

Report on
Resource Adequacy Plan
(Generation)
for
BSES Rajdhani Power Limited
(BRPL, Delhi)
(2025-26 to 2035-36)

(Version 2.0)

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Government of India
Ministry of Power
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Disclaimer

This Resource Adequacy study for BSES Rajdhani Power Limited (BRPL), a distribution utility in Delhi, has been conducted based on the data and inputs provided by BRPL. The findings, analysis and conclusions presented in this report are contingent upon the accuracy, completeness and timeliness of the information furnished by BRPL. 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 BRPL 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 BRPL.

Executive Summary

Ministry of Power had notified the Electricity (Amendment) Rules in December 2022. As per Rule 16 of the Electricity (Amendment) Rules, Ministry of Power has notified 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 optimization 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 optimizing the requirement for additional capacity.

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 2033-34, 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 RPO requirement for the utility has also been assessed in accordance with the gazette notified trajectory.

The electrical energy requirement and peak electricity demand for BRPL is increasing with a CAGR of 4.0% and 5.9% respectively from 2025-26 to 2035-36 as forecasted by CEA. For satisfying resource adequacy i.e., meeting the electricity demand reliably and at 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 panels and technology options like Battery Energy Storage Systems (BESS), 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.

A study has been carried out for BRPL considering the existing contracted capacity and planned capacity addition. It was found that BRPL'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 5809 MUs which is about 24% 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, long-term study has been carried out with the objective to minimize 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 RPO trajectory gazette notified by Ministry of Power considering the fungibility among different sources.

As per the Resource Adequacy studies, the likely total projected contracted capacity for the year 2035-36 is around 11,034 MW which consists of 1171 MW from Coal, 648 MW from Gas, 102 MW from Nuclear, 28 MW from Biomass, 501 MW from Hydro, 350 MW from Wind, 1580 MW from Solar, 72 MW from Hybrid, 1850 MW Solar + BESS (i.e., with 925 MW co-located BESS), 856 MW from Distributed Renewable Energy (DRE) sources, 264 MW of PSP, 960 MW/3803 MWh from Energy Storage System (ESS) and 2650 MW of MTOA/STOA arrangement will be required. This capacity shall be able to meet the projected demand with prescribed reliability criteria.

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 notification dated 20th October, 2023 had notified the RPO trajectory for the states/Discoms. 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/Discoms have to contract in addition to its 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 BRPL based on inputs furnished by 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 optimize long-term power procurement while ensuring resource adequacy to meet demand on a 24×7 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 2033-34, based on inputs from BRPL and in accordance with the RPO trajectory specified in the Ministry of Power's notification dated 20th October, 2023.

2.0 Highlights of the Previous RA Study (up to FY 2033–34)

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 2033-34. The fuel-wise contracted capacity as on 31st March, 2024:

