Report on
Resource Adequacy Plan
for the Utility
UPPCL, Uttar Pradesh

Government of India
Ministry of Power
Central Electricity Authority

Executive Summary

The electricity energy requirement and peak demand for Uttar Pradesh Power Corporation Ltd. (UPPCL), Uttar Pradesh is increasing with a CAGR of 5.8 % and 6.1% respectively from 2023-24 to 2031-32 as forecasted by 20th EPS. The projections of UPPCL indicate that electricity energy requirement and peak demand may increase with a CAGR of 7.0 % and 6.5% respectively from 2023-24 to 2029-30. For satisfying resource adequacy i.e., meeting the electricity demand reliably and at affordable cost, the utility 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 energy consumption of the utility is majorly constituted from Domestic consumers i.e., 47 % and the consumption pattern is observed to undergo seasonal and diurnal variation. The electricity demand starts increasing from the month of April and is maximum during the month of July. The demand during the months of June, July, August and September is significantly higher compared to rest of the year. The lowest electricity demand generally occurs in the month of November. The peak electricity load is generally observed during night hours.

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 Renewable Purchase Obligation (RPO) trajectory till 2029-30 vide gazette notification dated 20th October, 2023 which ensure certain amount of energy consumption to be met from renewable energy sources. While carrying out the RA Studies, it was ensured that RPO is met.

To find out the least cost option for generation capacity expansion for the period 2023-24 to 2033-34, long-term study for the State of UPPCL 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.

Reliability analysis was also carried out with varying demand, RE Generation and forced outage of coal-based capacities. Based on the study, it was found that the state's existing contracted capacity along with capacity addition plans for conventional as well as renewable energy sources may not be adequate to meet projected demand.

The likely contracted capacity of UPPCL in 2033-34 is arrived at 1, 21,297 MW (along with 25,437 MW/ 1,01,748 MWh of Storage) which includes the existing and planned capacity addition of UPPCL as well as the additional capacity (i.e., other than planned) from 10794 MW of coal, 1000 MW of Hydro, 7400 MW of Wind, 45000 MW of Solar, 8207 MW of DRE.

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 gazette notification dated 20th October, 2023 had notified the source wise minimum share of consumption of non-fossil sources (renewable energy) by designated consumers. Based on the trajectory specified, RPO quantum in million units (MUs) from hydro, wind, other (solar, biomass etc.) and distributed renewable energy (DRE) 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 UPPCL, Uttar Pradesh in fulfilment of the designated RPO trajectory, on the basis of the inputs received from UPPCL. The study suggests the optimal resource mix till 2033-34 taking into account the 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 UPPCL, UP catering to above highlighted uncertainties so that demand can be met reliably throughout the year.

2.0 UPPCL RA Study

2.1 Present Power Scenario in UPPCL

As of March, 2023, the total contracted capacity of UPPCL is 30,589 MW. Out of the total contracted capacity (CC), the share of non-fossil fuel based CC is 32 %.
The fuel-wise contracted capacity as of 31st March, 2023 is given in Table and Figure below:

Table 1 Fuel-wise Contracted Capacity as on 31st March, 2023

Source	Contracted Capacity (MW)	Percentage (%)
Coal	20121	66%
Gas	549	2%
Nuclear	289	1%
Hydro	3787	12%
Solar	2730	9%
Wind	1544	5%
Biomass	1568	5%
Total	**30589**	100%

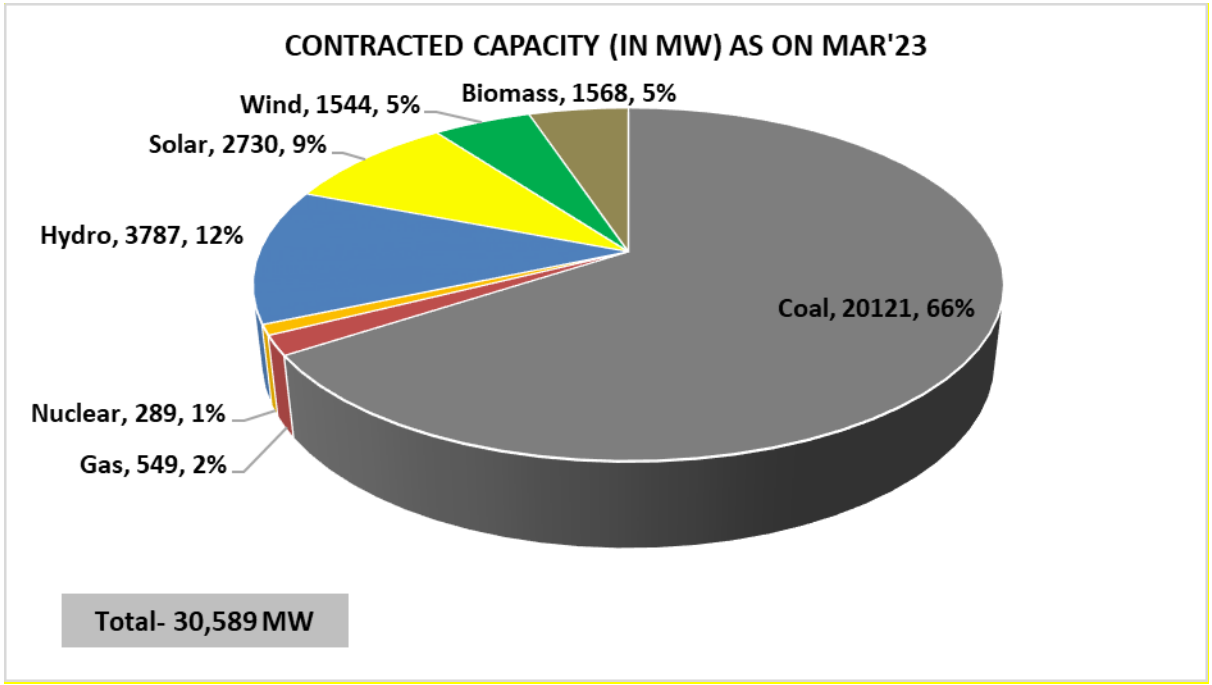

Figure 1 Fuel-wise Contracted Capacity (in MW) as on Mar 2023

2.2 Present Demand Analysis (2022-23)

Hourly demand pattern of 2022-23 was analyzed and it was observed that the peak demand of UPPCL typically occurs during night time in July month and it is observed that the demand is comparatively higher during summer months (i.e, in May, June, July) than the rest of the year.

Monthly average demand of UP for the year 2022-23 was derived from the hourly demand data of that year in which two (2) distinct plots are observed for the months Apr-Sep and Oct-Mar, as shown in the figure below. The average hourly demand for the months of Apr-Sep is found to be in the range of 15,000 to 24,000 MW and for the months of Oct-Mar is found to be in the range of 10,200 to 19,300 MW. This clearly indicates that the range of average demand is higher for Apr-Sep months than that of Oct-Mar months. Further, the plot explicitly depicts that average hourly demand is low during solar hours (i.e., 06:00 hrs to 18:00 hrs) when compared to non-solar hours and this difference is significant in the months of Apr-Sep.

