FINAL DRAFT REPORT ON RESOURCE ADEQUACY PLAN FOR THE STATE OF ANDHRA PRADESH

GOVERNMENT OF INDIA
MINISTRY OF POWER
CENTRAL ELECTRICITY AUTHORITY

Executive Summary

The electricity demand for the State of Andhra Pradesh is increasing with a CAGR of 7.96 % from 2023-24 to 2031-32, as forecasted by 20th EPS. The projections of APTRANSCO also indicate that electricity demand may increase with a CAGR of 6.27 % from 2023-24 to 2029-30. For satisfying resource adequacy i.e., meeting the electricity demand reliably and at affordable cost, the State needs to methodically plan its capacity expansion either by investing or by procuring power. Given the reduction in the 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 that the future generation capacity mix is cost-effective as well as environment friendly.

The electricity demand dynamics in Andhra Pradesh are significantly influenced by sectoral allocations, with 31% dedicated to industrial usage, 23% for irrigation, 30% for domestic consumption, 8% in commercial applications, and the remaining 8% for various other purposes. This sectoral distribution leads to distinctive patterns in the demand profile. Notably, the peak demand period spans from January to April. During these months, the electricity demand substantially exceeds that of the rest of the year. In contrast, the lowest demand is consistently observed in October. From October to December, the demand remains notably low compared to the other months, emphasizing the seasonality and varying requirements throughout the year.

Ministry of Power had notified Electricity (Amendment) Rules in December 2022. As per Rule 16 of the Electricity (Amendment) Rules, the 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 recently notified new Renewable Purchase Obligation (RPO) trajectory till 2029-30 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.

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 2031-32 for Andhra Pradesh based on inputs received from APTRANSCO. It was found that the state's existing contracted capacity, along with capacity addition plans for conventional and renewable energy sources, may not be adequate to meet projected demand.

To find out the least cost option for generation capacity expansion for the period 2023-24 to 2031-32, a long-term study for the State of Andhra Pradesh was carried with an objective of minimizing 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, the likely contracted capacity of the state of Andhra Pradesh is 83,737 MW, which comprises 10315 MW from Coal, 444 MW from Biomass, 1774 MW from Hydro, 25729 MW from Wind, 39642 MW from Solar, 134 MW from Nuclear, and 9013 MW from energy storage systems (i.e., Pumped Storage Plants and Battery (6 hours)).

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 Andhra Pradesh based on the inputs received from APTRANSCO and to fulfill the RPO trajectory. The study suggests the optimal resource mix till 2032 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 Andhra Pradesh for catering to above highlighted uncertainties so that demand can be met reliably throughout the year.

2.0 Andhra Pradesh RA Study

2.1 Present Power Scenario in Andhra Pradesh

As of March 2023, the total contracted capacity for Andhra Pradesh is 21,978 MW. Out of the total contracted capacity (CC), the share of non-fossil fuel-based CC is 49 %.
The fuel-wise contracted capacity as of March 2023 is given in Table and Figure below:

Table 1 Fuel-wise Contracted Capacity as on March 2023

Source	Contracted Capacity (MW)	Percentage (%)
Coal	10315	47
Gas	899	4
Nuclear	134	1
Hydro	1774	8
Solar	4279	19
Wind	4084	19
Bioenergy	444	2
Total	21978	100

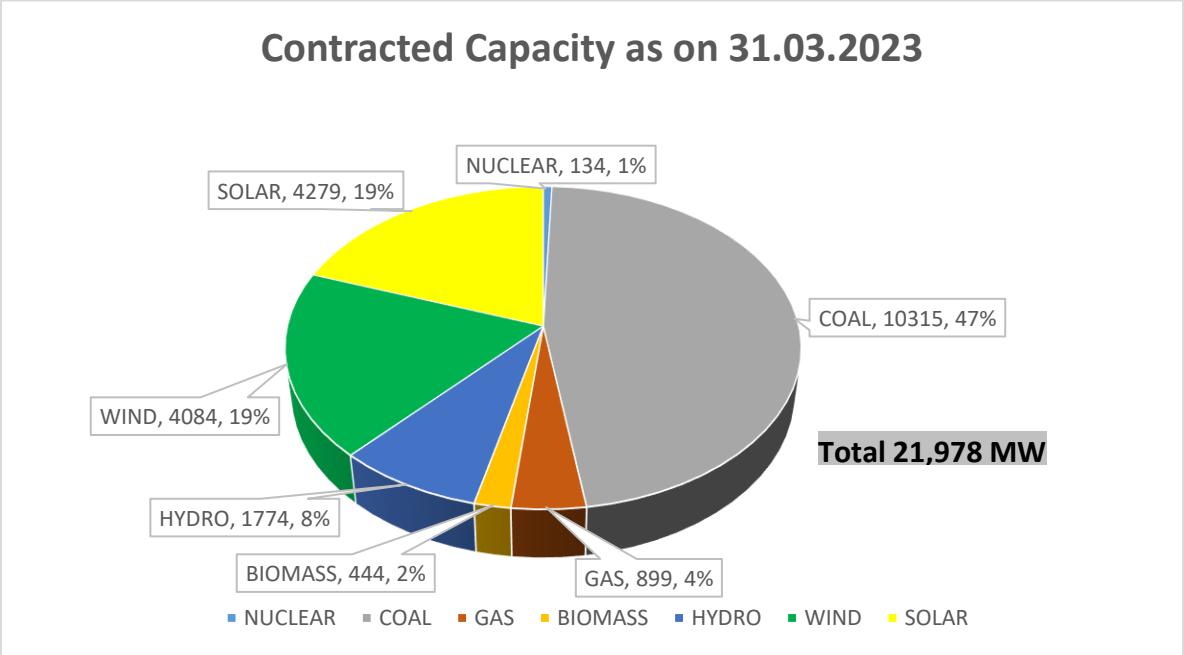


Figure 1 Fuel-wise Contracted Capacity (in MW) as on Mar 2023

2.2 Present Demand Analysis (2022-23)

Hourly demand pattern of 2022-23 was analyzed and it was observed that the peak demand season for Andhra Pradesh is during the months of January, February, March and April. The hourly demand pattern generally remains similar for all the months. Andhra Pradesh witnesses peak demand during day hours. The Demand during the months from October to December remains significantly low as compared to other months, which reflects the effect of seasonality in demand.