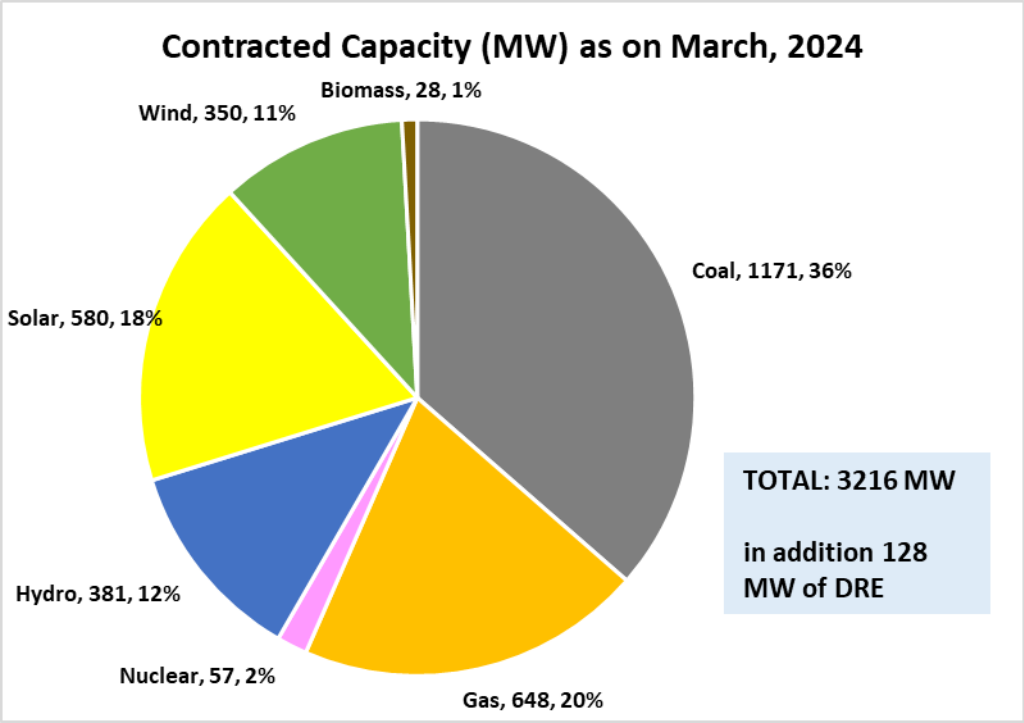


Figure 1 Fuel wise Contract Capacity (in MW) as on March 2024

2. The hourly demand pattern for 2022-23 had been analysed and considered for the study.
3. The peak electricity demand and electrical energy projections as furnished by BRPL in consultation with CEA, that had been considered in the study is tabulated below:

Table 1 Electrical Energy requirement (MU) and Peak electricity demand (MW) projections furnished by BRPL in consultation with CEA

Year	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34
Electrical energy Requirement Projections (MU)	15319	15817	16338	16882	17451	18047	18671	19326	20013	20734
Year on Year Growth *(Electrical Energy)*		3.30%	3.30%	3.30%	3.40%	3.40%	3.50%	3.50%	3.60%	3.60%
Peak electricity demand Projections (MW)	3939	4122	4317	4524	4743	4976	5224	5488	5769	6069
Year on Year Growth (Peak electricity demand)		4.70%	4.70%	4.80%	4.80%	4.90%	5.00%	5.10%	5.10%	5.20%

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 and Peak electricity demand in 2024-25

Year	Actual electrical energy requirement (in MU)	Actual peak electricity demand (in MW)
2024-25	16334	3758

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	Gas	Nuclear	Biomass	Hydro	Wind	Solar	Hybrid	Total	DRE	Storage (MW/MWh)	STOA/ MTOA
2024-25	1171	648	57	28	381	350	580	0	**3217**	181	264/1980	2140
2025-26	1171	648	57	28	410	350	980	110	**3756**	261	264/1980	2291
2026-27	1171	648	57	28	434	350	980	110	**3779**	347	264/1980	2468
2027-28	2607	648	57	28	504	388	1026	110	**5368**	438	264/1980	1468
2028-29	2616	648	57	28	554	452	1105	110	**5571**	535	264/1980	1633
2029-30	2647	648	57	28	585	515	1182	110	**5773**	638	264/1980	1808
2030-31	2691	648	57	28	585	631	1325	110	**6076**	660	264/1980	2004
2031-32	2929	648	57	28	585	732	1448	110	**6538**	683	264/1980	2062
2032-33	3003	648	57	28	585	831	1570	110	**6833**	707	264/1980	2269
2033-34	3083	648	57	28	585	933	1695	110	**7140**	733	264/1980	2489

*****The STOA/MTOA value represents the year-wise 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 BRPL (in MW)

	Coal	Hydro	Wind	Solar		Hybrid	Total		Storage	Distributed RE
Year	Additional Requirement	Planned Contracts	Additional Requirement	Planned Contracts	Additional Requirement	Planned Contracts	Planned contracts	Additional Requirement	Planned contracts	Additional Requirement
2024-25	0	0	0	0	0	0	0	0	264	53
2025-26	0	29	0	400	0	110	539	0	0	80
2026-27	0	24	0	0	0	0	24	0	0	86
2027-28	1435	70	38	0	46	0	70	1519	0	91
2028-29	9	50	64	0	79	0	50	152	0	97
2029-30	31	31	63	0	77	0	31	171	0	103
2030-31	44	0	116	0	143	0	0	303	0	22
2031-32	238	0	101	0	123	0	0	462	0	23
2032-33	74	0	99	0	122	0	0	295	0	24
2033-34	80	0	102	0	125	0	0	307	0	26
TOTAL	**1912**	**203**	**583**	**400**	**715**	**110**	**714**	**3209**	**264**	**605**

