

Report on Resource Adequacy Plan (Generation) for Andhra Pradesh (2025-26 to 2035-36)

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Government of India
Ministry of Power
Central Electricity Authority

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Disclaimer

This Resource Adequacy study for Andhra Pradesh has been conducted based on the data and inputs provided by Andhra Pradesh State Load Dispatch Centre (AP SLDC). The findings, analysis and conclusions presented in this report are contingent upon the accuracy, completeness and timeliness of the information furnished by Andhra Pradesh. Any discrepancies or limitations in the data may affect the outcomes of the study accordingly.

In accordance with the Resource Adequacy Guidelines dated 28th June 2023, each Distribution Licensee is mandated to prepare a Resource Adequacy Plan (RAP) for a 10-year horizon, referred to as the Long-Term Distribution Licensee Resource Adequacy Plan (LT-DRAP), which shall be vetted and validated by the Central Electricity Authority (CEA). CEA has facilitated this study and prepared the report solely to assist Andhra Pradesh in fulfilling this requirement.

It is expressly stated that the responsibility for the implementation of the study's recommendations, ensuring the adequacy of electricity resources, and undertaking any related actions, including financial implications if any, rests entirely with Andhra Pradesh.

Executive Summary

Ministry of Power had notified the Electricity (Amendment) Rules in December 2022. As per Rule 16 of the Electricity (Amendment) Rules, the Ministry of Power has notified the Resource Adequacy (RA) Guidelines. According to these Guidelines, the Central Electricity Authority (CEA) is entrusted with the responsibility of preparing the Long-Term National Resource Adequacy Plan (LT-NRAP). Further, each Distribution Utility is required to carry out a Long-Term Distribution Licensee Resource Adequacy Plan (LT-DRAP) to reliably meet its peak electricity demand and electrical energy requirements.

As per the Resource Adequacy Guidelines dated 28th June 2023, each Distribution Licensee shall undertake a Resource Adequacy Plan (RAP) with a 10-year planning horizon, LT-DRAP, to meet its own peak electricity demand and electrical energy requirements. This plan shall be vetted/validated by the CEA to leverage the benefits of national-level optimisation for the Distribution Licensees. The LT-DRAP shall be prepared by the Distribution Licensees on an annual rolling basis, factoring in the already contracted capacity and optimising the requirement for additional capacity.

The Government of India has gazette-notified the Renewable Purchase Obligation (RPO) trajectory up to 2029-30 vide gazette notification dated 20th October 2023, which mandates that a specified portion of electrical energy consumption must be met from renewable energy sources.

To support the utility in fulfilling this requirement, CEA, in collaboration with the utility, initially conducted a Resource Adequacy (RA) study with a planning horizon up to FY 2034-35, based on the data received from the utility and in compliance with the RPO trajectory specified vide gazette notification dated 20th October 2023. This study has now been updated and extended to cover the period up to FY 2035-36, incorporating the latest data furnished by the utility and planning assumptions.

The electrical energy requirement and peak electricity demand for Andhra Pradesh is projected to increase with a CAGR of 6.9% and 7.1% respectively, from 2025-26 to 2035-36 as forecasted by Andhra Pradesh. For satisfying resource adequacy, i.e., meeting the electricity demand reliably and at an affordable cost, the utility needs to methodically plan its capacity expansion either by investing in generation capacity or by procuring power. In view of the reduction in cost of solar, wind and technology options like Energy Storage Systems (ESS), planning for a long-term optimal generation capacity mix gains tremendous importance so that the future generation capacity mix is cost-effective as well as environmentally friendly.

A study has been carried out for Andhra Pradesh, considering the existing contracted capacity and planned capacity addition. It was found that Andhra Pradesh's likely contracted capacity may not be sufficient to meet the projected electricity demand. Further, the total unserved electrical

energy in the year 2035-36 is expected to be about 32,694 MU, which is about 19.4% of the projected annual electrical energy requirement during the year 2035-36.

To find out the least cost option for generation capacity expansion for the period 2025-26 to 2035-36, a long-term study has been carried out with the objective to minimise the total system cost of generation, including the cost of anticipated future investments, while fulfilling all the technical constraints associated with various power generation technologies. Additionally, reliability study has been carried out to determine the probability of unmet demand and hours, by implementing the variation in demand, variation in RE and forced outage of thermal generators (Coal/ Lignite), etc.

Generation capacity expansion pathways have been considered for the long-term study based on the yearly capacity addition plans of the utility, along with RPO constraints. The Renewable capacities have been assessed in view of adherence to the RPO trajectory gazette notified by the Ministry of Power, considering the fungibility among different sources.

The Resource adequacy studies have projected a likely optimal capacity mix for future years till 2035-36, which is able to meet the projected electrical demand reliably at every instance. Based on the study, the likely total projected contracted capacity for the year 2035-36 is around 73,699 MW which consists of 15,781 MW from Coal, 591 MW from Gas, 128 MW from Nuclear, 3,131 MW from Hydro, 8,257 MW from Wind, 24,501 MW from Solar, 9,960 MW from Distributed Renewable Energy (DRE) sources, 51 MW from Biomass, 3931 MW/11924 MWh of Storage, 7370 MW/55770 MWh of PSP will be required. This capacity shall be able to meet the projected demand with prescribed reliability criteria.

1.0 Introduction

The Ministry of Power has notified the 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 were notified in June 2023 by the Ministry of Power in consultation with the 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 the demand-supply situation in the grid precisely due to high seasonality and intermittency in RE generation. Resource Adequacy exercise may also help in the assessment of capacity requirements to be tied up or contracted on a long-term, medium-term, and short-term basis.

Further, the Ministry of Power vide notification dated 20th October, 2023, had notified the RPO trajectory for the states/Discoms. Based on the trajectory specified, 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/Discoms have to contract in addition to their existing/planned capacity to meet their RPO targets.

To support the utility in fulfilling the Resource Adequacy Guidelines and complying with the Renewable Purchase Obligation (RPO) notification, CEA has carried out the RA study for Andhra Pradesh based on inputs furnished by the Utility. The study recommends an optimal resource mix up to FY 2035-36, taking into account technical and financial parameters associated with various capacities. It aims to optimise long-term power procurement while ensuring resource adequacy to meet demand on a 24x7 basis, considering variations in demand, RE generation, and forced outages of thermal capacities. The study assesses the Planning Reserve Margin (PRM) required by the utility to account for the aforementioned uncertainties, ensuring that demand can be reliably met throughout the year.

Prior to this, CEA had conducted the RA study for the Utility up to FY 2034-35, based on inputs from AP SLDC and in accordance with the RPO trajectory specified in the Ministry of Power's gazette notification dated 20th October 2023.

2.0 Highlights of the Previous RA Study (up to FY 2034-35)

1. In the earlier Resource Adequacy (RA) study, financial year 2023-24 had been considered as the base year, and the study covered the period from 2024-25 to 2034-35. The fuel-wise contracted capacity as on 31st March, 2024:

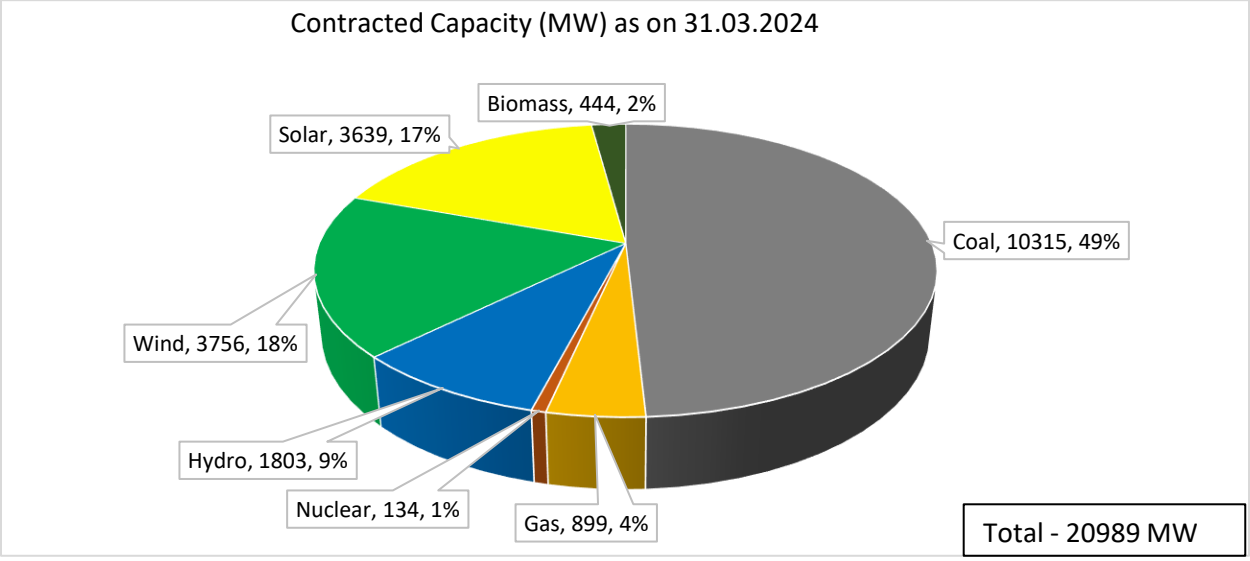


Figure 1: Fuel-wise Contract Capacity (in MW) as of March 2024

2. The hourly demand pattern for 2023-24 had been analysed and considered for the study.

3. Peak Electricity Demand and Electrical Energy Requirement for the State of Andhra Pradesh, as furnished by the utility, were compared with the 20th EPS projections. The electricity demand estimation by Andhra Pradesh is till 2034-35 while EPS projections are till 2031-32 only, and the demand projections by Andhra Pradesh were also found to be very close to the demand projections of 20th EPS. Therefore, the studies had been carried out considering the projections as per Andhra Pradesh, which is tabulated below:

Table 1: Electrical Energy requirement (MU) and Peak electricity demand (MW) projections

Energy Requirement (MU) and Peak Demand (MW) Projections												
	2023-24	**2024-25**	**2025-26**	**2026-27**	**2027-28**	**2028-29**	**2029-30**	**2030-31**	**2031-32**	**2032-33**	**2033-34**	**2034-35**
Energy Projections (MU)	81293 (80209*)	81025	86595	92538	98963	105910	113369	121504	130324	139819	150192	156630
Year on Year Growth (Energy)		-0.33%	6.87%	6.86%	6.94%	7.02%	7.04%	7.18%	7.26%	7.29%	7.42%	4.29%
Peak Demand Projections (MW)	13255 (13,237*)	14610	15600	16653	17793	19019	20341	21784	23355	25045	26902	28850
Year on Year Growth (Peak)		10.85%	8.91%	7.00%	7.01%	6.41%	6.41%	5.15%	5.13%	5.26%	5.24%	7.60%

*actual electricity demand

4. The actual peak electricity demand and electrical energy requirement of the utility observed during 2024-25 is tabulated below:

Table 2: Actual Electrical Energy Requirement and Peak Electricity Demand in 2024-25

Year	Actual electrical energy requirement (in MU)	Actual peak electricity demand (in MW)
2024-25	79,028	13,712

5. To meet the above projected peak electricity demand and electrical energy requirement reliably, the source-wise projected capacity (in MW) as outlined in the previous report is tabulated below.

Table 3: Year-wise capacity projections (in MW)

Year	COAL	HYDRO	WIND	SOLAR	NUCLEAR	PSP	BATTERY	DRE	STOA
2024/25	10315	2273	3756	6639	134	0	0	1002	1438
2025/26	10315	2753	3756	10389	134	0	0	1495	1112
2026/27	10315	2993	4151	11389	134	744	0	2108	878
2027/28	10315	2993	4151	11389	134	2000	0	2717	695
2028/29	10315	2993	4151	11389	134	3470	0	3400	384
2029/30	11245	2993	4751	12489	134	5530	0	4139	0
2030/31	11912	2993	5351	13589	134	6570	0	4856	0
2031/32	12672	2993	5951	14689	134	6570	0	5652	0
2032/33	13577	2993	6551	15789	134	6570	0	6517	0
2033/34	14679	2993	7151	16889	134	6570	0	7473	0
2034/35	15246	2993	7751	17989	134	6570	0	8582	0

*****The STOA/MTOA value represents the peak requirement in MW, and it was recommended that this requirement may be met through power procurement from the market or through bilateral agreements.

6. The year-wise planned and additional capacity contract addition (in MW) for the above tabulated cumulative capacity is detailed below.

Table 4: Year wise capacity additions for Andhra Pradesh (in MW)

FY	Thermal		Wind		Solar	
	Planned	Additional	Planned	Additional	Planned	Additional
2024/25	625	0	0	0	3000	0
2025/26	0	0	0	0	3750	0
2026/27	0	0	395.5	0	1000	0
2027/28	0	0	0	0	0	0
2028/29	840	0	0	0	0	0
2029/30	0	90	0	600	0	1100
2030/31	667	0	0	600	0	1100
2031-32	333	427	0	600	0	1100
2032/33	0	904	0	600	0	1100
2033/34	0	1103	0	600	0	1100
2034/35	0	567	0	600	0	1100

FY	Storage	DRE	Yearly STOA
	Planned	Additional	Additional
2024/25	0	1002	1438
2025/26	0	492	1112
2026/27	0	613	878
2027/28	744	609	695
2028/29	1256	683	384
2029/30	1470	739	0
2030/31	2060	717	0
2031-32	1040	796	0
2032/33	0	865	0
2033/34	0	956	0
2034/35	0	1109	0

3.0 RA Study for Andhra Pradesh (from 2025-26 to 2035-36)

3.1 Present Power Scenario in Andhra Pradesh

The power supply position for Andhra Pradesh for 2021-22 to 2024-25 is given in the Table 5.

Table 5: Power Supply Position of Andhra Pradesh

Power Supply Position						
Year	Energy required (MU)	Energy supplied (MU)	Gap (MU)	Peak Demand (MW)	Peak Met (MW)	Demand not met (MW)
2021-22	68,413	68,219	194	12,551	12,032	519
2022-23	72,302	71,893	410	13,167	12,293	874
2023-24	80,209	80,151	57	13,237	13,237	0
2024-25	79,028	79,025	3	13,712	13,712	0

As of March 2025, the total contracted capacity of Andhra Pradesh is 20393 MW, including 12 MW DRE. Out of the total contracted capacity (CC), the share of non-fossil fuel-based CC is 47%. Fuel-wise contracted capacity as on 31st March, 2025, is given in Table 6 and Figure 2:

Table 6: Fuel-wise Contracted Capacity as on March 2025

Technology	**Contracted Capacity (MW)**	**%**
Coal	10192	50%
Gas	591	3%
Nuclear	128	1%
Biomass	112	1%
Hydro	1773	9%
Wind	3579	18%
Solar	4006	20%
DRE	12	0%
Total	**20393**	100%

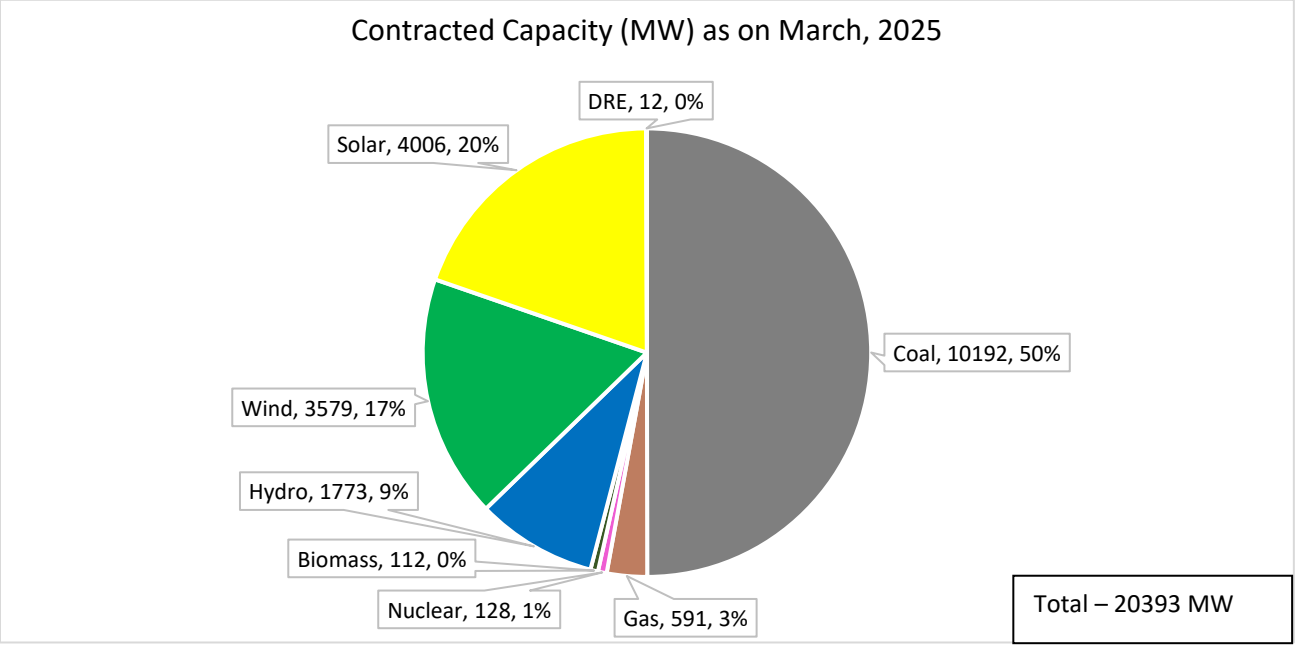


Figure 2: Fuel-wise Contracted Capacity (in MW) as on March, 2025

3.2 Demand Analysis of the FY 2024-25

The hourly demand pattern of 2024-25 was analyzed (as shown in Figure 3 and Figure 4), and it was observed that the peak electricity demand for Andhra Pradesh occurs in the months of March and April. The Demand Pattern of Andhra Pradesh indicates that the state has a higher Day peak in comparison to its Night Peak, with the daily peak mostly occurring during the 10:00 Hrs to 15:00 Hrs.