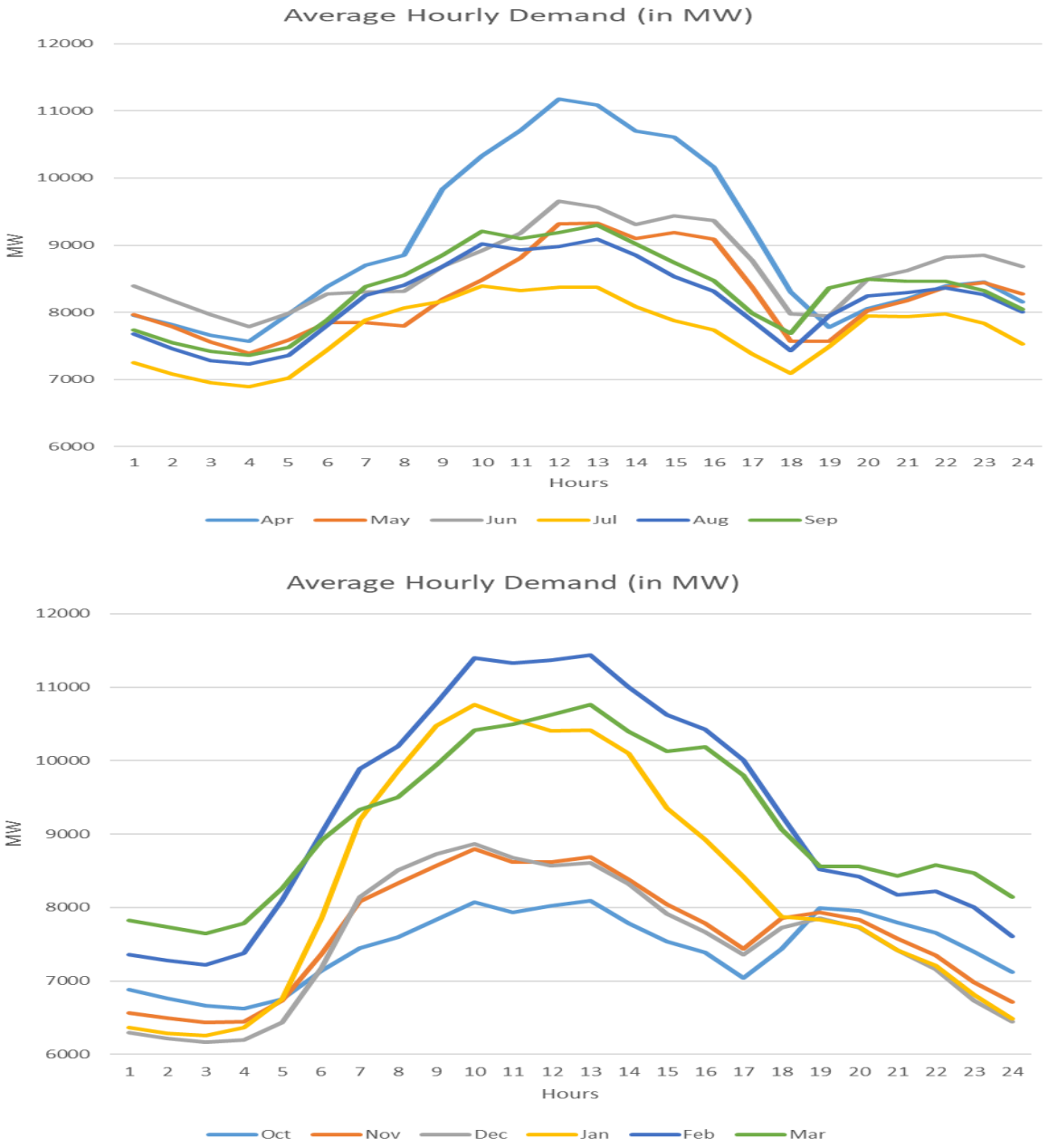


Figure 2 Average Hourly Demand Profile (MW)

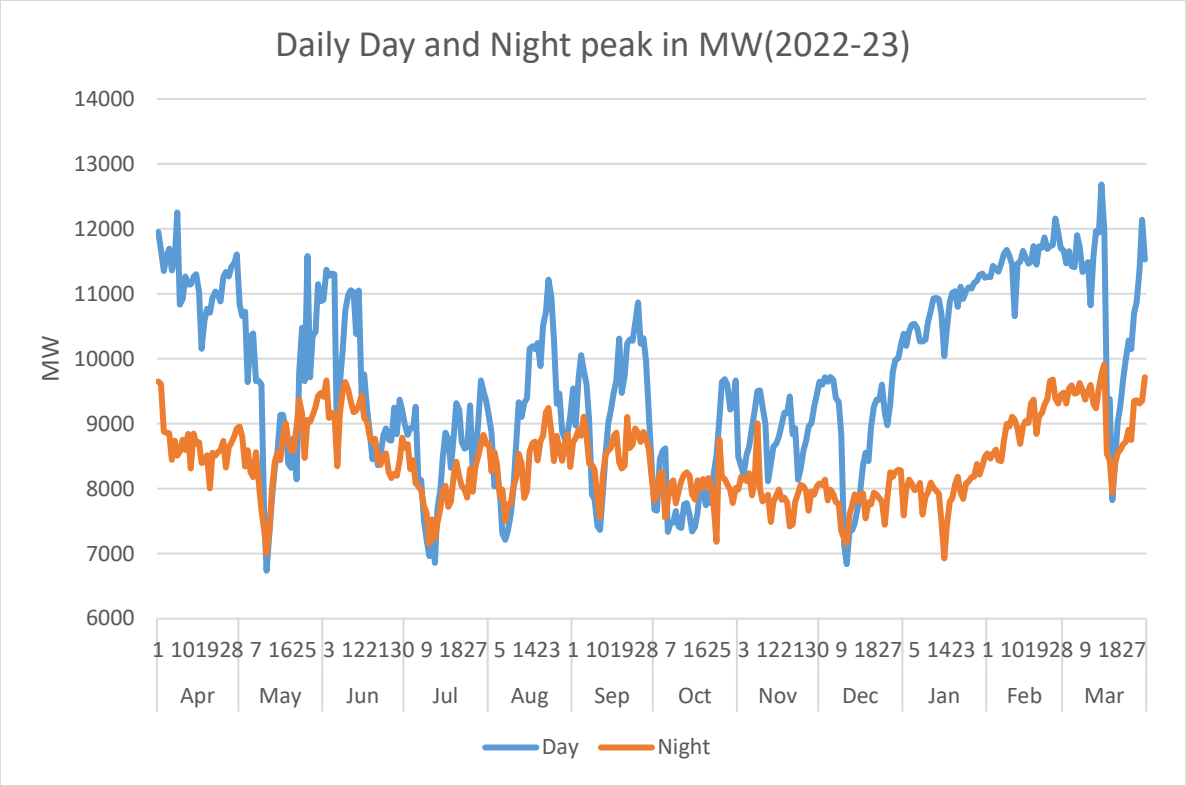


Figure 3 Day and Night Peak in MW of Andhra Pradesh (2022-23)

3.0 Inputs/Assumptions for the Study

i) Peak and Energy Demand for Andhra Pradesh has been taken as per APTRANSCO Projections. The projections of both APTRANSCO and 20th EPS are close to each other as can be seen from Figure 4. However, the Demand estimation furnished by APTRANSCO was closer than that projected by the 20th EPS for 2023-24, and actual demand recorded in 2022-23, in terms of energy requirement. Therefore, the Studies have been carried out using APTRANSCO projections. The demand projections provided by APTRANSCO were until the year 2029-30 only. The demand projections for 2030-31 and 2031-32 were calculated using the CAGR of demand projections provided by APTRANSCO

Table 2 Future Demand Projection by 20th EPS

	2023-24	**2024-25**	**2025-26**	**2026-27**	**2027-28**	**2028-29**	**2029-30**	**2030-31**	**2031-32**
Energy Projections (MU)	78134	84245	90889	98162	105792	113859	123361	130196	137022
Year on Year Growth	-	7.82%	7.89%	8.00%	7.77%	7.63%	8.35%	5.54%	5.24%