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

3.1 Present Power Scenario in BRPL

As of 1st April 2025, the total contracted capacity of BRPL is 3,396 MW. Out of the total contracted capacity (CC), the share of non-fossil fuel-based CC is 46 %. Fuel-wise contracted capacity as on 1st April, 2025, is given in Table and Figure below:

Table 5 Fuel-wise Contracted Capacity as on 1st April 2025

Source	Contracted Capacity (MW)	Percentage (%)
Coal	1171	34%
Gas	648	19%
Nuclear	57	2%
Hydro	381	11%
Wind	350	10%
Solar	580	17%
Biomass	28	1%
DRE	161	5%
BESS (2 Hrs)	20	1%
Sub-Total	**3396**	100%

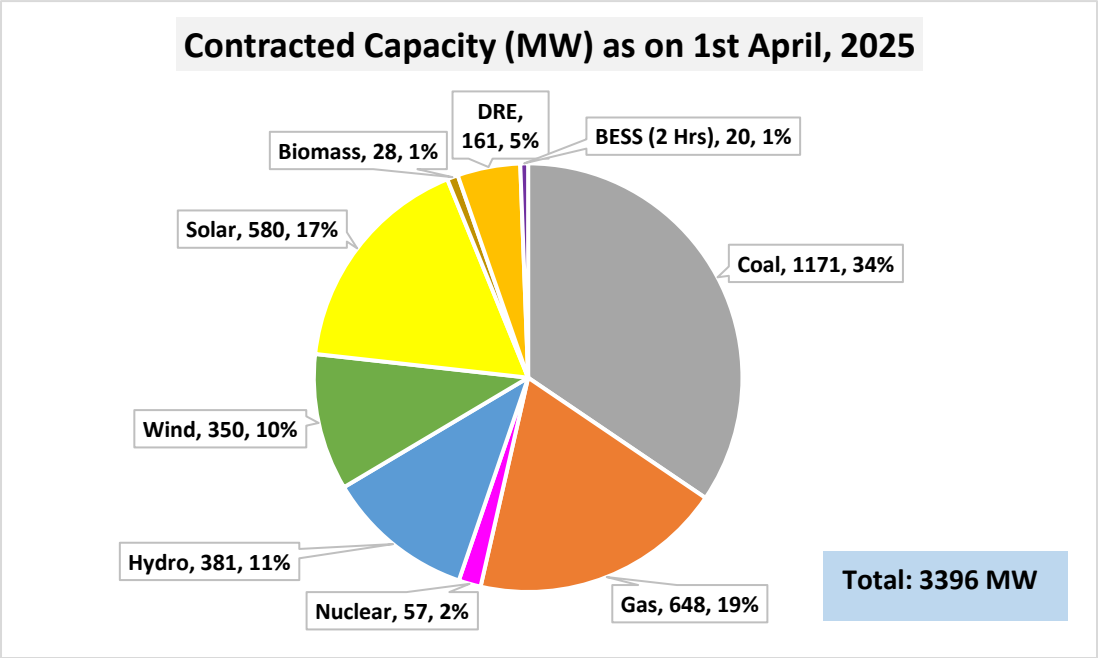


Figure 2 Fuel-wise Contracted Capacity (in MW) as on 1st April, 2025

3.2 Demand Analysis of the FY 2024-25

Hourly demand pattern of 2024-25 was analyzed and it was observed that peak electricity demand in BRPL occurs during night time in June / July months and it is observed that the demand is comparatively higher during summer months (i.e., in April to September) than the rest of the year. Further, the range of average demand is higher for April-September months than that of October-March months. The month wise variation in average hourly demand observed for the year 2024-25 is depicted in Figure 3.