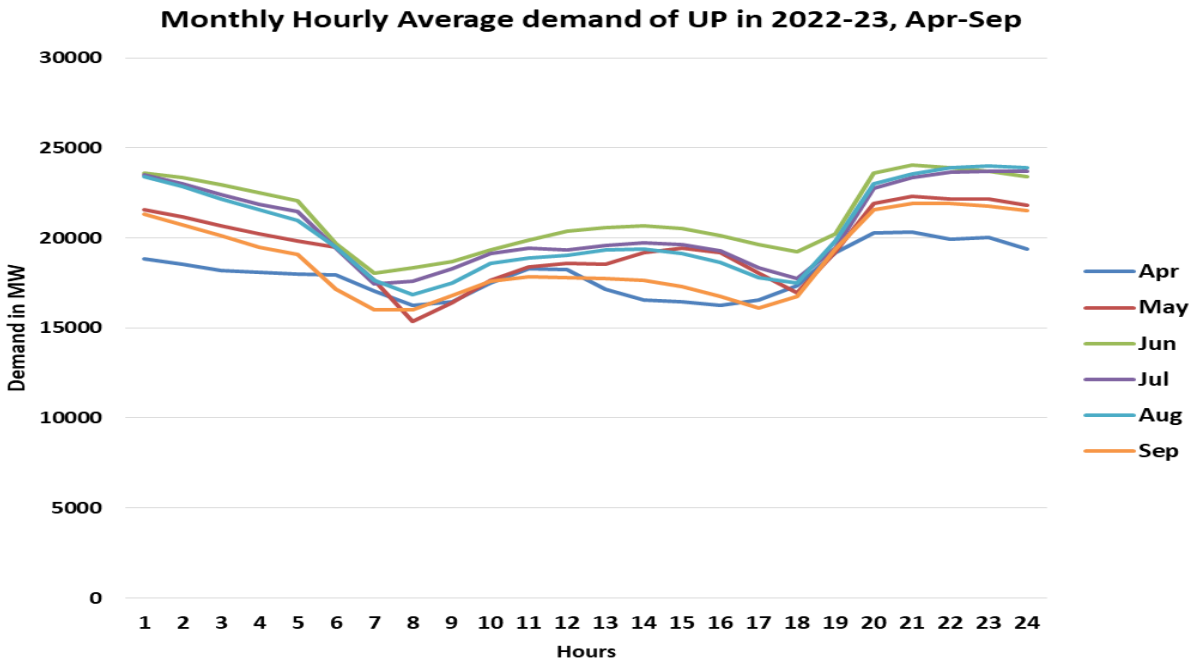

Figure 2 Hourly average demand of utility in 2022-23 for the month Apr-Sep

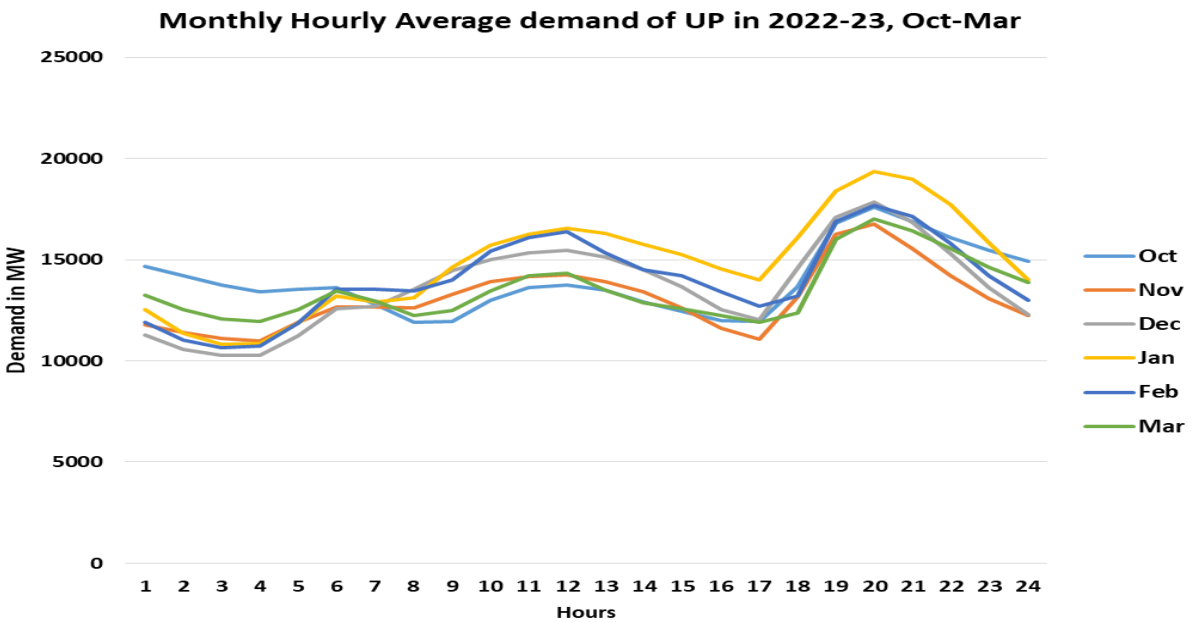

Figure 3 Hourly average demand of utility in 2022-23 for the month Oct-Mar

From the hourly demand of 2022-23 the daily peak in day hours (06:00 to 18:00 hrs) and night hours is plotted in the below figure. It is clearly visible that, the night peak is significantly higher than the day peak throughout the year.

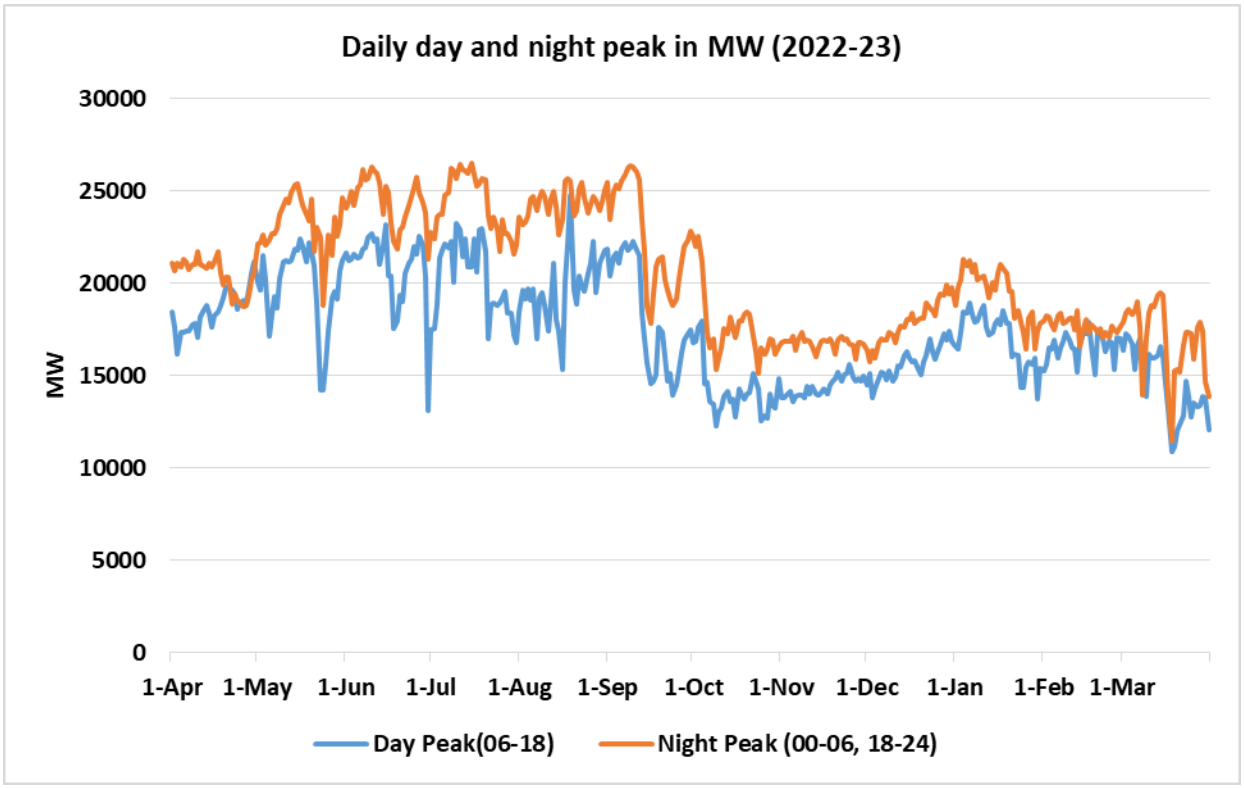

Figure 4 Day and Night Peak in MW of UPPCL (2022-23)

3.0 Inputs/Assumptions for the Study

i) The electrical energy requirement projections and peak demand projections received from UPPCL was compared with the projections provided in the 20th EPS. The following observations was found:

Table 2 Energy requirement projection comparision

Comparison in Energy requirement projections (MU)@

	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32
As per 20th EPS	156253	165548	175456	186034	197147	208885	222274	233729	245284
Year on Year Growth (Energy)		5.9%	6.0%	6.0%	6.0%	6.0%	6.4%	5.2%	4.9%
As per UPPCL, UP	162297	173262	185390	198367	212738	227111	243009	N/A	N/A
Year on Year Growth (Energy)		6.8%	7%	7%	7.2%	6.8%	7%		

@The 20th EPS projections for the UPPCL discoms till 2031-32 have been considered.