Peak Demand Projections (MW)	14269	15337	16495	17758	19076	20461	22091	23243	24387
Year on Year Growth	-	7.48%	7.55%	7.66%	7.42%	7.26%	7.97%	5.21%	4.92%

Table 3 Future Demand Projection by APTRANSCO

	2023-24	**2024-25**	**2025-26**	**2026-27**	**2027-28**	**2028-29**	**2029-30**	**2030-31**	**2031-32**
Energy Projections (MU)	79472	85365	90924	99731	105179	111378	117510	123980	130805
Year on Year Growth	-	7.42%	6.51%	9.69%	5.46%	5.89%	5.51%	5.51%	5.50%
Peak Demand Projections (MW)	13746	15226	16256	17831	18805	19913	21042	22235	23496
Year on Year Growth	-	10.77%	6.76%	9.69%	5.46%	5.89%	5.67%	5.67%	5.67%

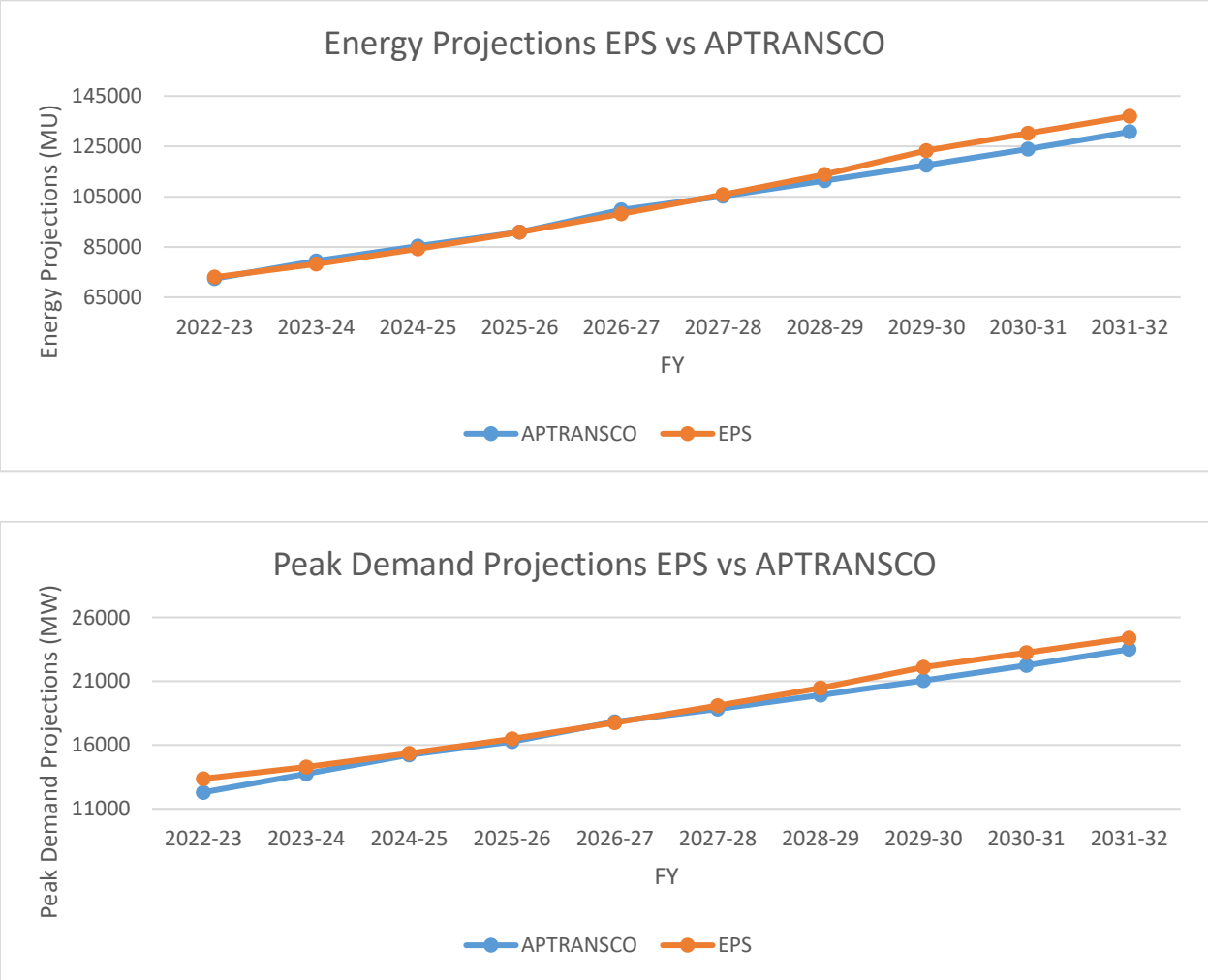


Figure 4 Comparison of Energy Requirement and peak Demand Projections of EPS vs APTRANSCO

ii) The future hourly demand profile for 2031-32 has been projected using the hourly demand profile for 2022-23 as the base profile.

iii) The actual hourly solar and wind generation profiles and CUFs, as available with CEA, have been considered for the Study as the CUF from the data submitted by APTRANSCO was on the lower side.

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

v) Existing & Planned Capacity: As per the information received from Andhra Pradesh, 21,645 MW of Wind-based capacity is planned till 2029-30, and 35,363 MW of Solar-based capacity is planned till 2029-30.

vi) RPO trajectory: In order to meet its Renewable Purchase Obligation (RPO), as per RPO trajectory notified by the Ministry vide order dated 22nd July, 2022, Andhra Pradesh's requirement to add/contract additional renewable capacity (MW) has been assessed as below.

Table 4 Total Energy required to meet RPO (MU) as per MoP order dated 22.07.2022

	2023-24	**2024-25**	**2025-26**	**2026-27**	**2027-28**	**2028-29**	**2029-30**
Wind	1250	2072	3054	4211	5533	7014	8561
Hydro	516	910	1345	1767	2275	2858	3479
Other RPO	19385	22215	25603	29311	33250	37221	41412

Table 5 Generation eligible for RPO (MU) as per existing and planned capacity addition*

	2023-24	**2024-25**	**2025-26**	**2026-27**	**2027-28**	**2028-29**	**2029-30**
Wind	6241.71	11751.03	18115.03	24784.74	31849.94	36720.39	47403.21
Hydro	6	3391	4399	8428	15480	24547	34721
Other RPO	21925	36783	52021	64613	76928	80168	88441

Table 6 Surplus/Shortfall (-) in RPO Generation considering Fungibility for Hydro RPO and Other RPO (MU)

	2023-24	**2024-25**	**2025-26**	**2026-27**	**2027-28**	**2028-29**	**2029-30**
Wind	4482	9679	15061	20574	26317	29707	38842
Hydro	0	2481	3053	6661	13205	21689	31242
Other RPO	2540	14568	26418	35302	43678	42948	47029

Additional capacity to be contracted by Andhra Pradesh to meet RPO is given below:

Table 7 As per RPO trajectory, Andhra Pradesh needs to add/contract following additional capacity (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**
Large + Small Hydro	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Solar + Other RE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**

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.