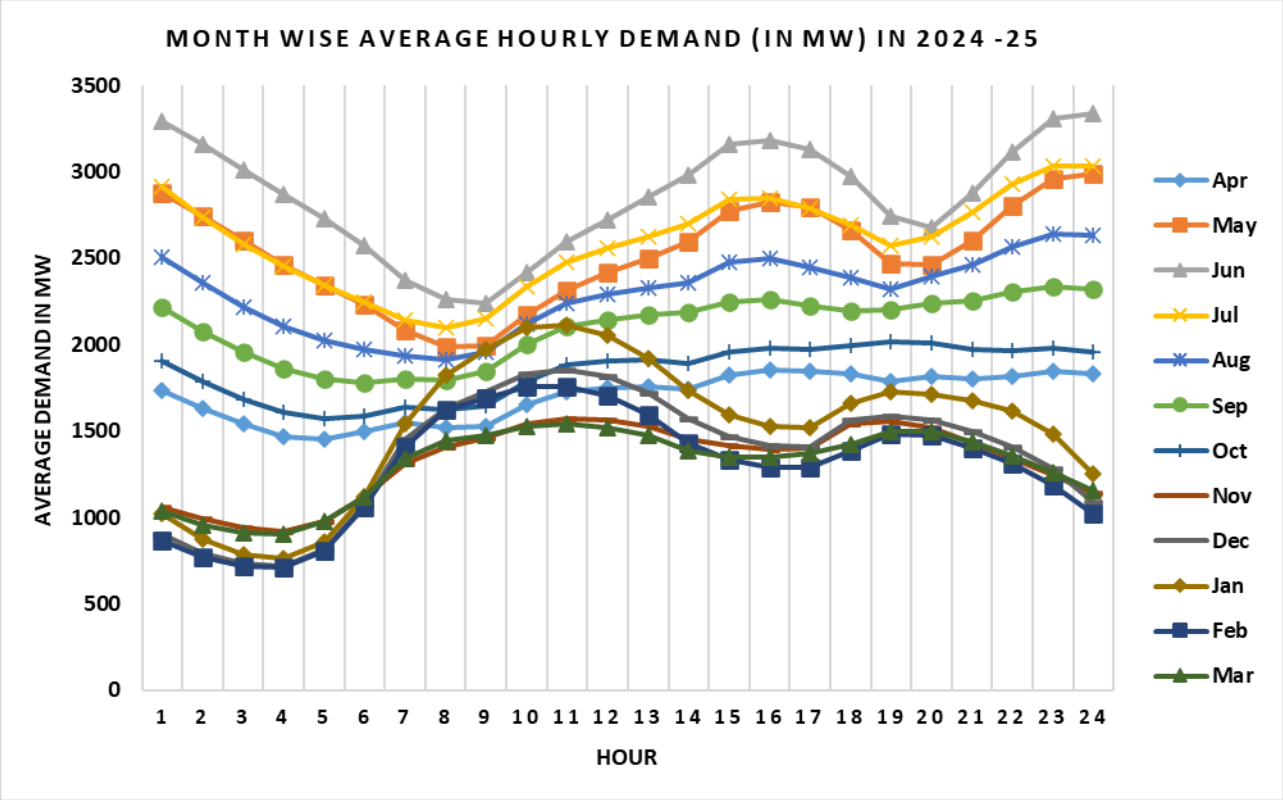


Figure 3 Average Hourly Demand Variation (Month-wise) for 2024-25

From the hourly demand data of 2024-25, the daily peak electricity demand during solar hours (06:00 to 18:00 hrs) and non-solar hours are plotted in the below figure.