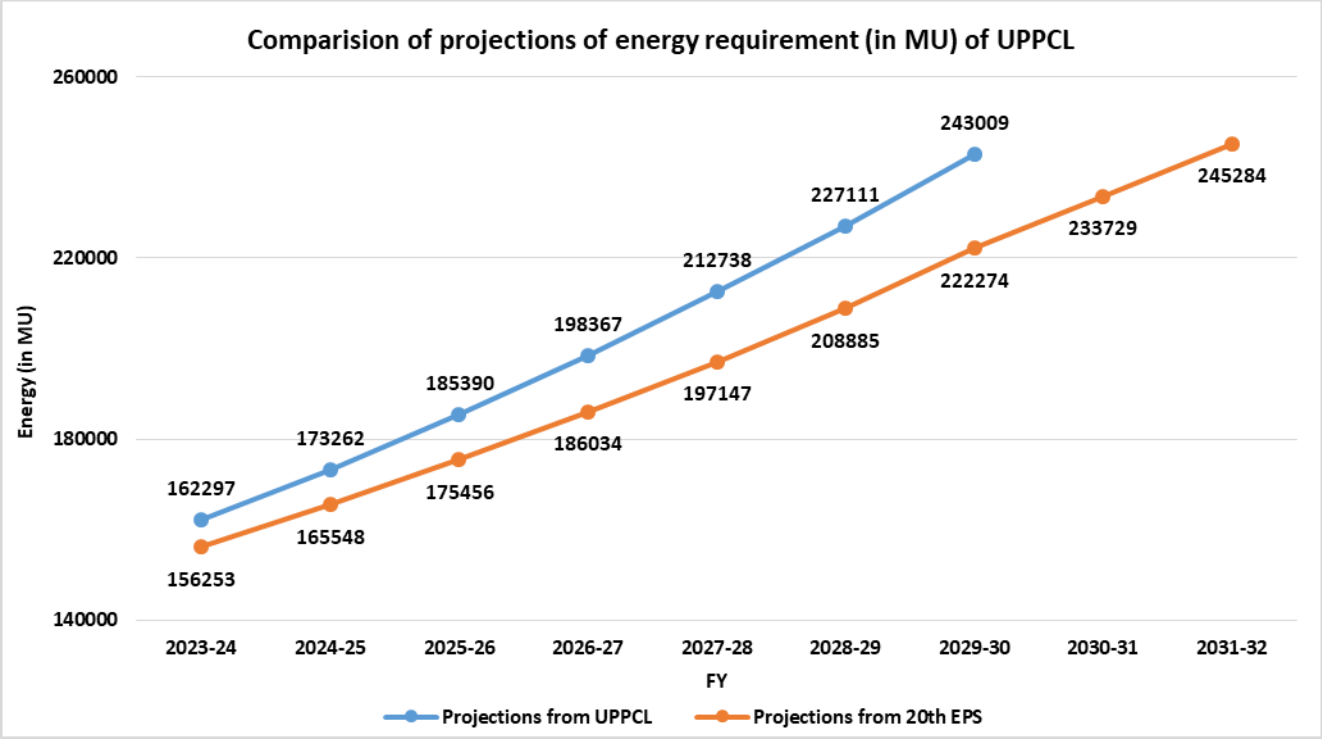

Figure 5 Graph on Energy requirement comparison

Table 3 Peak demand projection comparison

Comparison in Peak demand projections (MW) [@]

	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32
As per 20th EPS	27531	29235	31061	33017	35082	37270	39781	41910	44066
Year on Year Growth (MW)		6.2%	6.2%	6.3%	6.3%	6.2%	6.7%	5.4%	5.1%
As per UPPCL, UP	28737	30605	32595	34713	36970	39373	41932	N/A	N/A
Year on Year Growth (MW)		6.5%	6.5%	6.5%	6.5%	6.5%	6.5%		

[@]The 20th EPS projections for the UPPCL discoms till 2031-32 have been considered.

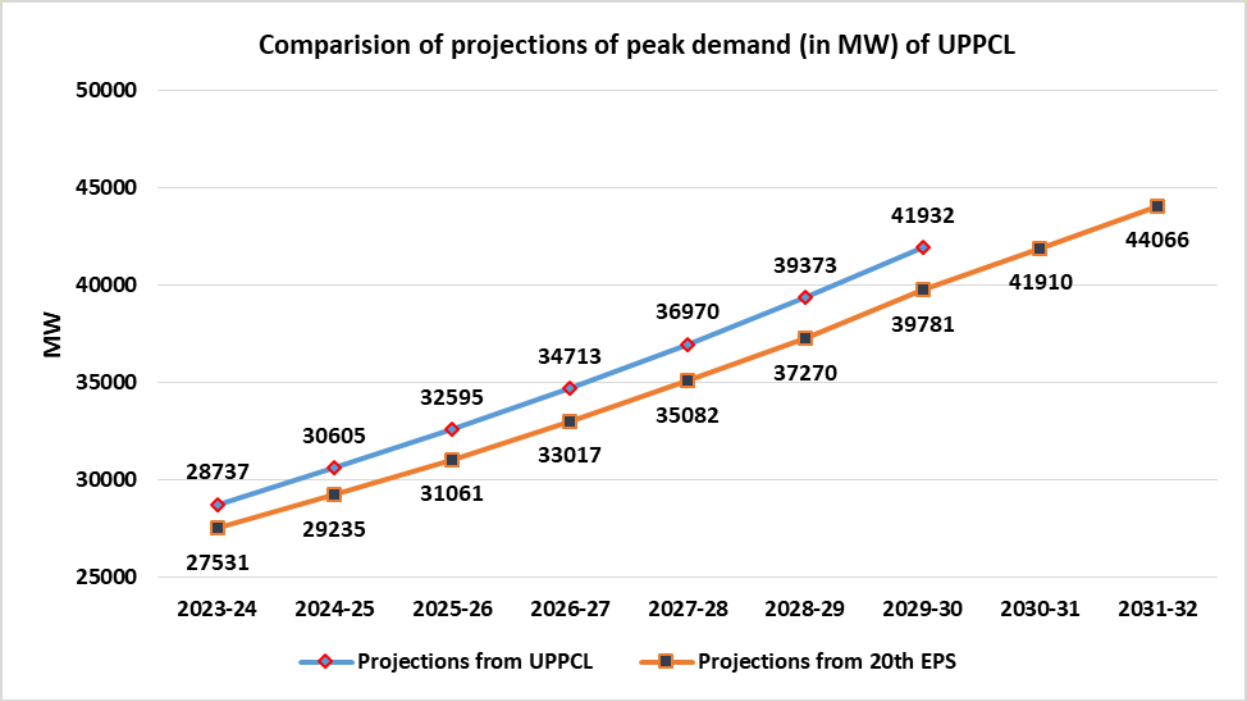

Figure 6 Graph on Peak demand comparison

Based on the meetings held with UPPCL officials, wherein the likely demand growth for UP was discussed, it was concluded that considering the past and present trend of demand growth for the state, the demand projections received from UPPCL may be considered for the RA studies. Since, the suppression of future demand estimate may lead to underestimation in capacity requirement in RA studies.