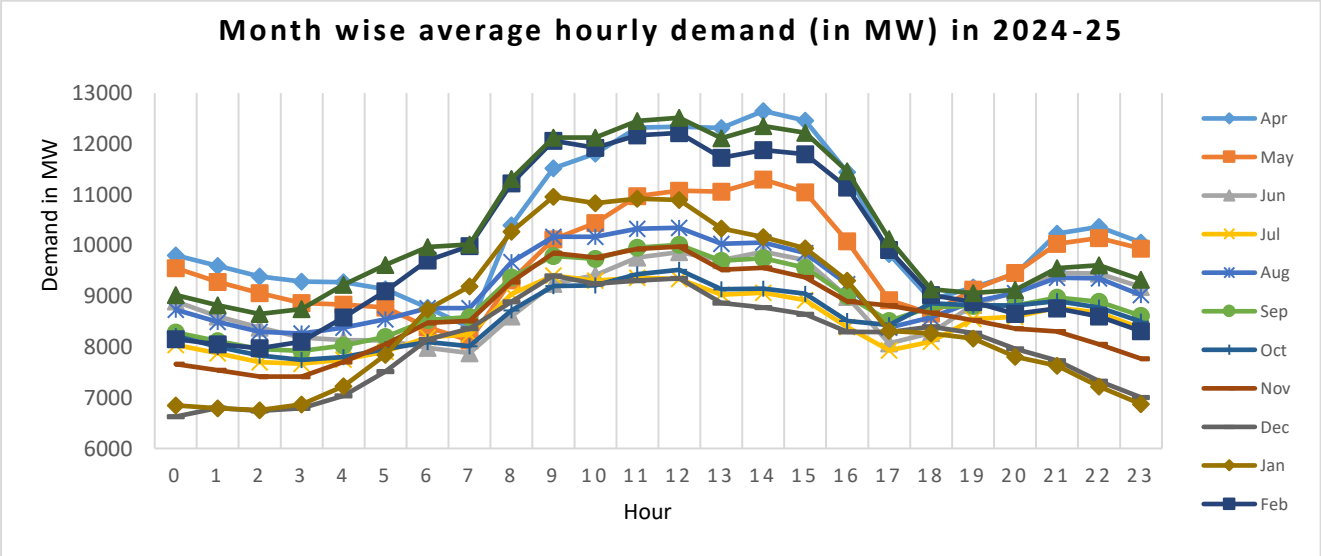


Figure 3: Average Hourly Demand Variation (Month-wise) for 2024-25

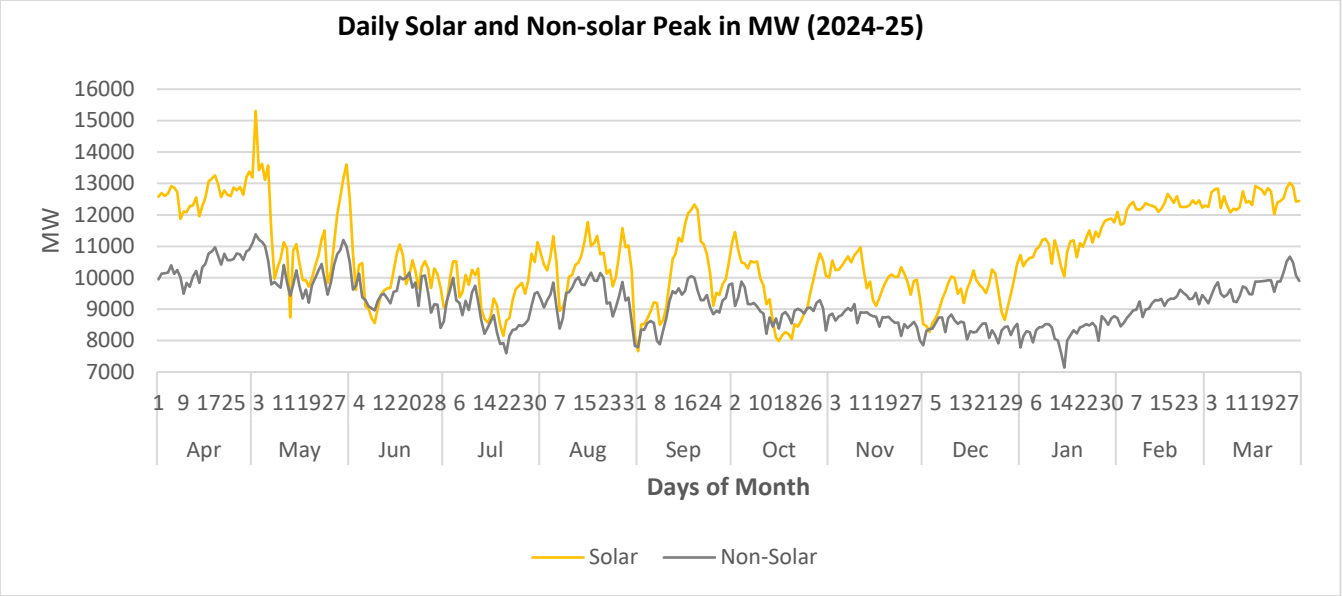


Figure 4: Solar and Non-Solar Peak Electricity Demand in MW for the year 2024-25

The hourly demand pattern of 2024-25 was analysed to find out the number of occurrences of the peak electricity demand and near-peak electricity demand. Such instances are critical for study purpose as it is necessary to ensure resource adequacy during such instances with an optimal mix of long-term, medium-term and short-term contracts.

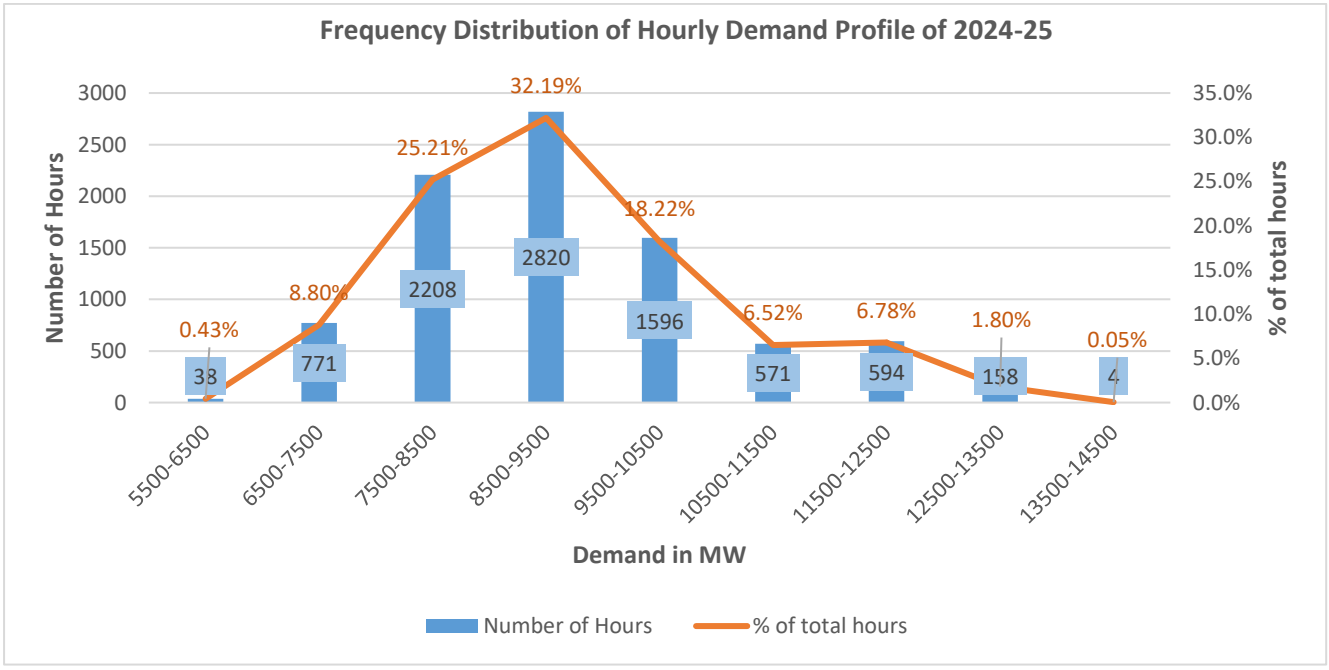


Figure 5: Frequency Distribution of Hourly Demand Profile of 2024-25

4.0 Principles of Generation Planning

The objective of Generation Planning is to determine the optimal cost-effective mix of generation capacities that can reliably meet electricity demand at all times while making the best use of available resources. Rather than attempting to predict the future, generation planning studies aim to collaboratively examine and understand the important factors and interrelationships that will influence the power sector moving forward. As such, planning is a continuous process focused on balancing demand and supply across all times and locations.

The major aspects considered in the planning process are:

i) To supply 24x7 reliable power to consumers
ii) To achieve the objectives of all policies of the Government of India, such as RPO trajectory, RE capacity addition, etc.
iii) To achieve sustainable development.
iv) To fulfil desired operational characteristics of the system, such as reliability and flexibility.
v) Most efficient use of resources.
vi) Fuel availability

4.1 Generation Expansion Planning Tool -ORDENA

The studies were carried out using a generation expansion planning model, namely ORDENA. ORDENA is a mixed integer linear optimisation program that minimises the Net Present Value (NPV) of investment and operation costs subject to several constraints. The major constraints include balancing electricity demand and supply, resource supply limits, planning and operating reserve limits, and policy targets. These constraints are met considering a broad portfolio of conventional generation, renewable generation, and storage.