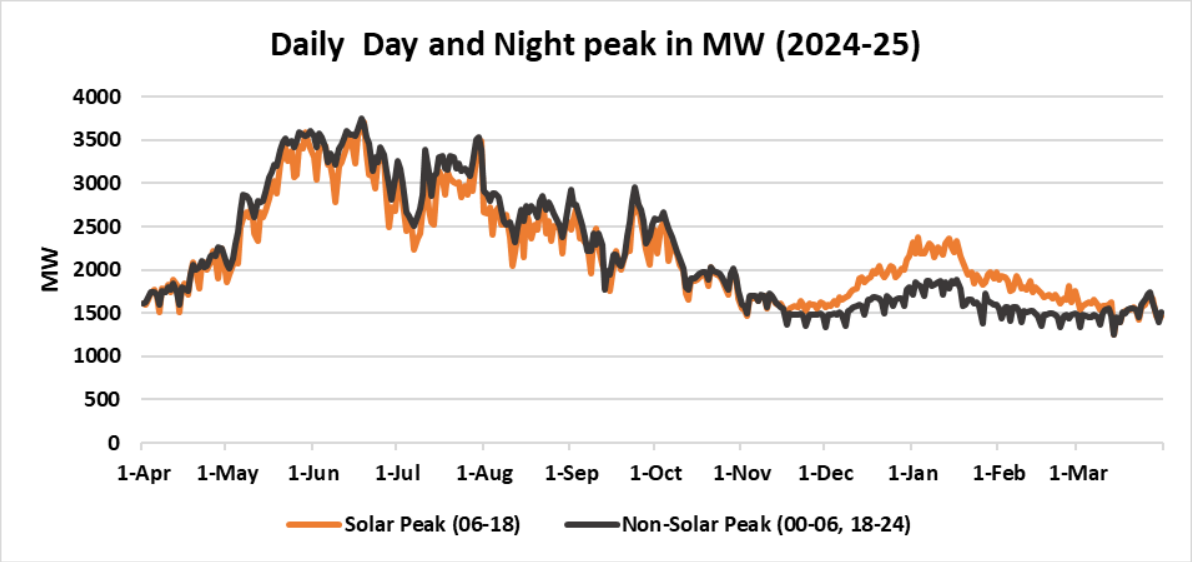


Figure 4 Day and Night Peak Electricity demand in MW for the year 2024-25

As seen from figure 4 above, the daily peak electricity demand during the months from April to October is observed during non-solar hours. However, from November to March, the daily peak electricity demand is observed in solar hours.

The hourly demand pattern of 2024-25 was analysed for finding 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.

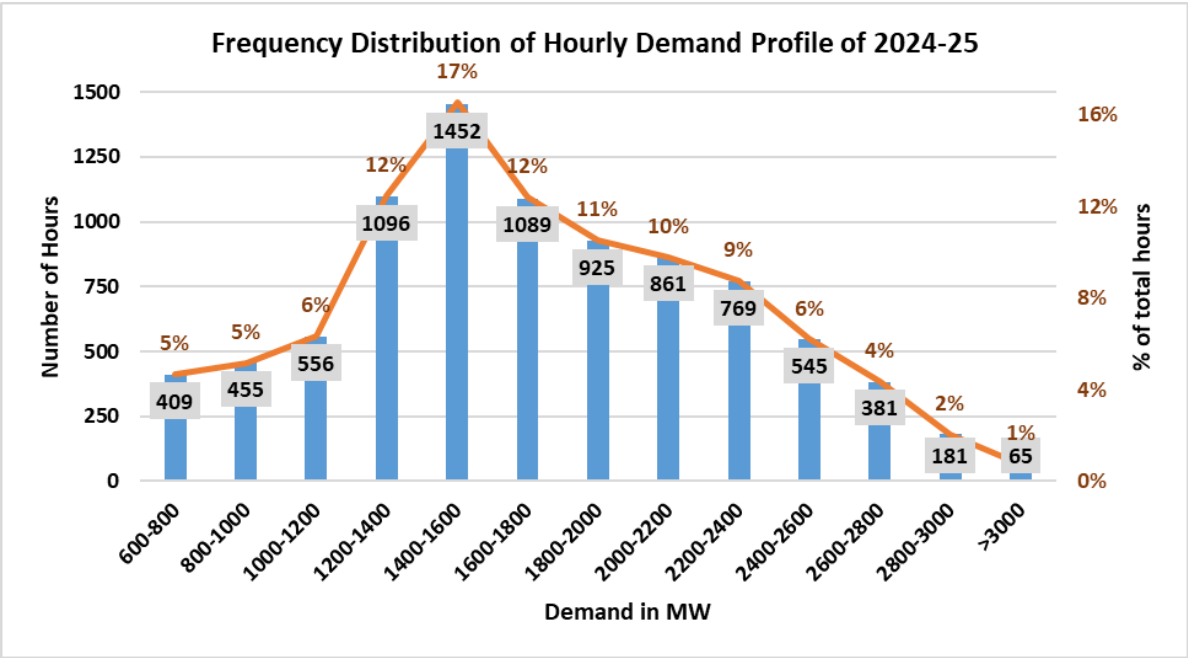


Figure 5 Frequency Distribution of Hourly Demand Profile of 2024-25

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 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 optimization program that minimizes 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 Exhibit.