Hence the projections considered for the study (as received from UPPCL) is tabulated:

Table 4

Energy Requirement (MU) and Peak demand projections (MW) considered for RA study*

Year	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31*	2031-32*	2032-33*	2033-34*
Energy Requirement Projections (MU)	162297	173262	185390	198367	212738	227111	243009	260020	278222	296306	315566
Year on Year* Growth *(Energy)		6.8%	7.0%	7.0%	7.2%	6.8%	7.0%	7.0%	7.0%	6.5%	6.5%
Peak Demand Projections (MW)	28737	30605	32595	34713	36970	39373	41932	44657	47560	50651	53943
Year on Year Growth (Peak)		6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%	6.5%

*Peak demand projections for the years after 2029-30 have been assumed considering similar growth rates as furnished by UPPCL.

ii) Future hourly demand profiles have been projected using the hourly demand profile for the year 2022-23 as the base profile.

iii) The hourly solar generation profile of northern region with a CUF of 18.48% and wind generation profile of southern region with a CUF of 23.92% as per the information available in CEA have been considered for the Study.

iv) Capital cost of candidate plants for Coal, Battery and PSP have been referred from National Electricity Plan.

v) Existing & Planned Capacity has been considered as per the information received from UPPCL (List of Planned Thermal, Nuclear and Hydro is attached in **Annexure-I**). The planned capacity addition is tabulated below:

Table 5 Year on Year source wise Planned capacity addition

FY	COAL	HYDRO	WIND	SOLAR	NUCLEAR	BIOMASS	DRE	TOTAL
2024/25	2739	340	622	225	0	0	1450	5376
2025/26	0	100	1400	610	0	0	1600	3710
2026/27	0	368	0	0	0	0	1600	1968
2027/28	0	0	0	0	0	0	1600	1600
2028/29	800	0	0	0	0	0	1600	2400
2029/30	0	0	0	0	162	0	0	162
2030/31	0	0	0	0	0	0	0	0
2031/32	0	0	0	0	0	0	0	0
2032/33	0	0	0	0	0	0	0	0
2033/34	0	0	0	0	0	0	0	0
TOTAL	**3539**	**808**	**2022**	**835**	**162**	**0**	**7850**	**15216**

Renewable Purchase Obligation (RPO) trajectory: Ministry of Power gazette notification dated 20th October, 2023 had notified the source wise minimum share

of consumption of non-fossil sources (renewable energy) by designated consumers, till the year 2029-30. In view of the country's energy transition goals as well as the long term net zero target of 2070, it is estimated that the share of RE generation in the generation mix will continue to increase beyond 2029-30. Therefore, the RPO trajectory is assumed to rise steadily beyond 2029-30 and hence, RPO targets till 2033-34 are given below:

Table 6 RPO trajectory

Sl. No.	Year	Wind renewable energy	Hydro renewable energy	Other renewable energy	Distributed renewable energy	Total renewable energy
(1)	(2)	(3)	(4)	(6)	(5)	(7)
1.	2024-25	0.67%	0.38%	27.35%	1.5%	29.91%
2.	2025-26	1.45%	1.22%	28.24%	2.1%	33.01%
3.	2026-27	1.97%	1.34%	29.94%	2.7%	35.95%
4.	2027-28	2.45%	1.42%	31.64%	3.3%	38.81%
5.	2028-29	2.95%	1.42%	33.10%	3.9%	41.36%
6.	2029-30	3.48%	1.33%	34.02%	4.5%	43.33%
7.	2030-31	40.50%			5.0%	45.50%
8.	2031-32	41.50%			5.5%	47.00%
9.	2032-33	42.30%			6.0%	48.30%
10.	2033-34	43.00%			6.5%	49.50%

Note:- RPO trajectory for the years till 2029-30 is considered based on MoP RPO Notification dated 20th October,2023. RPO targets beyond 2029-30 is considered based on RE generation in National Electricity Plan (Vol-I Generation) (2022-32).

Based on the trajectory specified, RPO quantum in million units (MUs) from hydro, wind, other (solar, biomass, etc.) and distributed renewable energy (DRE) is calculated and tabulated below:

Table 7 Energy required in fulfilment of RPO trajectory

Sl. No.	Year	Wind renewable energy (MU)	Hydro renewable energy (MU)	Other renewable energy (MU)	Distributed renewable energy (MU)	Total renewable energy (MU)
(1)	(2)	(3)	(4)	(6)	(5)	(7)
1	2024-25	1161	658	47387	2599	51823
2	2025-26	2688	2262	52354	3893	61197
3	2026-27	3908	2658	59391	5356	71313
4	2027-28	5212	3021	67310	7020	82564
5	2028-29	6700	3225	75174	8857	93933
6	2029-30	8457	3232	82672	10935	105296
7	2030-31	105308			13001	118309
8	2031-32	115462			15302	130764

9	2032-33	125337	17778	143116
10	2033-34	135693	20512	156205

Accordingly, the year on year additional source wise MW requirement considering the fungibility aspects in the RPO has been estimated and is tabulated below:

Table 8 Source wise year on year RE capacity required to fulfil RPO

FY	HYDRO		WIND		SOLAR		DRE		TOTAL	
	Planned	Additional	Planned	Additional	Planned	Additional	Planned	Additional	Planned	Additional
2024/25	340	0	622	0	225	0	1450	0	2637	0
2025/26	100	0	1400	0	610	0	1600	0	3710	0
2026/27	368	250	0	800	0	8000	1600	0	1968	9050
2027/28	0	250	0	800	0	8000	1600	0	1600	9050
2028/29	0	250	0	800	0	8000	1600	0	1600	9050
2029/30	0	250	0	1800	0	3613	0	710	0	6373
2030/31	0	0	0	800	0	5457	0	1617	0	7874
2031/32	0	0	0	800	0	4891	0	1801	0	7492
2032/33	0	0	0	800	0	4774	0	1938	0	7512
2033/34	0	0	0	800	0	2265	0	2140	0	5205
TOTAL	**808**	**1000**	**2022**	**7400**	**835**	**45000**	**7850**	**8206**	**11515**	**61606**

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.

In addition to the above two metrics, the Planning Reserve Margin (PRM) is a predominant metric used to ensure adequacy of generation resources in the system. PRM in a power system is expressed as certain percentage of peak load forecast of the system.

5.0 Demand variation:

The variation in demand pattern of UPPCL, Uttar Pradesh for last 2 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.

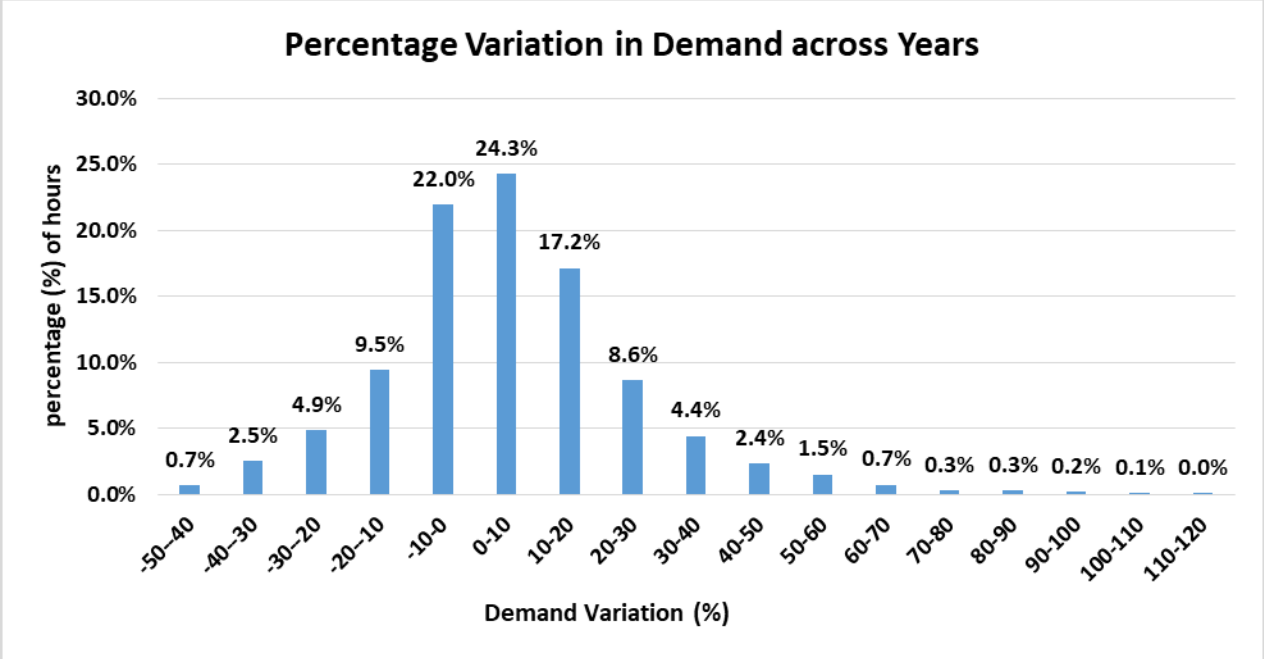

Figure 7 Hourly Percentage Variation in Demand across years

It can be observed that the hourly demand typically varies ±20% and ±10% from corresponding hour in previous years (Normalized figure) for 81.6% and 63.5% of instances respectively. 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 ±15% by introducing a random variable (with normal distribution) for demand as per the observed behavior over the years.