ORDENA has a reliability module to determine the trustworthiness of the system using Monte Carlo simulations. The software is also capable of carrying out hourly/sub-hourly economic generation dispatch considering all the technical constraints associated with various generation technologies.

The schematic diagram of the software is given in the Exhibit.

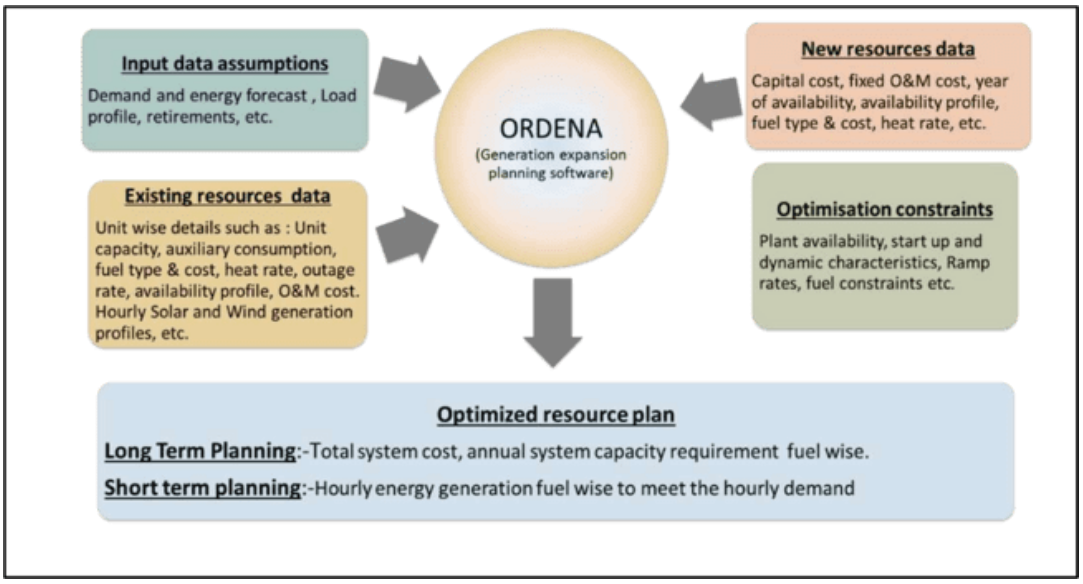


Exhibit: Schematic Diagram -Ordena

5.0 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 every instance in 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 not served, calculated in megawatt-hours (MWh). The metric can be normalised (i.e., divided by the projected electrical energy requirement) to create a Normalised 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 that 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 the economic dispatch model. Monte Carlo simulation helps in analysing the randomness associated with RE energy resource, demand pattern changes and forced outages of the plant. A large number 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 the above variation of system parameters.

Planning Reserve Margin (PRM): To meet the prescribed standard of LOLP / NENS conditions, a sufficient reserve margin needs to be maintained in the system to adequately address 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 percentage of the projected peak electricity demand of the system.

5.1 Variation in Electricity Demand

The hourly variation in electricity demand variation for consecutive years (i.e. 2023-24 and 2024-25, considering 2023-24 as the base) has been analysed. The demand pattern variation of 2023-24 and 2024-25 is shown below:

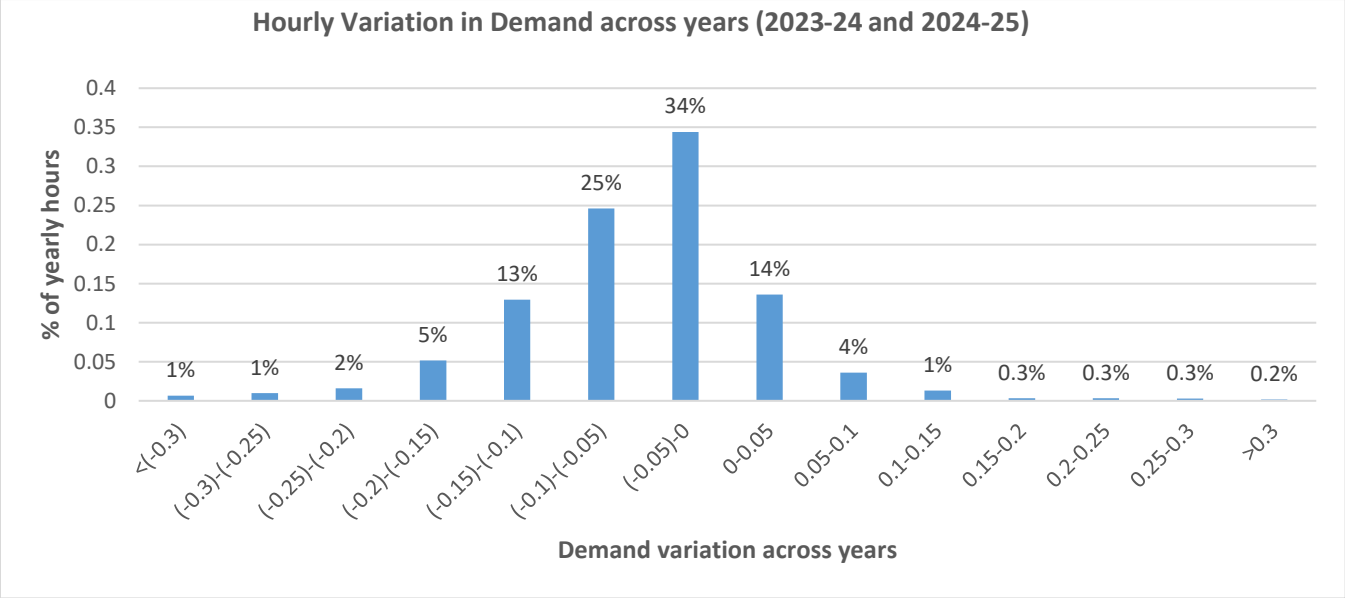


Figure 6: Hourly Variation in Electricity Demand across years

It can be observed that the hourly demand typically varies by ±10% for around 76% of instances. This variation is primarily due to temperature, weather parameters or any random outages of transmission lines and generation units, etc. This variation has been captured in the reliability study by varying the projected hourly demand for the future years by ±10% by introducing a random variable (with normal distribution) for demand as per observed behaviour over the years.

5.2 Variation in RE

In the Long-term capacity expansion planning studies, a particular profile for Solar is considered based on the observed solar 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 and hydro-based generation have been varied by ±10 % and wind generation has been varied by ± 50% to incorporate the variation in these generation sources and plan for the requisite measures to mitigate such behaviour.

5.3 Forced Outage of Thermal Generators

The average forced outage rate of thermal generators is typically 10% with ± 5% variation. The same has been incorporated in the model.

Based on these variations, reliability studies are carried out to ascertain the robustness of the system.

6.0 Inputs/Assumptions for the Study

i) The Electrical Energy Requirement (MU) and Peak Electricity Demand (MW) for the state of Andhra Pradesh has been taken as per the projection by AP SLDC.

Table 7: Electricity Demand Projection as provided by Andhra Pradesh

Electrical Energy Requirement (MU) and Electrical Peak Demand (MW) Projections				
	Energy Projections (MU)	Year-on-Year Growth	Peak Demand Projections (MW)	Year-on-Year Growth
2025-26	86595		15600	
2026-27	92538	6.9%	16653	6.7%
2027-28	98963	6.9%	17793	6.8%
2028-29	105910	7.0%	19019	6.9%
2029-30	113369	7.0%	20341	7.0%
2030-31	121504	7.2%	21784	7.1%
2031-32	130324	7.3%	23355	7.2%
2032-33	139819	7.3%	25045	7.2%
2033-34	150192	7.4%	26902	7.4%
2034-35	156630	4.3%	28850	7.2%
2035-36	168221	7.4%	30927	7.2%

ii) Future demand profile till the year 2035-36 has been projected using the demand profile for the year 2024-25 as the base profile.

iii) The actual solar and wind generation profiles and CUFs have been referred from the previous year's generation data provided by AP SLDC, while the hydro generation profiles and PLFs as per the data available in CEA.

iv) The capital costs of candidate plants for coal, wind, solar, and storage technologies is detailed in the Annexure and are aligned with current market trends and recent price discovery.

v) The planned capacity has been considered based on the tie-up information furnished by Andhra Pradesh. Source-wise planned capacity is given below:

Table 8: Source-wise planned capacity addition

FY	Coal	Hydro	Wind	Solar	PSP 6hr	PSP 8hr	PSP 9hr	Storage 2hr	DRE
2025-26	660	0	0	4500	0	0	0	0	0
2026-27	0	243	633	1067	0	0	0	900	1324
2027-28	0	52	0	0	0	0	0	1000	1824
2028-29	0	1038	0	400	0	0	0	0	2500
2029-30	0	25	0	1933	0	1350	1200	0	100
2030-31	1600	0	0	0	0	0	1750	0	100
2031-32	0	0	0	0	1000	0	0	0	100
2032-33	0	0	0	0	2070	0	0	0	100
2033-34	0	0	0	0	0	0	0	0	0
2034-35	0	0	0	0	0	0	0	0	0
2035-36	0	0	0	0	0	0	0	0	0
Total	2260	1358	633	7900	3070	1350	2950	1900	6048

vi) **Renewable Purchase Obligation (RPO) trajectory**: 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, till the year 2029-30.