4.1 Demand variation:

The variation in demand pattern of Andhra 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.

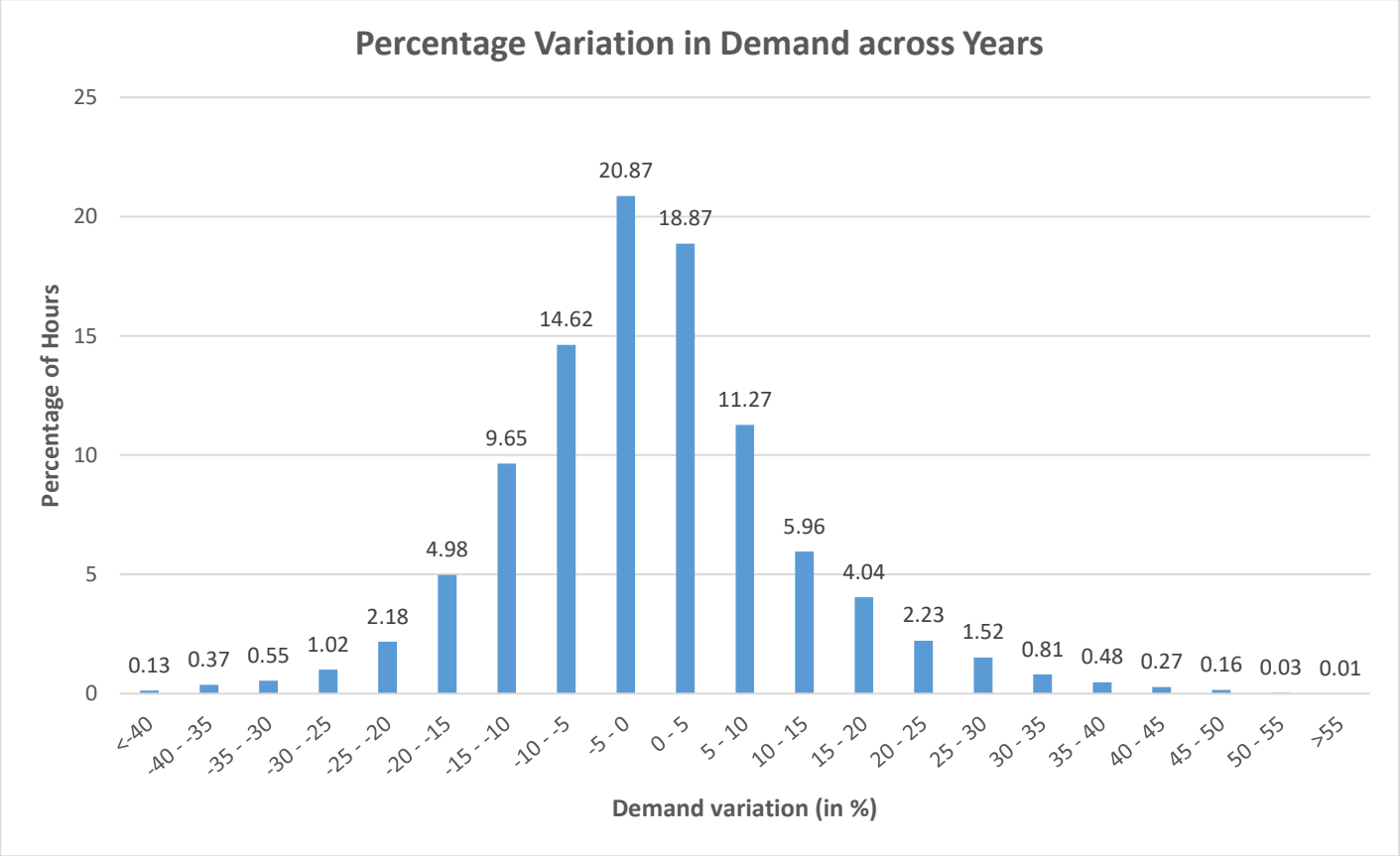


Figure 5 Hourly Percentage Variation in Demand across years

It can be observed that the hourly demand typically varies ±20% and ±15% from a corresponding hour in previous years (Normalized figure) for 90% and 81% of instances, respectively. This variation is primarily due to temperature, weather parameters or any random outages of transmission lines and generation units, etc. The reliability study has captured this variation 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 behaviour over the years.

4.2 RE variation

In the long-term capacity expansion planning studies, a particular profile for Solar and Wind Plants is considered based on the observed solar and wind generation data to determine the optimal capacity mix. However, due to the 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 have been varied by 10% and 50%, respectively, to incorporate the variation in these generation sources and plan for requisite measures to mitigate such behaviour.

4.3 Forced Outage of Thermal Generators

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

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

5.0 Results of the study

5.1 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 2031-32 is about 2814 MU. The yearly likely unserved energy with the planned capacities is given below.

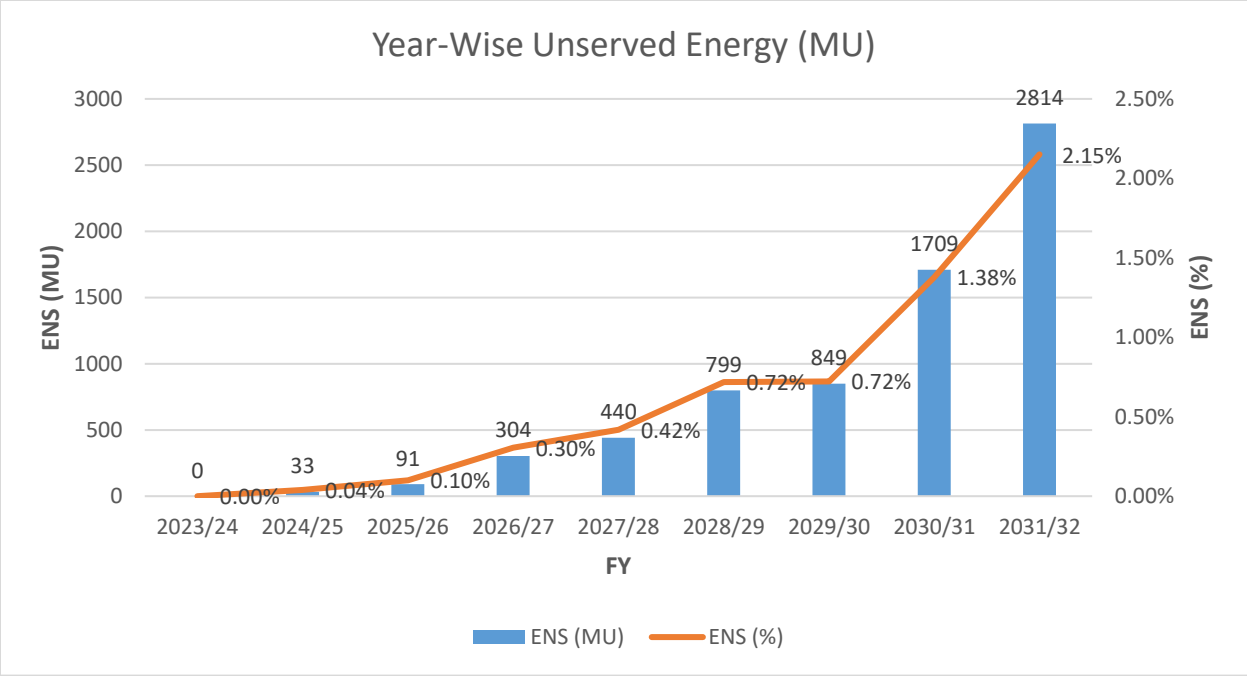


Figure 6 Yearly likely unserved energy with the planned capacities for Andhra Pradesh (in MU)

The study has also analyzed the Daily and monthly pattern of unserved energy in the year 2031-32, 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.