5.1 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 10% and 50% respectively to incorporate the variation in these generation sources and plan for requisite measures to mitigate such behavior.

5.2 Forced Outage of Thermal Generators

The forced outage rate of thermal generators of KPTCL 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.

6.0 Results of the study

6.1 Unserved Energy Projections

The study was carried out considering existing capacity, planned capacity & capacity required to fulfil the RPO obligations. It was observed that the total unserved energy in the year 2033-34 is about 89,113 MU. The yearly likely unserved energy with the planned capacities is given below.

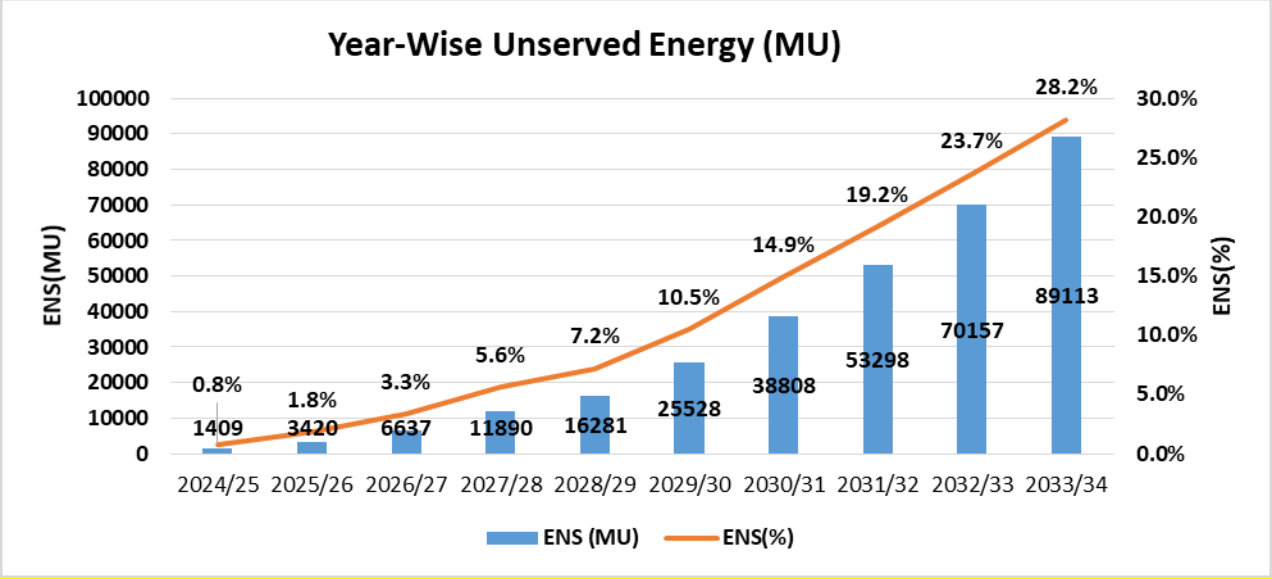

Figure 8 Yearly likely unserved energy with the planned capacities for UPPCL, Uttar Pradesh (in MU)

The study has also analyzed the Daily and monthly pattern of unserved energy in the year 2033-34, it can be seen that the unserved energy coincides with peak demand months when the contracted capacity (present and planned) is unable to meet the demand.

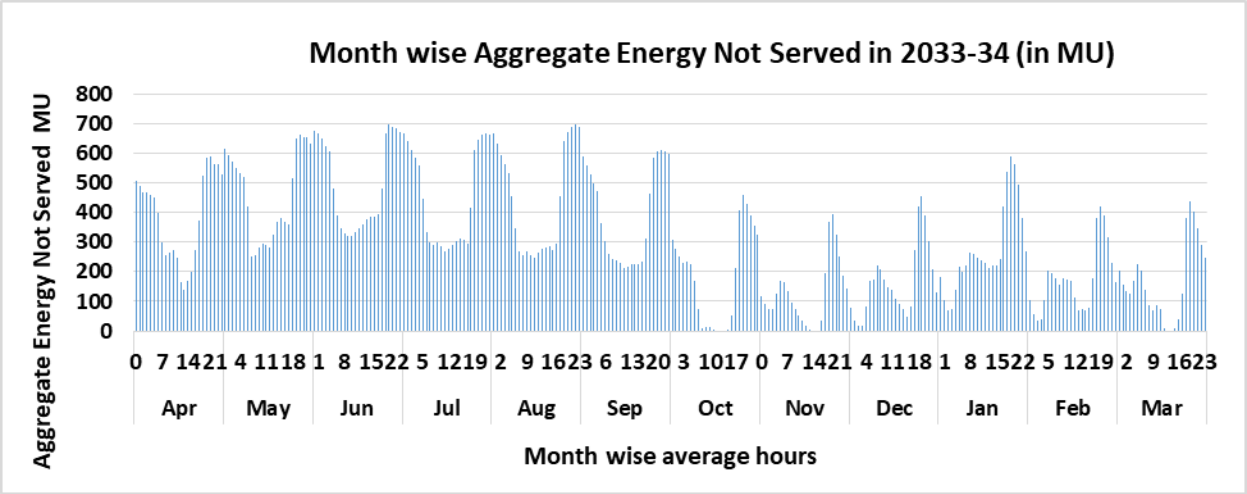

Figure 9 Month wise Aggregate Energy Not Served in 2033-34 (in MU)

6.2 Capacity Mix Projection

To meet the unserved energy, energy investment options (candidate capacities) is given to the model to find the least cost optimal capacity mix required to meet the demand. The following is observed:

i) There is requirement of Coal-based capacity from 2026/27 onwards.
ii) The STOA/MTOA requirement can be fulfilled through power procurement from markets or bilateral agreements.
iii) The STOA/MTOA value reflects the peak value requirement in terms of MW.

The capacity projections for UPPCL, Uttar Pradesh are given below:

Table 9 Year-wise capacity projections (in MW)

YEAR	COAL	GAS	NUCLEAR	BIOMASS	HYDRO	WIND	SOLAR	STORAGE (MW/MWh)	DRE	STOA
2024/25	25763	549	289	1629	4127	2630	3169	0/0	1450	5538
2025/26	25653	549	289	1629	4227	4030	3779	0/0	3050	7000
2026/27	30680	549	289	1629	4845	4830	11779	0/0	4650	4544
2027/28	32881	549	289	1629	5095	5630	19779	3535.4/14141.7	6250	1212
2028/29	33571	549	289	1629	5345	6430	27779	6061.1/24244.6	7850	166
2029/30	33461	549	451	1629	5595	8230	31392	9187/36748	8560	0
2030/31	33351	549	451	1629	5595	9030	36849	13610.8/54443.2	10177	0
2031/32	34050	549	451	1629	5595	9830	41740	17202.8/68811.2	11979	0
2032/33	35624	549	451	1629	5595	10630	46514	20341.5/81366.1	13917	0
2033/34	36807	549	451	1629	5595	11430	48779	25437/101748.3	16057	0