Table 9: Renewable Purchase Obligation (RPO) trajectory as per the MoP order

Sl. No.	Year	Wind renewable energy	Hydro renewable energy	Other renewable energy	Distributed renewable energy	Total renewable energy
(1)	(2)	(3)	(4)	(5)	(6)	(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%	33.1%	3.9%	41.36%
6.	2029-30	3.48%	1.33%	34.02%	4.5%	43.33%

Further, 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 proportionally increase beyond 2029-30. Therefore, the RPO trajectory has been assumed to rise steadily beyond 2029-30. Hence, the suggested trajectory of Renewable Purchase Requirement up to FY 2035-36 is given in Table 10.

Table 10: Renewable Purchase Obligation (RPO) trajectory considered for the study

Sl. No.	Year	Wind renewable energy	Hydro renewable energy	Other renewable energy	Distributed renewable energy	Total renewable energy
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%	33.1%	3.9%	41.36%
6.	2029-30	3.48%	1.33%	34.02%	4.5%	43.33%
7.	2030-31	40.50%			5.0%	45.5%
8.	2031-32	41.50%			5.5%	47.0%
9.	2032-33	42.30%			6.0%	48.3%
10.	2033-34	43.00%			6.5%	49.5%
11.	2034-35	43.50%			7.0%	50.5%
12.	2035-36	44.00%			7.5%	51.5%

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 and is tabulated below.

Table 11: Total Energy required to meet RPO (MU)

Sl. No.	Year	Wind renewable energy (MU)	Hydro renewable energy	Other renewable energy	Distributed renewable energy	Total renewable energy
1.	2025-26	1256	1056	24454	1818	28585
2.	2026-27	1823	1240	27706	2499	33267
3.	2027-28	2425	1405	31312	3266	38408
4.	2028-29	3124	1504	35056	4130	43804
5.	2029-30	3945	1508	38568	5102	49123
6.	2030-31	49209			6075	55284
7.	2031-32	54084			7168	61252
8.	2032-33	59143			8389	67533
9.	2033-34	64583			9762	74345
10.	2034-35	68134			10964	79098
11.	2035-36	74017			12617	86634

The year-wise total renewable energy, excluding DRE, met from the existing and planned capacity along with the deficit is shown in Table 12.

Table 12 Renewable Energy Deficit/Surplus

FY	RE Generation required to meet RPO (excluding DRE)		RE Generation (excluding DRE) available or to be met from existing and planned contracts		RE Generation Surplus (+)/ Deficit (-) (excluding DRE)
	(MU)	(%)	(MU)	(%)	(%)
2025-26	26767	30.91%	29168	33.68%	2.77%
2026-27	30769	33.25%	32737	35.38%	2.13%
2027-28	35142	35.51%	33826	34.18%	-1.33%
2028-29	39674	37.46%	36629	34.58%	-2.88%
2029-30	44021	38.83%	41567	36.66%	-2.17%
2030-31	49209	40.50%	41384	34.06%	-6.44%
2031-32	54084	41.50%	41305	31.69%	-9.81%
2032-33	59143	42.30%	41244	29.50%	-12.80%
2033-34	64583	43.00%	41244	27.46%	-15.54%
2034-35	68134	43.50%	41244	26.33%	-17.17%
2035-36	74017	44.00%	41244	24.52%	-19.48%

Similarly, the year-wise total renewable energy for Distributed Renewable Energy (DRE) met from the existing and planned capacity along with the deficit is shown in Table 13:

Table 13 Distributed Renewable Energy (DRE) Deficit/Surplus

FY	DRE Generation required to meet RPO		DRE generation available or met from existing and planned contracts		DRE Generation Surplus (+)/ Deficit (-)
	(MU)	(%)	(MU)	(%)	(%)
2025-26	1818	2.10%	17	0.02%	-2.08%
2026-27	2499	2.70%	1705	1.84%	-0.86%
2027-28	3266	3.30%	4031	4.07%	0.77%
2028-29	4130	3.90%	7218	6.82%	2.92%
2029-30	5102	4.50%	7345	6.48%	1.98%
2030-31	6075	5.00%	7473	6.15%	1.15%
2031-32	7168	5.50%	7600	5.83%	0.33%
2032-33	8389	6.00%	7728	5.53%	-0.47%
2033-34	9762	6.50%	7728	5.15%	-1.35%
2034-35	10964	7.00%	7728	4.93%	-2.07%
2035-36	12617	7.50%	7728	4.59%	-2.91%

As indicated in the tables above, the state will not be able to meet its RPO requirements based on the existing and planned contracts from 2027-28 to 2035-36. Further, with the existing and planned contracts, DRE shortfall is likely to occur in FY 2026-27 and from FY 2032-33 onwards.

7.0 Outcome of the model

7.1 Unserved Electrical Energy Projections

Initially, the study was carried out considering only the existing and planned capacity contracts by Andhra Pradesh and does not include any banking arrangements or short-term contracts. The

total unserved electrical energy for the year 2035-36 would be 32694 MU. Year-wise likely unserved electrical energy with the existing and planned capacities is given in Figure 7.

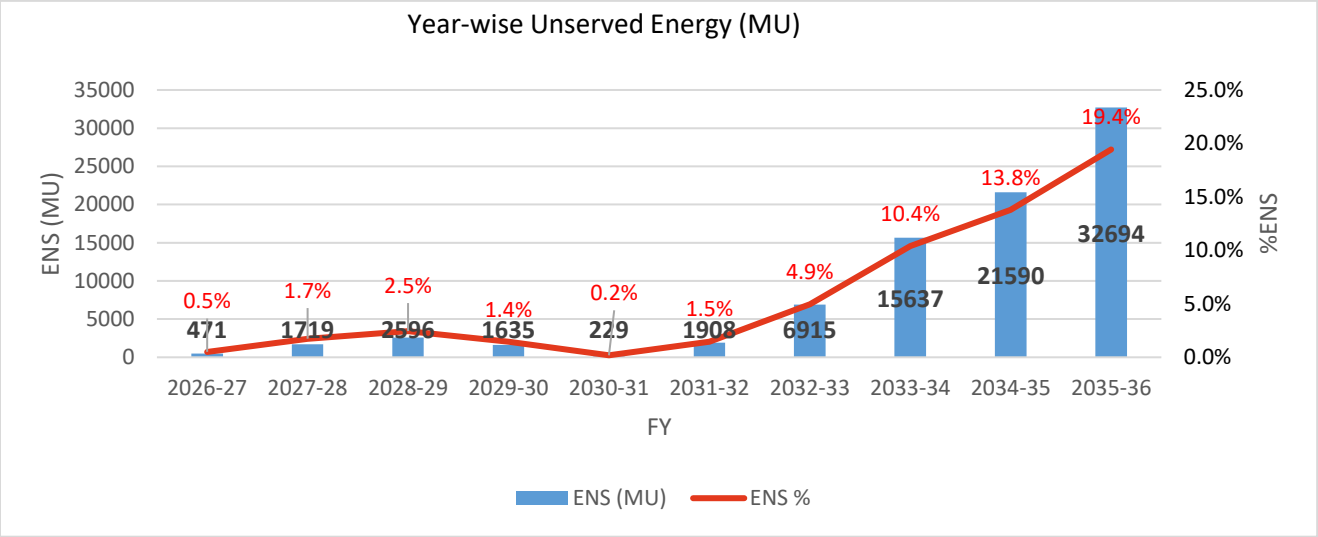


Figure 7: Yearly likely unserved electrical energy (in MU) with the existing and planned capacities

The study has also analyzed the daily and monthly pattern of unserved energy in the year 2035-36 and it can be seen that contracted capacity (existing and planned) will not be sufficient to meet the projected electricity demand.