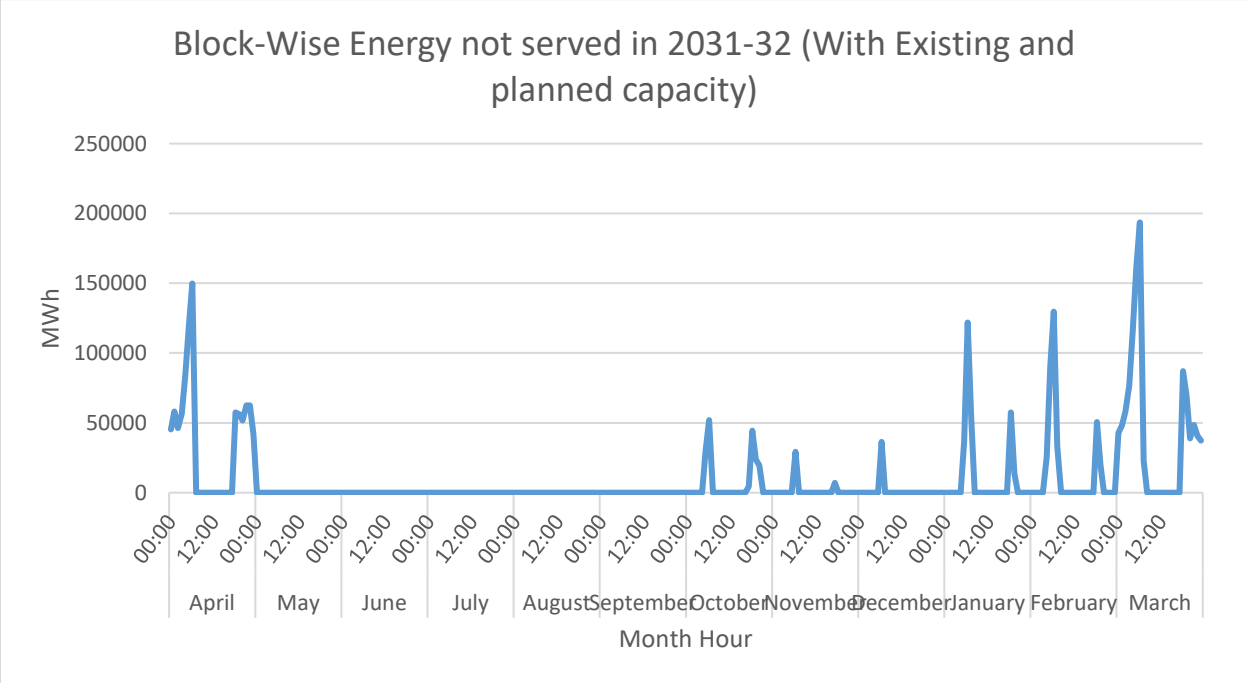


Figure 7 Daily Unserved Energy Pattern MU (2031-32)

5.2 Capacity Mix Projection

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

i) There is a requirement for storage 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 Andhra Pradesh are given below:

Table 8 Year-wise capacity projections (in MW)

	COAL	NUCLEAR	GAS	BIOMASS	HYDRO	WIND	SOLAR	STORAGE (6 Hours)	STOA
2023/24	10315	134	899	444	1774	6034	6242	0	691
2024/25	10315	134	899	444	1774	8745	13639	0	868
2025/26	10315	134	899	444	1774	11863	21304	0	1444
2026/27	10315	134	899	444	1774	15141	27574	3020	401
2027/28	10315	134	899	444	1774	18611	33687	5813	0
2028/29	10315	134	899	444	1774	20851	35350	6613	0
2029/30	10315	134	899	444	1774	25729	39642	7413	0
2030/31	10315	134	899	444	1774	25729	39642	8213	0
2031/32	10315	134	899	444	1774	25729	39642	9013	0

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

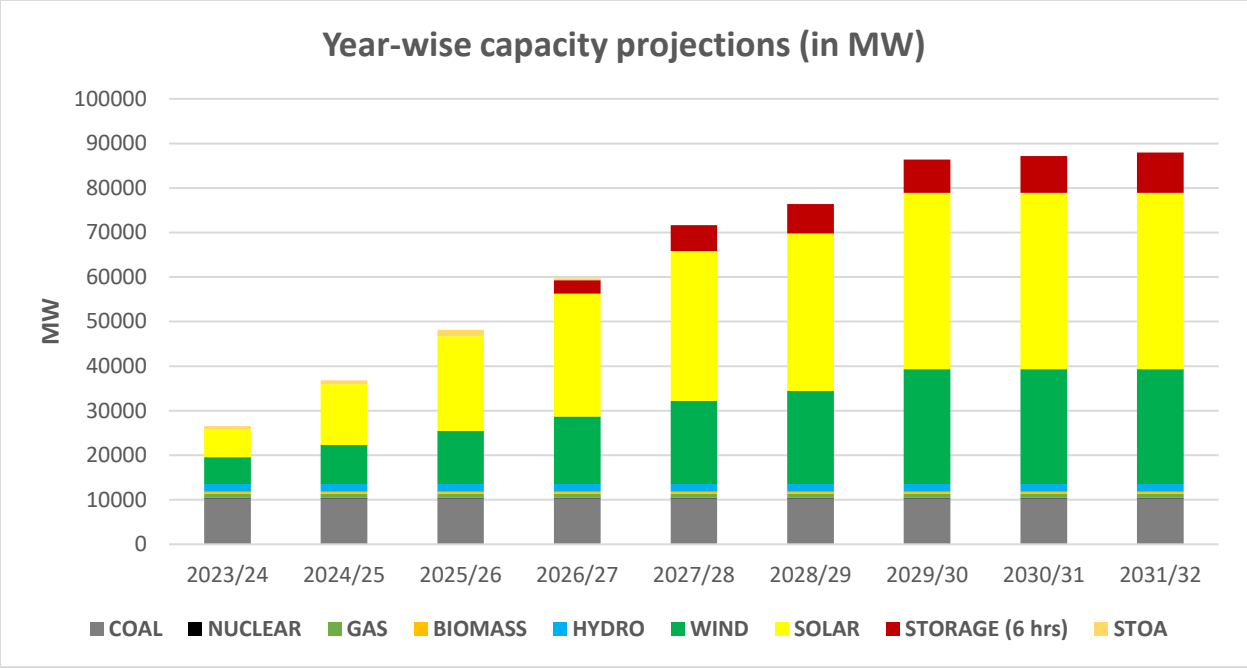


Figure 8 Projected Capacity Mix Year-wise (MW) for Andhra Pradesh

As per the Resource Adequacy studies, the total projected Capacity for the year 2031-32 is 83,737 MW, which comprises 10315 MW from Coal, 444 MW from Biomass, 1774 MW from Hydro, 25729 MW from Wind, 39642 MW from Solar, 134 MW from Nuclear, and 9013 MW from energy storage systems (i.e., Pumped Storage Plants and Battery (6 hours)). This CC 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 the state of Andhra Pradesh has been assessed as 33.5%, indicating that the capacity addition that has been planned is excess. In addition, the projected/contracted capacity fulfils the stipulated Renewable Purchase Obligation.