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

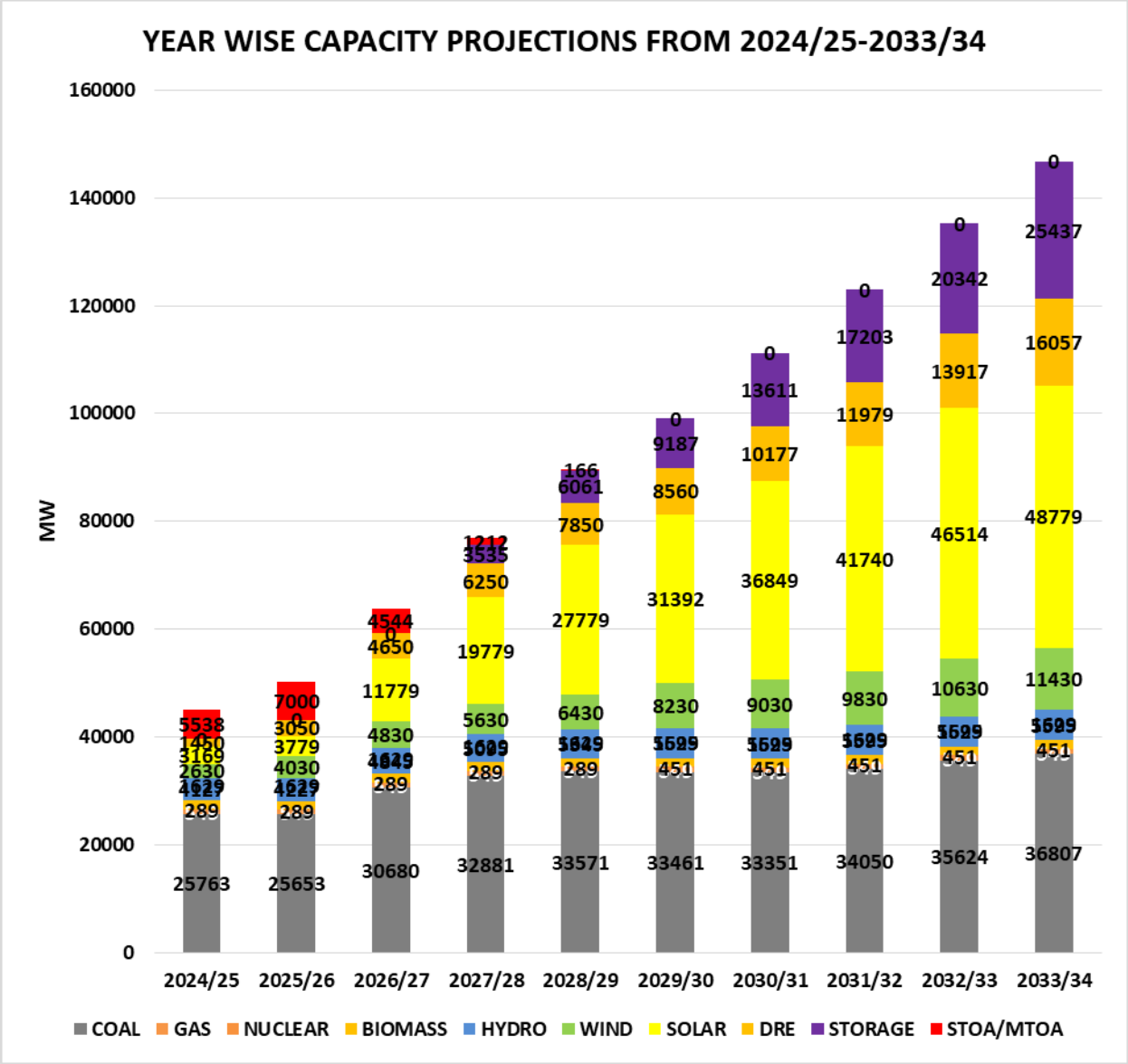

Figure 10 Projected Capacity Mix Year-wise (MW) for UPPCL

As per the Resource Adequacy studies, the total projected Capacity for the year 2033-34 is 1,21,297 MW (along with 25,437 MW of Storage) which consist of 36,807 MW of coal, 549 MW of Gas, 451 MW of Nuclear, 1629 MW of Biomass, 5595 MW of Hydro, 11430 MW of Wind, 48779 MW of Solar, 16057 MW of Distribute Renewable Energy (DRE) and 0 MW from STOA. This IC shall be able to meet the projected demand with prescribed reliability criteria.

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 UPPCL, Uttar Pradesh has been

assessed as 16%. In addition, the projected/contracted capacity fulfilling the stipulated Renewable Purchase Obligation.

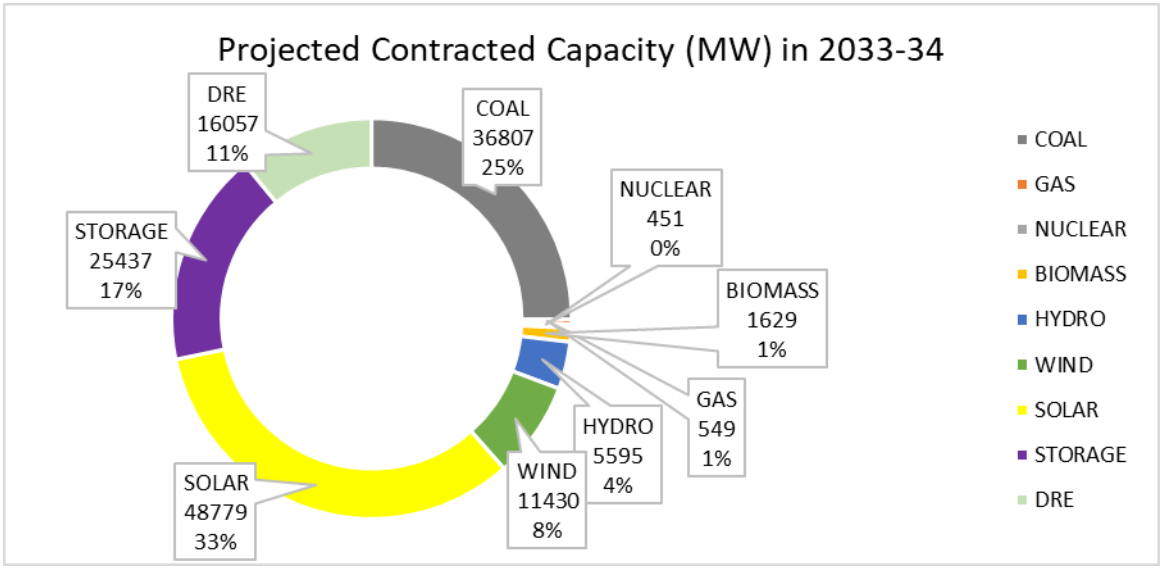

Figure 11 Contracted Capacity Mix in 2031-32 with 16% PRM

The share of non-fossil fuel-based capacity in the total contracted capacity is projected to increase to around 74 % in 2034 from 32.5% in 2022-23 with higher contribution from non-fossil fuel-based capacities in alignment with RPO trajectory.