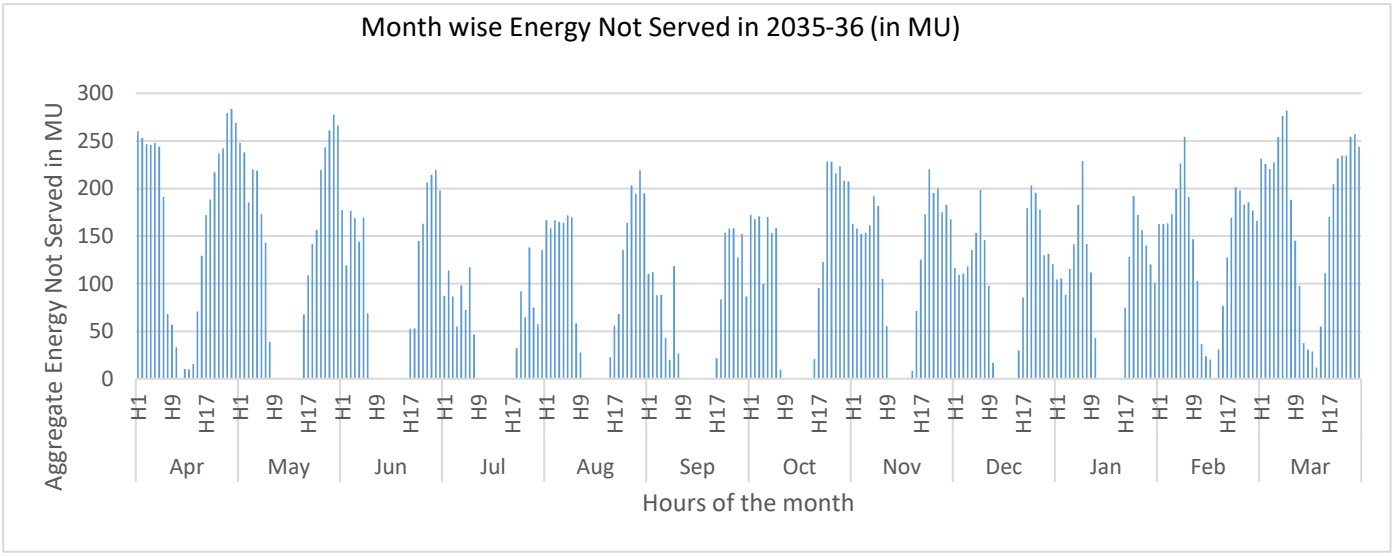


Figure 8: Block-wise Unserved Electrical Energy Pattern MU (2035-36)

The unmet demand occurs mainly during non-solar hours throughout the year. Additionally, the utility is expected to face unmet demand even during solar hours in the months of March and April, when electricity demand is higher compared to other months. To meet unserved energy, the utility needs to tie up additional capacity.

7.2 Options to meet the unserved electrical energy

To meet this unserved energy, options (i.e., candidate capacities) have been given to the model to find the least cost optimal capacity mix required to meet the demand with RPO obligations. The capacity projections for Andhra Pradesh are given below in Table 14 and Figure 9:

Table 14: Likely requirement of contracted capacity (existing + planned + additional) (in MW)

	Coal	Gas	Nuclear	Biomass	Hydro	Wind	Solar	PSP	STORAGE	DRE	STOA
2025-26	10852	591	128	89	1773	3573	8506	0	0	12	2177
2026-27	10852	591	128	88	2016	4605	10773	0	900	2036	831
2027-28	10852	591	128	86	2068	5005	11973	0	3514	3860	687
2028-29	10852	591	128	72	3106	5404	13573	0	3514	6360	1016
2029-30	10852	591	128	52	3131	5804	16706	2550	3514	6460	273
2030-31	12452	591	128	52	3131	6122	17901	4300	3514	6560	0
2031-32	12452	591	128	51	3131	6486	19101	5300	3514	6660	0
2032-33	12513	591	128	51	3131	6857	20301	7370	3514	6760	0
2033-34	13631	591	128	51	3131	7257	21501	7370	3514	7660	0
2034-35	14450	591	128	51	3131	7657	22701	7370	3514	8660	0
2035-36	15781	591	128	51	3131	8257	24501	7370	3931	9960	0

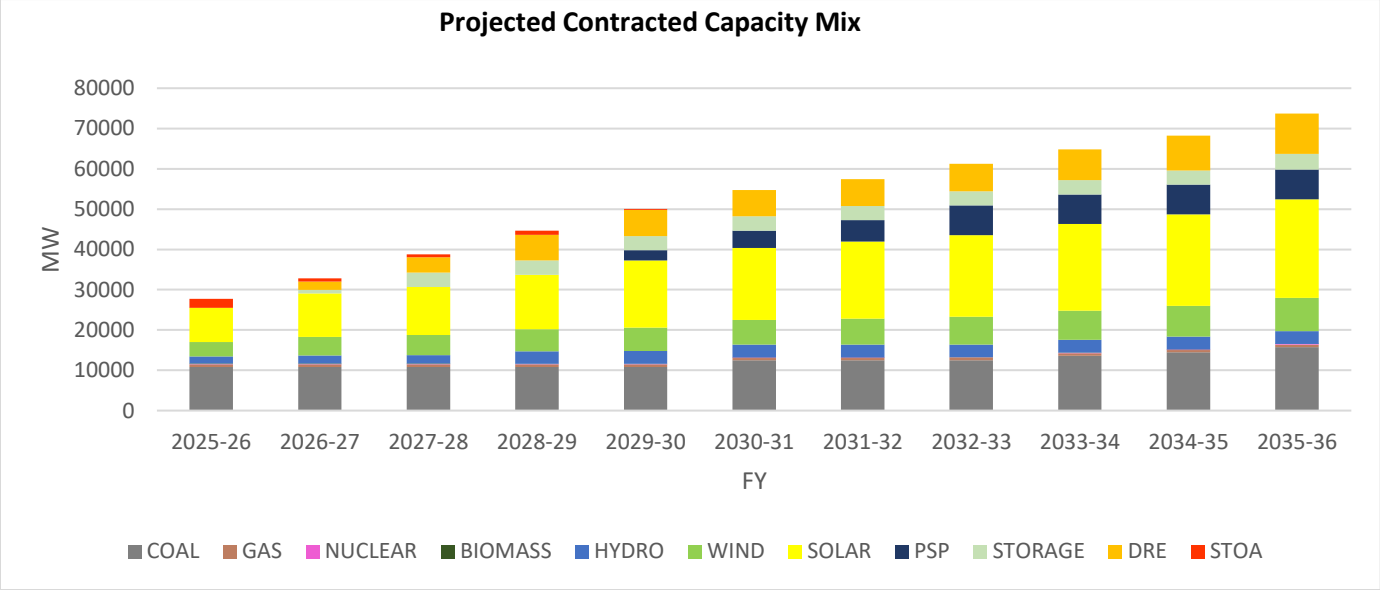


Figure 9: Projected Contracted Capacity Mix Year-wise (MW)

As per the study, the utility needs to contract the following capacities (planned and additional) per year till 2035-36 to meet its demand reliably.

Table 15: Likely planned and additional capacity to be contracted by the utility (in MW)

	COAL		HYDRO	SOLAR		WIND	
	Planned	**Additional**	**Planned Hydro**	**Planned**	**Additional**	**Planned**	**Additional**
2025-26	660	0	0	4500	0	0	0
2026-27	0	0	243	1067	1200	633	400
2027-28	0	0	52	0	1200	0	400
2028-29	0	0	1038	400	1200	0	400
2029-30	0	0	25	1933	1200	0	400
2030-31	1600	0	0	0	1200	0	400
2031-32	0	0	0	0	1200	0	400
2032-33	0	61	0	0	1200	0	400
2033-34	0	1118	0	0	1200	0	400
2034-35	0	819	0	0	1200	0	400
2035-36	0	1330	0	0	1800	0	600
Total	**2260**	**3328**	**1358**	**7900**	**12600**	**633**	**4200**
	Storage		**PSP**			**DRE**	
	Planned Storage 2h	**Additional Storage 4 hr**	**Planned PSP 6h**	**Planned PSP 8h**	**Planned PSP 9h**	**Planned**	**Additional**
2025-26	0	0	0	0	0	0	0
2026-27	900	0	0	0	0	1324	700
2027-28	1000	1614	0	0	0	1824	0
2028-29	0	0	0	0	0	2500	0
2029-30	0	0	0	1350	1200	100	0
2030-31	0	0	0	0	1750	100	0
2031-32	0	0	1000	0	0	100	0
2032-33	0	0	2070	0	0	100	0
2033-34	0	0	0	0	0	0	900
2034-35	0	0	0	0	0	0	1000
2035-36	0	417	0	0	0	0	1300
Total	**1900**	**2031**	**3070**	**1350**	**2950**	**6048**	**3900**

The STOA/MTOA requirement can be fulfilled through power procurement from markets or bilateral agreements. The STOA/MTOA value reflects the peak electricity demand value requirement and seasonal banking requirements in terms of MW.

Reliability studies have been conducted based on the projected capacity for the year 2035-36. The analysis confirms that the projected capacity meets the reliability criteria specified in the National Electricity Plan (NEP), with the Loss of Load Probability (LoLP) and Not-Served Energy

(NENS) remaining within the permissible limits of 0.2% and 0.05%, respectively (as specified in the National Electricity Plan (NEP)).

As per the Resource Adequacy studies, the likely total projected contracted capacity for the year 2035-36 is around 73,699 MW which consists of 15781 MW from Coal, 591 MW from Gas, 128 MW from Nuclear, 3131 MW from Hydro, 8257 MW from Wind, 24501 MW from Solar, 9960 MW from Distributed Renewable Energy (DRE) sources, 51 MW from Biomass, 3931 MW/11924 MWh of Storage, 7370 MW/55770 MWh of PSP will be required. This capacity shall be able to meet the projected demand with prescribed reliability criteria.

It is important to note that any deviations in the commissioning schedule of the planned capacity could result in a situation where the utility is unable to meet the projected peak electricity demand and electrical energy requirements identified in this study with the available resources. Such changes may also lead to an increase in the cost of reliably meeting the utility's power demand.