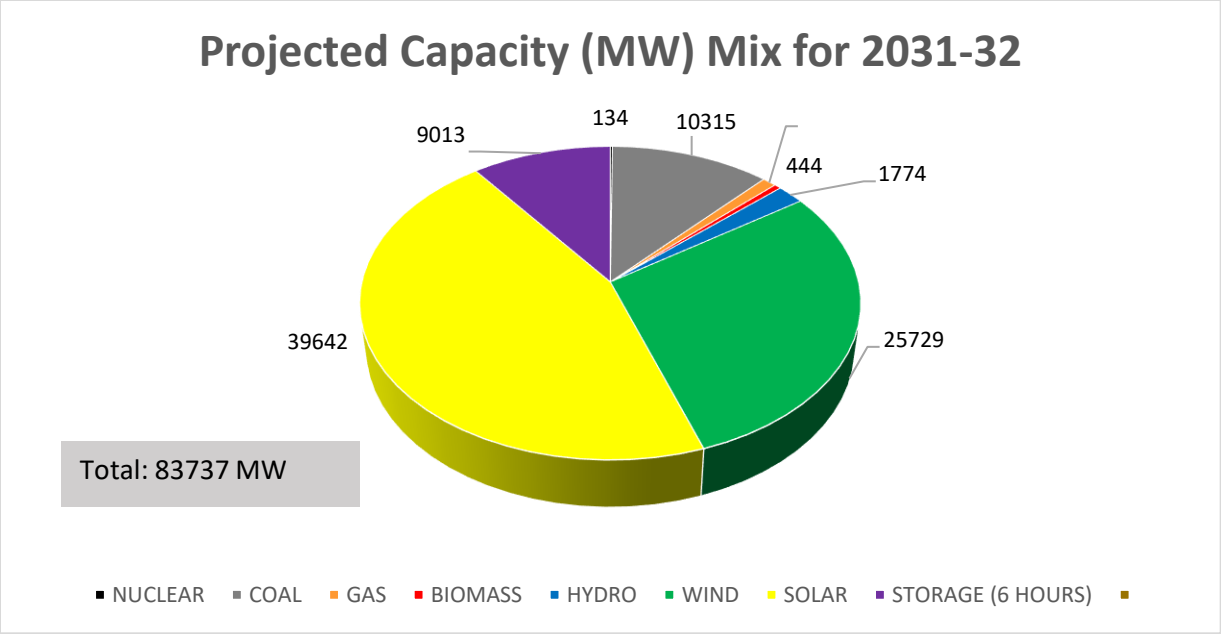
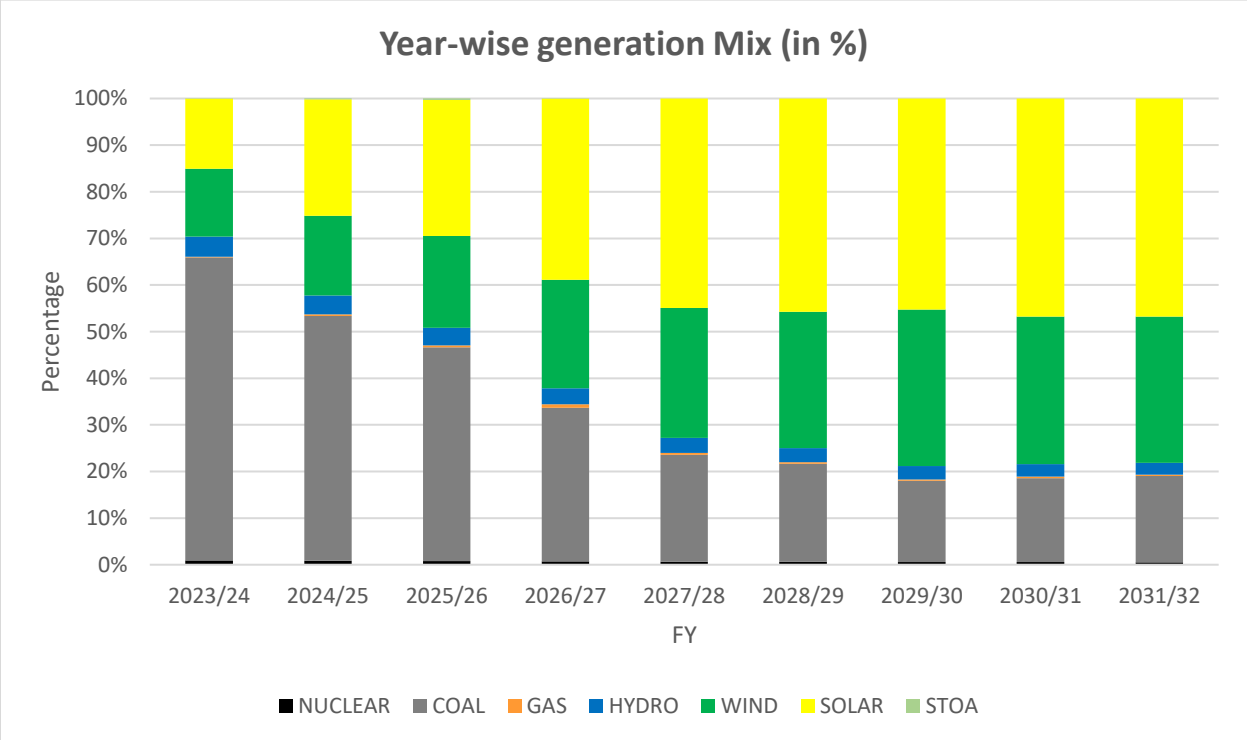
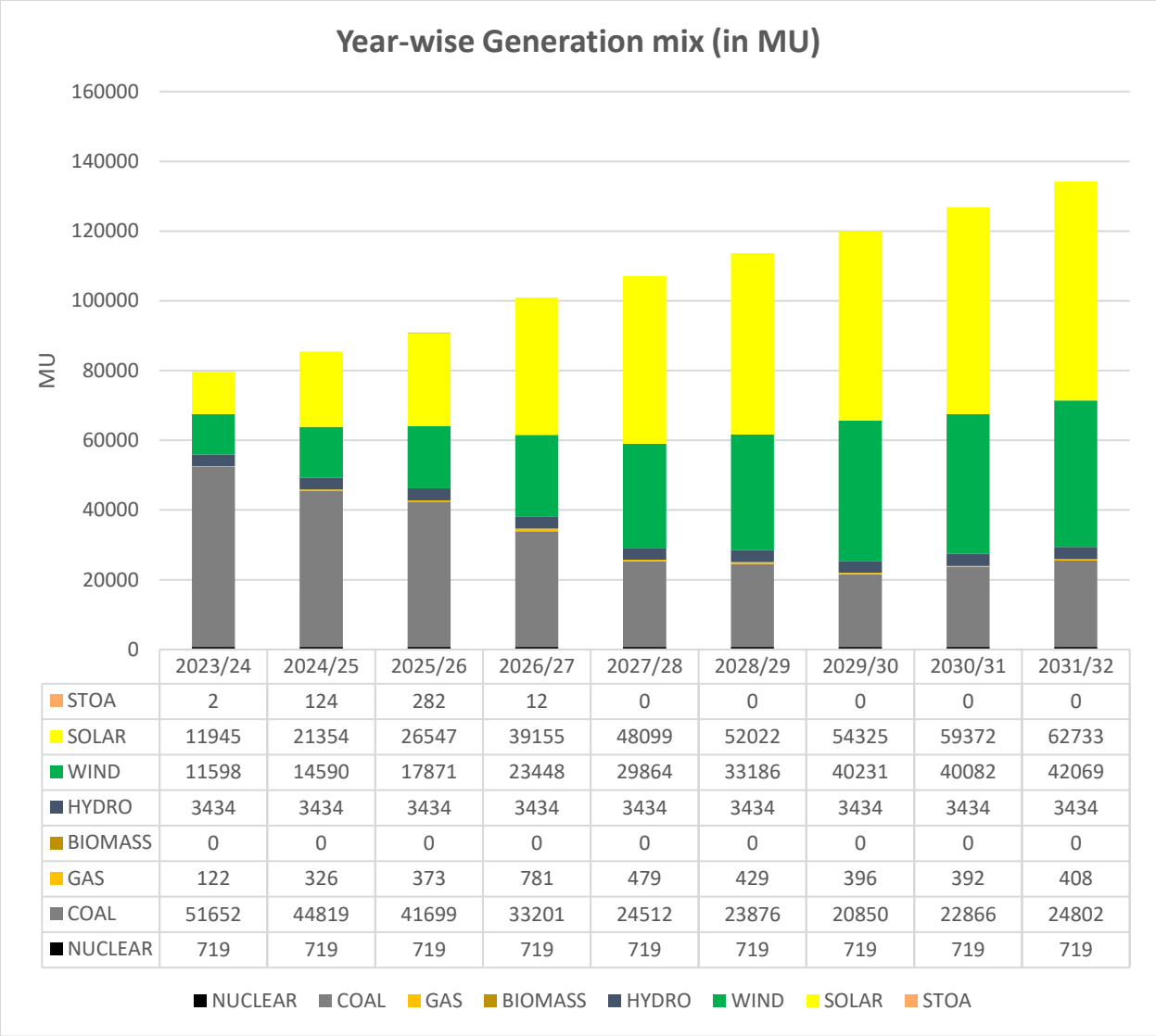