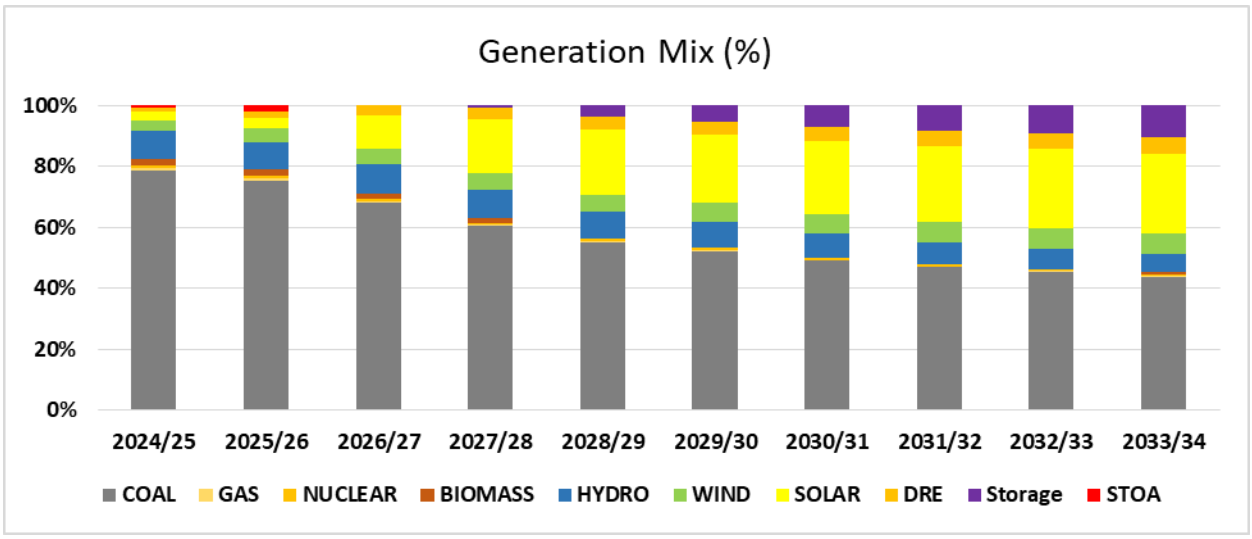

Figure 12 Yearly Source wise Generation mix

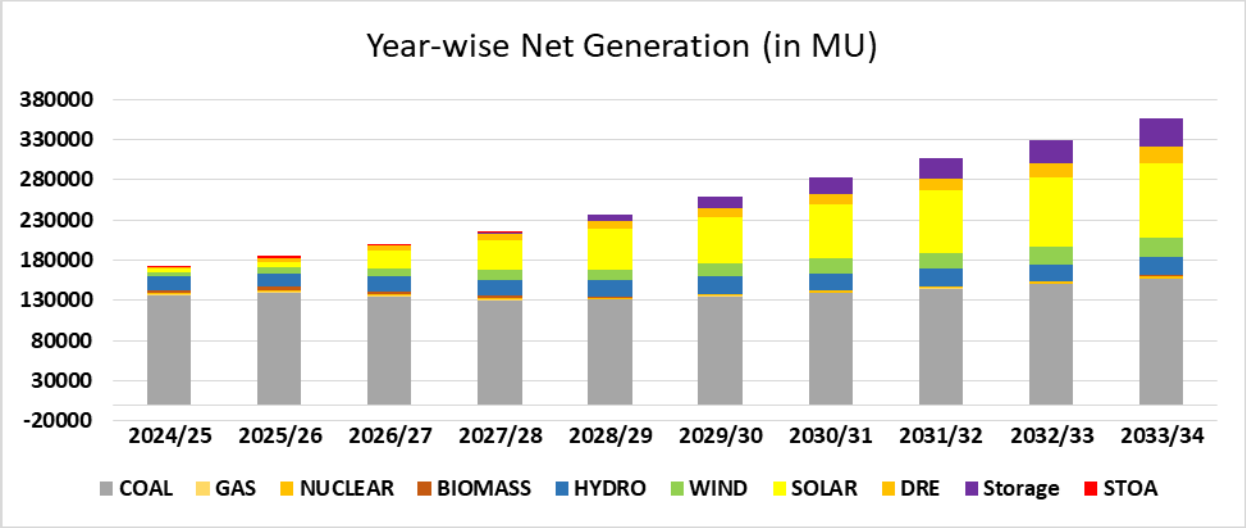

Figure 13 Source wise net generation in each year

6.3 Day-wise Surplus Capacity UPPCL, Uttar Pradesh (MW)

The pattern of surplus capacities has been observed as below. Available Surplus capacity can be due to seasonal variation of demand. This capacity can be shared with other states, thereby reducing the fixed cost burden on the utilities resulting in reduction in the cost for consumer. UPPCL has likely surplus capacity available during the months from October to March which can be shared with other states. The surplus power is higher in the off peak months of Oct-March.

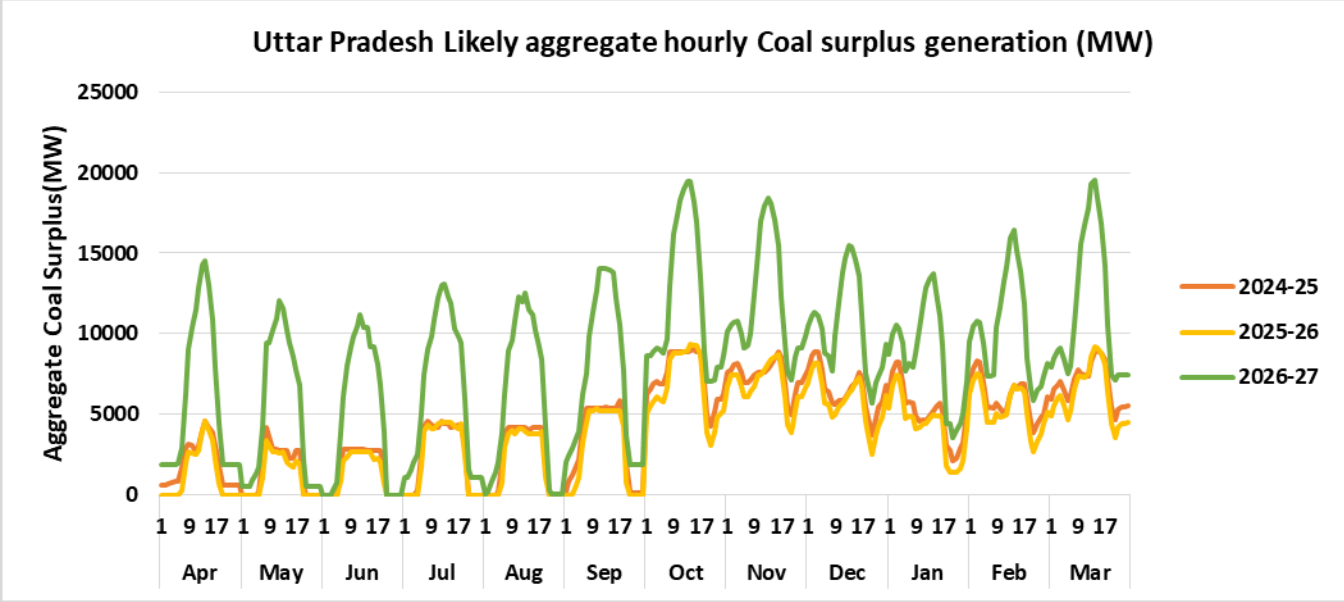

Figure 14 Surplus Coal Capacity Year-wise (MW)

7.0 Capacity contract requirement for future

It has been found out in the studies that UPPCL 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 Ministry of Power.

Table 10 Year wise Capacity Addition for UPPCL (in MW)

	COAL		HYDRO		WIND		SOLAR	
Year	**Planned Contracts**	**Additional Requirement**	**Planned Contracts**	**Additional Requirement**	**Planned Contracts**	**Additional Requirement**	**Planned Contracts**	**Additional Requirement**
2024/25	2739	0	340	0	622	0	225	0
2025/26	0	0	100	0	1400	0	610	0
2026/27	0	5027	368	250	0	800	0	8000
2027/28	0	2312	0	250	0	800	0	8000
2028/29	800	0	0	250	0	800	0	8000
2029/30	0	0	0	250	0	1800	0	3613
2030/31	0	0	0	0	0	800	0	5457
2031/32	0	699	0	0	0	800	0	4891
2032/33	0	1574	0	0	0	800	0	4774
2033/34	0	1183	0	0	0	800	0	2265
	Nuclear		**Distributed RE**		**TOTAL**		**Storage**	
Year	**Planned Contracts**	**Additional Contracts**	**Planned Contracts**	**Additional Requirement**	**Planned contracts**	**Additional Requirement**	**Planned contracts**	**Additional Requirement**
2024/25	0	0	1450	0	**5376**	**0**	0	0/0
2025/26	0	0	1600	0	**3710**	**0**	0	0/0
2026/27	0	0	1600	0	**1968**	**14077**	0	0/0
2027/28	0	0	1600	0	**1600**	**11362**	0	3535/14141
2028/29	0	0	1600	0	**2400**	**9050**	0	2525/10102
2029/30	162	0	0	710	**162**	**6373**	0	3125/12503
2030/31	0	0	0	1617	**0**	**7874**	0	4423/17695
2031/32	0	0	0	1801	**0**	**8191**	0	3591/14367
2032/33	0	0	0	1938	**0**	**9086**	0	3138/12554
2033/34	0	0	0	2140	**0**	**6388**	0	5095/20382