The Planning Reserve Margin (PRM) for Andhra Pradesh has been assessed as 5%. Furthermore, the projected/contracted capacity is in compliance with the stipulated Renewable Purchase Obligation (RPO) targets.

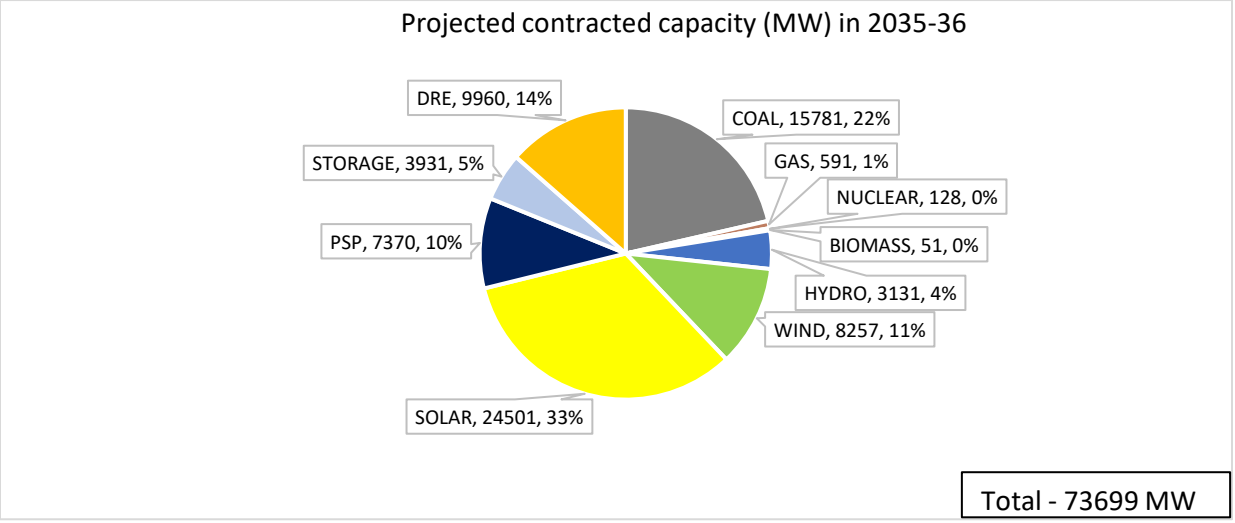


Figure 10: Contracted Capacity Mix in 2035-36

The share of non-fossil fuel-based capacity is projected to increase to around 77% by 2035-36 from 47% in 2024-25. Further, the share of non-fossil fuel-based generation will be around 58% in the year 2035-36. The projected generation mix for the utility is shown in Figure 11.

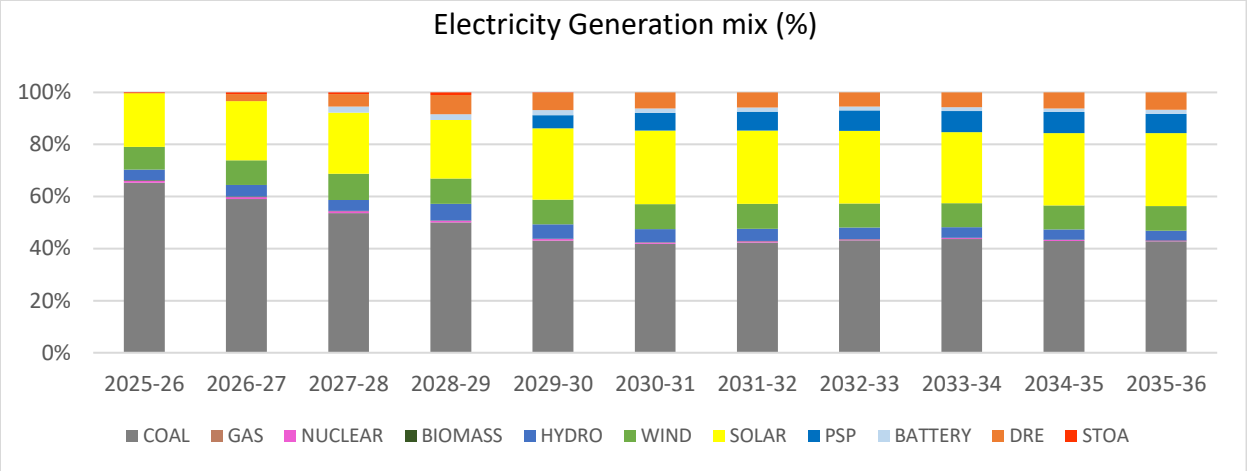
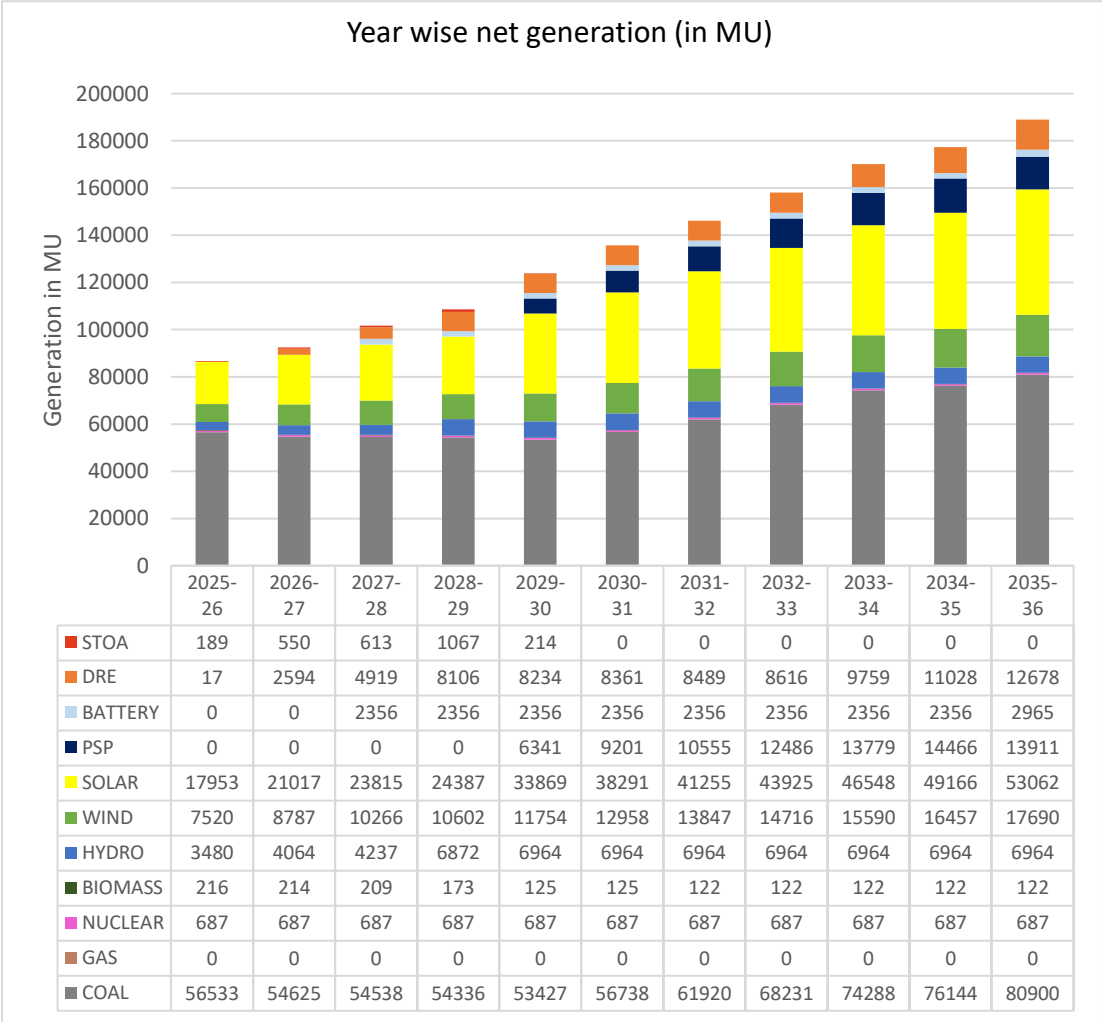


Figure 11: Year-wise projected electricity generation mix (in %)

The year-wise projected generation in MU is depicted below:



	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35	2035-36
STOA	189	550	613	1067	214	0	0	0	0	0	0
DRE	17	2594	4919	8106	8234	8361	8489	8616	9759	11028	12678
BATTERY	0	0	2356	2356	2356	2356	2356	2356	2356	2356	2965
PSP	0	0	0	0	6341	9201	10555	12486	13779	14466	13911
SOLAR	17953	21017	23815	24387	33869	38291	41255	43925	46548	49166	53062
WIND	7520	8787	10266	10602	11754	12958	13847	14716	15590	16457	17690
HYDRO	3480	4064	4237	6872	6964	6964	6964	6964	6964	6964	6964
BIOMASS	216	214	209	173	125	125	122	122	122	122	122
NUCLEAR	687	687	687	687	687	687	687	687	687	687	687
GAS	0	0	0	0	0	0	0	0	0	0	0
COAL	56533	54625	54538	54336	53427	56738	61920	68231	74288	76144	80900

Figure 12: Year-wise projected net generation (in GWh)

7.3 Day-wise Surplus Capacity (in MW)

The pattern of surplus capacities has been observed as given in Figure 13. Available Surplus capacity can be due to seasonal variation in demand. This capacity can be used for banking arrangements or shared with other states through bilateral agreements / Pushp portal, thereby reducing the fixed cost burden on the utility, resulting in a reduction in the cost for the consumer. Andhra Pradesh is likely to have surplus capacity during the off-peak electricity demand months (July to September), which can be shared with other states. Specifically, the utility is likely to have a minimum surplus of around 1200 MW to 2500 MW in the month from July to September in FY 2028-29, which can be shared with other states/Discoms.