Figure 9 Contracted Capacity Mix in 2031-32 with 5% PRM

The share of non-fossil fuel-based capacity in the total contracted capacity is projected to increase to around 77% in 2032 from 49 % in 2022-23 with higher contribution from non-fossil fuel-based capacities in alignment with RPO trajectory. The contribution of STOA or dependence on market in the generation mix for meeting the peak demand requirement is in the range of 0-3% in different years till 2032.





	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32
STOA	2	124	282	12	0	0	0	0	0
SOLAR	11945	21354	26547	39155	48099	52022	54325	59372	62733
WIND	11598	14590	17871	23448	29864	33186	40231	40082	42069
HYDRO	3434	3434	3434	3434	3434	3434	3434	3434	3434
BIOMASS	0	0	0	0	0	0	0	0	0
GAS	122	326	373	781	479	429	396	392	408
COAL	51652	44819	41699	33201	24512	23876	20850	22866	24802
NUCLEAR	719	719	719	719	719	719	719	719	719

Figure 10 Year-wise projected generation mix (in GWh)

5.3 Day-wise Surplus Capacity Andhra Pradesh (MW)

The pattern of surplus capacities has been observed as below. Available Surplus capacity can be due to seasonal variation of demand wherein the demand in the months from May to December is significantly lower as compared to other months of the year. 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. Andhra Pradesh has likely surplus capacity available during the months from May to December (tentatively in the range of 1200-7000 MW for different years as shown below) which can be shared with other states.

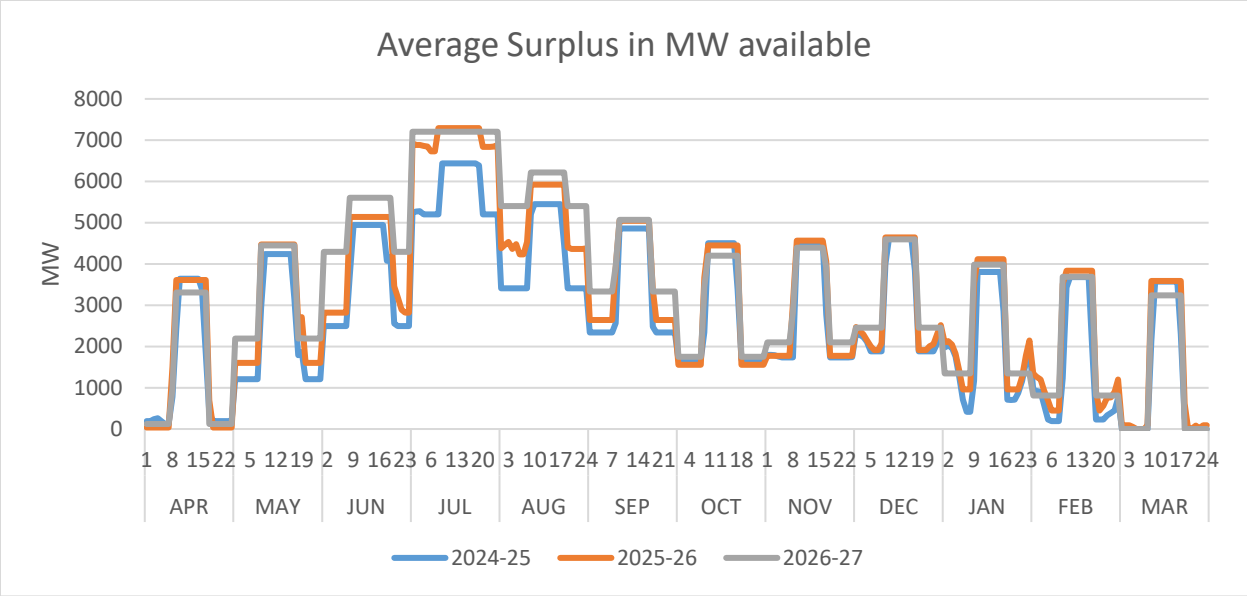


Figure 11 Surplus Coal Capacity Year-wise (MW)

5.4 Coal Capacity Performance

The coal capacity PLF is expected to reduce from 57% in 2023-24 to the range of 23%- 27% for the years till 2032 indicating higher absorption of renewable energy. The low PLF of coal-based capacity can also be attributed to the fact that peak demand of Andhra Pradesh occurs during day time when abundant solar generation is available.