8.0 Conclusions

Based on the RA studies carried out for the state of Uttar Pradesh (UPPCL only), the following conclusions may be drawn: -

1. The study has been done based on the hourly load pattern of the year 2022-23. Based on the demand pattern of last few years, it is seen that the peak demand season is typically from June to July with peak demand occurring during night time of July. The demand during the months from October to March remains significantly low as compared to other months which reflects the effect of seasonality in demand. Optimal utilization of resources through short-term contracts like banking or STOA as currently practiced for managing the seasonal variation in demand is one of the effective ways for ensuring resource adequacy in such periods.
2. The study has considered peak demand and energy requirement projections as per the projections furnished by UPPCL which envisages that the peak demand for the region is likely to grow at a CAGR of 6.5% while the annual demand is likely to grow at the CAGR of 6.9% for the period of 2024-25 to 2033-34. The peak demand projections and energy requirement provided by UPPCL are higher compared to the demand projections as per the 20th EPS report.
3. UPPCL is likely to witness energy deficit ranging from 1409 MUs to 89113 MUs in different years from 2023-24 to 2033-34 with the existing and planned capacity addition.
4. UPPCL is deficit in fulfilment of its Renewable Purchase Obligations (RPO) and there is need to contract the designated renewable capacities. The projected capacity and generation mix as specified in the report, fulfils the RPO obligations for the utility for the years after 2027-28.
5. UPPCL is likely to have unserved energy in coming years and need to contract fossil-based capacities for meeting energy requirements other than the planned capacities. UPPCL requires additional coal-based capacities to be procured other than the capacity already planned. The quantum of coal-based capacities required to be contracted is about 5000 MW in the year 2026-27 which increases to around 10800 MW in the year 2033-34.
6. 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 UPPCL, Uttar Pradesh has been assessed as 16%.
7. The current capacity mix in UPPCL has 67.5% of contracted capacity from fossil fuel sources. The share of fossil fuel based capacity is likely to reduce to 25 % in 2033-34. In 2033-34, in view of the RPO fulfillment, the solar based generation sources are likely to constitute around 75% of the total installed capacity and an estimated energy storage of 25437 MW/ 101748 MWh is likely to be required to complement the solar generation.

8. Additionally, based on the studies it is observed that the utility may benefit from the substantial solar based capacity addition by implementing the following recommendations pertaining to demand management:

    i) Steps must be taken to encourage the shifting of load during the day hours. This has been done by many states.

    ii) Ensure 24x7 supply to all consumer category including rural domestic consumers so that the electricity consumption is encouraged during the solar hours and this will further facilitate behavioral change in the electricity consumption.

    iii) The thermal units within the state need to operate in flexible mode up to 55% of Minimum Technical Load (MTL). Action must also be initiated to reach up to 40% of Minimum Technical Load (MTL) as per the Central Electricity Authority (Flexible Operation of Coal based Thermal Power Generating Units) Regulations, 2023. This will help in reduction in cost of supply as during day time cheaper solar power can be used and will also help in reduced consumption of coal. This will also help in meeting the RPO.

9. The energy requirement to be met from STOA/MTOA (short term/medium term/market based contracts) is around 1-2% of the total energy requirement in the initial years of study (i.e. till 2026-27). However, the state would not require STOA/MTOA beyond 2026-27. STOA/MTOA is critical in months of peak demand to fulfil the end consumer demand.

10. The coal based PLF is expected to decrease from 70% in 2024-25 to 52% in 2033-34 ensuring higher absorption of higher renewable energy.

11. It is likely that UPPCL may have surplus capacity available during the months from October to March which can be shared with other states.

Annexure-I

Future Contracted/Approved Capacity (MW) of Central and State Sector

Plant Name	Type	Generator	Expected COD/ Remark	UP share
JAWAHARPUR (2x660 MW) Unit 1	Thermal	UPRUVNL	2023-24	660
JAWAHARPUR (2x660 MW) Unit 2	Thermal	UPRUVNL	2024-25	660
OBRA -C (2x660MW) Unit 1	Thermal	UPRUVNL	2023-24	660
OBRA – C (2x660MW) Unit 2	Thermal	UPRUVNL	2024-25	660
GHATAMPUR (3x660MW) Unit 1	Thermal	UPRVUNL+ NLC	2023-24	1487.28 (as per Govt. Order dated 15 Feb 2023)
GHATAMPUR (3x660MW) Unit 2	Thermal	UPRVUNL+ NLC	2024-25	
GHATAMPUR (3x660MW) Unit 3	Thermal	UPRVUNL+ NLC	2024-25	
PANKI (660MW)	Thermal	UPRUVNL	2023-24	660
KHURJA STPP (2x660 MW) Unit 1	Thermal	THDC	2024-25	854.4 (as per Govt. order dated 15 Nov 2022)
KHURJA STPP (2x660 MW) Unit 2	Thermal	THDC	2023-24	
SINGRAULI STAGE –III (2x800MW) 2 Units	Thermal	NTPC	2028-29	800
TAPOVAN VISHNU-GARH*(4x130 MW)	Hydro	NTPC	2025-26	100
VISHNUGARH PIPAL KOTHI (4x111 MW)	Hydro	THDC	2026-27	168
PAKALDUL (4X250 MW)	Hydro	CVPPPL (NHPC+JKSPDL+PTC)	2026-27	200
SUBANSIRI LOWER (8x250 MW) 8 Units	Hydro	NHPC	2024-25	184
PARBATI-II (4x200MW) 4 Units	Hydro	NHPC	2024-25	156
Rawatbhata APP unit 7 & 8 (2x700 MW)	Nuclear	NPCIL	2029-30	161.96 Order dated 17 Jun 2011)

Assumption for Resource Adequacy Studies for UPPCL, Uttar Pradesh

1. Energy requirement as per 20th EPS projections & peak demand as per UPPCL projections.
2. Demand Profile: Based on hourly demand profile of 2022-23.
3. Existing & Planned Capacity: As per the information received from UPPCL
4. Future Capacity addition: based on RPO trajectory
5. Cost parameters: based on information received from UPPCL and NEP

List of Coal based plants considered for likely retirement in the study period:

S. No.	Name of project	State	Organisation	Total Capacity	Retirement year
1	Harduaganj TPS Unit 7	UP	UPRVUNL	110	Retired in 2025-26
2	Tanda TPS Unit 1-4	UP	NTPC	4*110=440	Retired from 2027-28 onwards, 1 units in a year till 2030-31

RE CUF considered

Hydro Existing /Planned PLF	Bioenergy PLF	Solar Existing/ Planned CUF	Wind Planned/ Existing CUF	PSP/ Small Hydro CUF	Distributed RE
45.35%/ 42.76%	20%	18.5 % / 22.23 %	23.85 %	25.0% /15.0%	14.59%

RPO Trajectory

Sl. No.	Year	Wind renewable energy	Hydro renewable energy	Distributed renewable energy	Other renewable energy	Total renewable energy
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1.	2024-25	0.67%	0.38%	1.5%	27.35%	29.91%
2.	2025-26	1.45%	1.22%	2.1%	28.24%	33.01%
3.	2026-27	1.97%	1.34%	2.7%	29.94%	35.95%
4.	2027-28	2.45%	1.42%	3.3%	31.64%	38.81%
5.	2028-29	2.95%	1.42%	3.9%	33.10%	41.36%
6.	2029-30	3.48%	1.33%	4.5%	34.02%	43.33%

In consideration of the fungibility clause as and when available.

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	20	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	-	-	-	-

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
Nuclear	Existing/ Planned	2777	2777	10	6	4	-	-	-
	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 for the candidate capacities:

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
Solar	4.1	1 % of Capex	0.5	25
Pumped Storage	6 Cr	4 % of Capex	7	40
Battery Energy Storage (4-Hour)	5.62 Cr to 4.72 Cr	1 % of Capex	0.5	14
Battery Energy Storage (5-Hour)	6.62 Cr to 5.51 Cr	1 % of Capex	0.5	14
Battery Energy Storage (6-Hour)	7.61 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 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.