnished by the respective developers for state and private sector plants and as per RCEs done periodically by CEA for central sector plants.

**Solar Cost is assumed to reduce from Rs 4.5 Cr/MW in 2021-22 to Rs 4.1 Cr/MW in 2029-30.