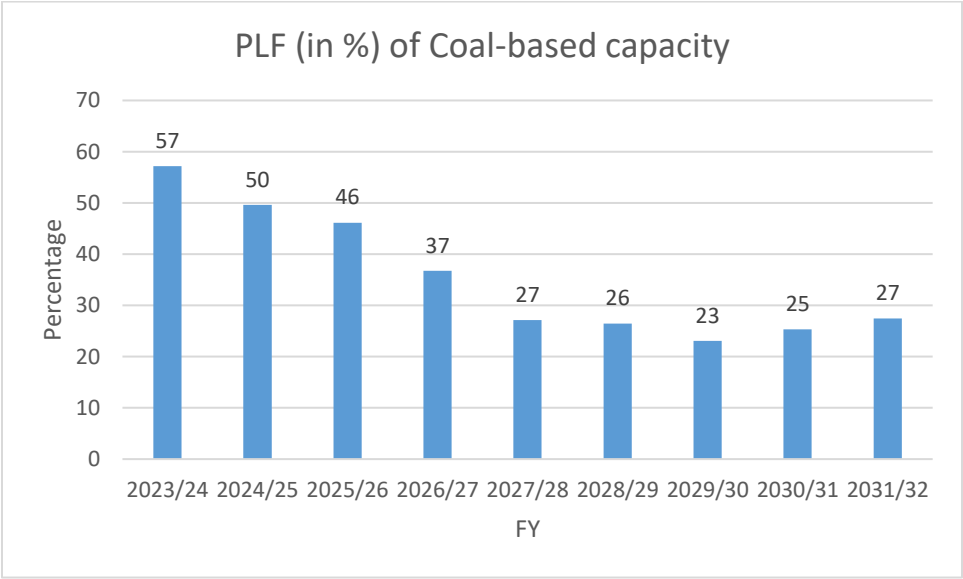


Figure 12 Year-wise coal capacity PLF for Andhra Pradesh (in %)

6.0 Capacity contract requirement for future

It has been found out in the studies that Andhra Pradesh 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.

Table 9 Year wise Capacity Addition for Andhra Pradesh (in MW)

Year	WIND		SOLAR		STORAGE (6 Hours)	STOA/MTOA	TOTAL	
	Planned	Additional	Planned	Additional	Additional	(NET)	Planned	Additional
2023/24	1950	0	1963	0	0	691	3913	691
2024/25	2711	0	7397	0	0	868	10108	868
2025/26	3118	0	7665	0	0	1444	10783	1444
2026/27	3278	0	6270	0	3020	401	9548	3421
2027/28	3470	0	6113	0	2793	0	9583	2793
2028/29	2240	0	1663	0	800	0	3903	800
2029/30	4878	0	4293	0	800	0	9171	800
2030/31	0	0	0	0	800	0	0	800
2031/32	0	0	0	0	800	0	0	800

7.0 Alternate Resilient Scenario Analysis

In view of the recent surge in Power demand during the year 2023-24 and capacity addition being delayed vis-a –vis 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 Demand and Energy Requirement- 5% increase compared to the APTRANSCO demand projections.
- Capacity Addition being delayed from their anticipated year as follows:

Table 13 Time Delay in commissioning of contracted capacity

Contracted Capacity Type	Years Delayed
Renewable Energy Capacity	1

7.1 Capacity Mix Projections

	COAL	NUCLEAR	GAS	BIOMASS	HYDRO	WIND	SOLAR	STORAGE (6 Hours)	STOA
2023/24	10315	134	899	444	1774	4084	4279	0	2024
2024/25	10315	134	899	444	1774	6034	6242	0	2932
2025/26	10315	134	899	444	1774	8745	13639	0	2041
2026/27	10315	134	899	444	1774	11863	21304	3662	0
2027/28	10315	134	899	444	1774	15141	27574	7095	0
2028/29	10315	134	899	444	1774	18611	33687	7895	0
2029/30	10315	134	899	444	1774	20851	35350	8695	0
2030/31	10315	134	899	444	1774	25729	39642	9495	0
2031/32	10315	134	899	444	1774	25729	39642	9618	0

Figure 13: Year-wise capacity projections (in MW) for Most Resilient Scenario

In this scenario, the storage requirement in the year 2031-32 increases by around 605 MW in the case of the stress case scenario compared to the base case.

Also, the requirement of Short term market-based contracts for meeting the peak demand in a stress case scenario increases in the initial three years in the range of 597 to 2064 MW.

8.0 Conclusion

The study has considered demand projections of APTRANSCO for assessing the resource adequacy of Andhra Pradesh. The demand projections by APTRANSCO are higher compared to the demand projections by 20th Electric Power Survey (EPS) in terms of energy requirement and are closer to the actual power supply position, while there is negligible difference between the overall projections of APTRANSCO and 20th Electric Power Survey (EPS).

The current capacity mix in Andhra Pradesh has 51% of contracted capacity from fossil fuel sources. The peak demand season is typically from January to April with peak demand occurring during day time. The Demand during the months from October to December 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 practised for managing the seasonal variation in demand, is one of the effective ways to ensure resource adequacy in such periods.

The study has been done based on the hourly load pattern of the year 2022-23.

Andhra Pradesh is likely to witness an energy deficit ranging from 33 MUs to 2814 MUs in different years from 2023-24 to 2031-32 with the existing and planned capacity addition. Andhra Pradesh is surplus in fulfilment of its Renewable Purchase Obligations (RPO) and does not need to contract any renewable capacities. The projected capacity and generation mix fulfil the RPO obligations by 2030 as specified by the Ministry of Power.

Andhra Pradesh is likely to have unserved energy in coming years and needs to contract storage-based capacities for meeting energy requirements other than the planned capacities, owing to the high quantum of renewable based capacity i.e., solar and wind that is planned by Andhra Pradesh. The quantum of storage-based capacities required to be contracted is about 2222 MW in the year 2027-28 which increases to around 5140 MW in the year 2031-32.

The energy requirement to be met from STOA is less than 1% of the total energy requirement but is critical in months of peak demand to fulfil the end consumer demand. STOA value reflects the peak value (MW) requirement in the capacity mix. However, in energy terms, the requirement from STOA is quite less.

The coal capacity PLF expected to reduce from 57% in 2023-24 to the range of 23%- 27% for the years till 2032 indicating higher absorption of renewable energy.

The Alternate Resilient Scenario carried out for Andhra Pradesh for possibility of higher demand than projected by APTRANSCO has revealed that the storage requirement increases by around 605 MW in 2031-32 compared to the base case scenario. The dependency on STOA also increases compared to the base case scenario.

It is likely that Andhra Pradesh may have surplus capacity available during the months from May to December (tentatively in the range of 1200-7000 MW for different years), which can be shared with other states.

Assumption for Resource Adequacy Studies for the state of Andhra Pradesh

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

RE CUF considered

Hydro Planned/ Existing PLF	Bioenergy PLF	Solar Existing/ Planned CUF	Wind Planned/ Existing CUF	PSP/ Small Hydro CUF
23%	20%	21.80 % / 22.0%	20.80 % / 25.0 %	17.0%

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	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.