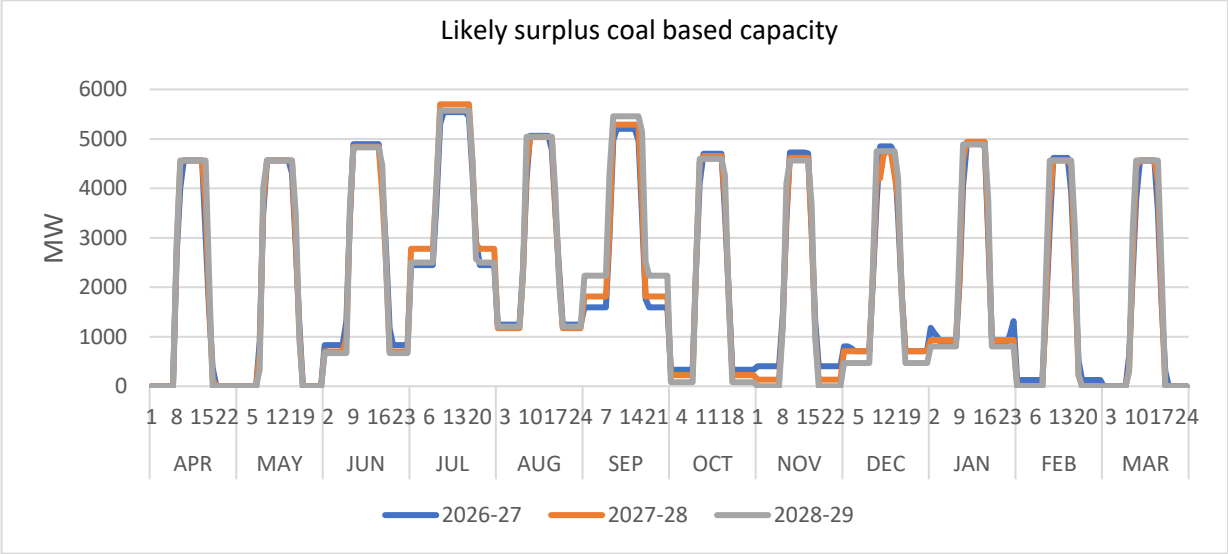


Figure 13: Surplus Coal Capacity (MW)

8.0 Conclusions

Based on the Resource Adequacy studies of Andhra Pradesh up to the year 2035-36, the following conclusions may be drawn:

1. Based on the demand pattern of the last few years, it is seen that high electricity demand typically occurs in Andhra Pradesh in the months of March and April, with peak electricity demand occurring during solar hour. The demand during the months from July to September remains significantly low compared to other months, reflecting the seasonality in demand. Optimal utilisation of resources through short-term contracts like banking or MTOA/STOA 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 electrical energy requirement projections and peak electricity demand projections as prepared by Andhra Pradesh which envisages that the annual electrical energy requirement of the utility is likely to grow at a CAGR of 6.9% while the peak

electricity demand for the utility is likely to grow at a CAGR of 7.1% for the period of 2025-26 to 2035-36. The peak electricity demand and electrical energy requirement is projected to increase to 30,927 MW and 1,68,221 MU respectively in 2035-36.

3. Andhra Pradesh is likely to witness energy deficit ranging from 471 MUs to 32694 MUs in different years from 2025-26 to 2035-36 with the existing and planned capacity addition only. The deficit may reduce depending upon the banking or MTOA/STOA arrangement, etc.
4. As per the Resource Adequacy studies, the likely total projected contracted capacity for the year 2035-36 is around 73,699 MW which consists of 15,781 MW from Coal, 591 MW from Gas, 128 MW from Nuclear, 3131 MW from Hydro, 8257 MW from Wind, 24,501 MW from Solar, 9,960 MW from Distributed Renewable Energy (DRE) sources, 51 MW from Biomass, 3931 MW/11924 MWh of Storage, 7370 MW/55770 MWh of PSP will be required.
5. To ensure reliability of supply and adherence to the Renewable Purchase Obligation (RPO) trajectory up to 2035-36, the existing and planned generation capacities may require augmentation. An additional capacity of approximately 2260 MW of coal-based power, 12600 MW of solar and 4200 MW of wind is projected to be required.
6. The current capacity mix of the utility has 53% of contracted capacity from fossil fuel sources (Coal + Gas). The share of fossil fuel-based capacity is likely to reduce to 23% in 2035-36. In 2035-36, the RE-based contract capacity (that includes hydro, solar, wind) is likely to constitute around 62% of the total contract capacity.
7. It is likely that Andhra Pradesh may have surplus capacity available during the months from July to September, which can be shared with other utilities/states through banking/bilateral arrangements, including the Pushp portal.
8. The Planning Reserve Margin (PRM) for Andhra Pradesh has been assessed as 5%. Further, the study indicates year-wise short-term/medium-term/bilateral requirements to meet the demand optimally.
9. Accurate demand assessment is fundamental to capacity expansion modelling and directly impacts the Resource Adequacy (RA) study outcomes. To achieve realistic and data-driven results, utilities are strongly encouraged to adopt scientific tools and robust methodologies for demand forecasting.
10. Timely commissioning of planned capacities is critical to ensure that the utility can meet the projected peak electricity demand and electrical energy requirements identified in this study. Any deviation from the planned schedule may lead to resource shortfalls and could significantly increase the cost of reliably meeting the utility's power demand.

Annexure

Future Contracted/Approved Capacity Expansion and Termination (MW)

Sl. No.	Tied capacity name	Type	Expected CoD	Share of Andhra Pradesh (in MW)
1	Sembcorp	Coal	2025-26	660
2	APGENCO+CIL	Coal	2030-31	1600
3	Rangit-IV (NHPC)	Hydro	2026-27	13
4	Lower Sileru power House	Hydro	2026-27	230
5	Pakal Dul (NHPC)	Hydro	2027-28	52
6	Polavaram Hydroelectric Project	Hydro	2028-29	960
7	Teesta- VI (NHPC)	Hydro	2028-29	36
8	Kwar (NHPC)	Hydro	2028-29	42
9	Ratle (NHPC)	Hydro	2029-30	25
10	Upper Sileru	PSP	2029-30	1350
11	Gandikota	PSP	2029-30	1200
12	Kamalapadu	PSP	2030-31	950
13	Rajupalem	PSP	2030-31	800
14	Yaganti	PSP	2031-32	1000
15	Aravetipalli	PSP	2032-33	1320
16	Deenepalli	PSP	2032-33	750

Assumption for Resource Adequacy Studies

1. Electrical energy requirement & peak electricity demand requirement: As per projections of AP SLDC.
2. Demand Profile: Based on the hourly demand profile of 2024-25.
3. Existing & Planned Capacity: As per the information shared by the utility.
4. Cost parameters: based on information in the National Electricity Plan, recent market trends, and existing tariff information received from Andhra Pradesh.

RE CUF considered

Hydro	Solar CUF Existing & Planned	Wind CUF Existing & Planned	DRE
25 %	23.7% & 25%	24.1% & 25%	14.5%

Technical Parameters

Technology	Type	Availability (%)	Ramping (%/min)	Min. Technical (%)
Coal/ Lignite	Existing/Planned	85	1	55
	Candidate	88	1	55
Gas	Existing	90	5	40
Nuclear	Existing/Planned	68	Const. Load	-
Biomass	Existing/Planned	60	2	50
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. (%)
Coal	Existing/ Planned	2200 to 2890	7.0
	Candidate (SC & USC)	2200	6.5
Gas	Existing	2000 to 2900	2.5
Nuclear	Existing/ Planned	2777	10
	Candidate	2777	10
Biomass	Existing/ Planned	4200	8
Hydro	Existing/ Planned	-	0.7
	Candidate	-	0.7
Pumped Storage	Existing/ Planned	-	pump efficiency 80 %
	Candidate	-	
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

The following cost parameters have been assumed:

Resource	Capex (in ₹/MW)	O&M Fixed Cost (in ₹/MW)	Construction Time (in years)	Amortization /Lifetime (in years)
Coal	12 Cr	19.54 Lakh	4	25
Solar	4.4 Cr to 4.1 Cr	1 % of Capex	1	25
Wind	7.5 Cr	1 % of Capex	1.5	25
Battery Energy Storage (2-Hour)	3.21 Cr to 2.63 Cr	1 % of Capex	1	14
Battery Energy Storage (4-Hour)	4.98 Cr to 3 Cr	1 % of Capex	1	14
Pumped Storage	6 Cr	5 % of Capex	5	40