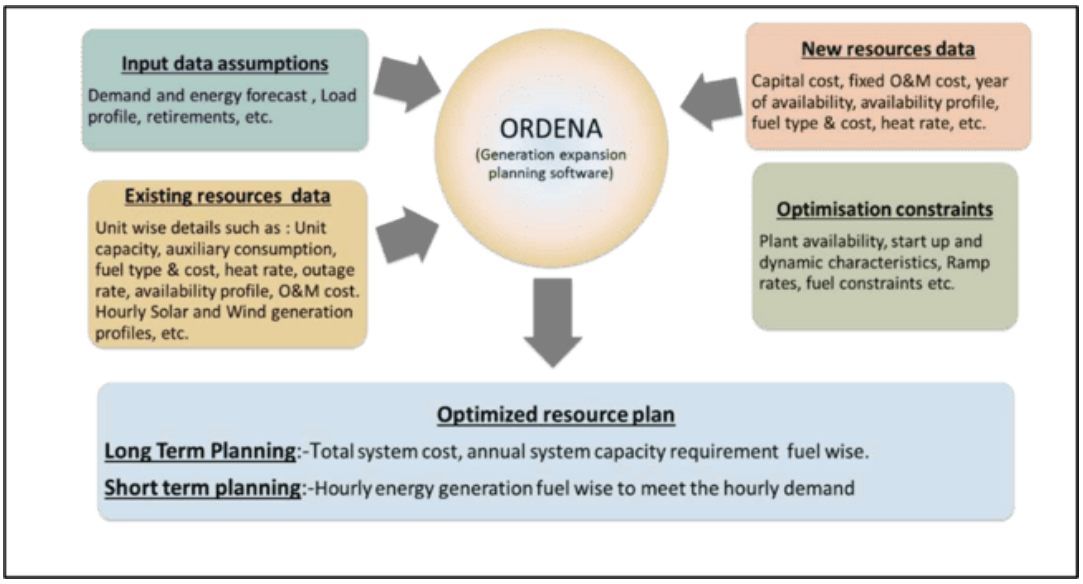


Exhibit : Schematic Diagram -Ordena

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 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 the projected electrical energy requirement) 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 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 above variation of system parameters.

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

5.1 Demand variation

The hourly demand variation for consecutive years (i.e., 2023-24 and 2024-25) has been analyzed. The demand pattern variation of 2023-24 and 2024-25 is shown below:

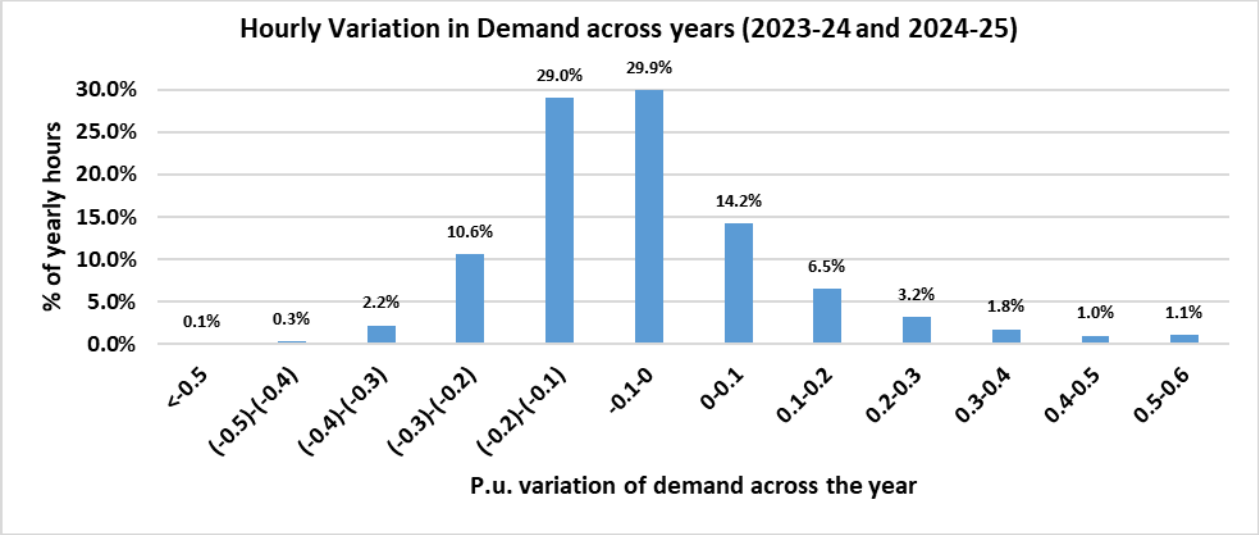


Figure 6 Hourly Variation in Demand across years

It can be observed that the hourly demand typically varies ±20% for around 80% of instances. 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 ±20% by introducing a random variable (with normal distribution) for demand as per observed behavior over the years.

5.2 Variation in RE

In the Long-term capacity expansion planning studies, a particular profile for solar and wind generation is considered based on the observed generation data to determine the optimal capacity mix. However, due to intermittent nature of these sources, generation from these non-dispatchable sources may vary across years. As per the analyses carried out based on historical generation data, solar 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. Hydro based generation has been varied by ± 10 %.

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 robustness of the system.

6.0 Inputs/Assumptions for the Study

i) The electrical energy requirement projections and peak demand projections as estimated by CEA, after considering the projections of BRPL is tabulated below:

Table 6 Electricity Demand Projection as provided by the utility

	Electrical Energy Requirement Projections (in MU)	Year on Year Growth	Peak electricity demand Projections (in MW)	Year on Year Growth
2025-26	16424		3799	
2026-27	17075	4.0%	4039	6.3%
2027-28	17743	3.9%	4281	6.0%
2028-29	18429	3.9%	4534	5.9%
2029-30	19137	3.8%	4797	5.8%
2030-31	19861	3.8%	5070	5.7%
2031-32	20618	3.8%	5349	5.5%
2032-33	21424	3.9%	5659	5.8%
2033-34	22290	4.0%	6004	6.1%
2034-35	23224	4.2%	6364	6.0%
2035-36	24229	4.3%	6740	5.9%

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 BRPL, while the hydro generation profiles and PLFs is as per the data available in CEA.

iv) The capital costs of candidate plants for coal, wind, solar, and battery 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 BRPL. Source-wise planned capacity is given below:

Table 7 Source wise planned capacity addition

FY	Nuclear	Hydro	Hybrid	PSP	Solar + BESS	DRE
2025-26	44	16	-	-	-	80
2026-27	-	3	72	264	-	86
2027-28	-	43	-	-	-	91
2028-29	-	20	-	-	1500 MW Solar with 750 MW / 3000 MWh BESS	97
2029-30	-	38	-	-	-	103
2030-31	-	-	-	-	-	22
2031-32	-	-	-	-	-	23
2032-33	-	-	-	-	-	20
2033-34	-	-	-	-	-	20
2034-35	-	-	-	-	-	20
2035-36	-	-	-	-	-	20
Total	**44**	**120**	**72**	**264**	**1500**	**582**

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 8 Renewable Purchase Obligation (RPO) trajectory as per 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 is assumed to rise steadily beyond 2029-30. The RPO trajectory for Distributed Renewable Energy (DRE) beyond 2029-30 has been capped at 4.50% due to the constraints highlighted by the utility. These include the limited available area for rooftop solar installations and the fact that Delhi is already among the top three states in terms of rooftop solar capacity installed per square kilometre, indicating a saturation point has been reached. Hence, the suggested trajectory of Renewable Purchase Requirement up to FY 2035-36 is given in the table below:

Table 9 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	41.0%			4.5%	45.5%
8.	2031-32	42.5%			4.5%	47.0%
9.	2032-33	43.8%			4.5%	48.3%
10.	2033-34	45.0%			4.5%	49.5%
11.	2034-35	46.0%			4.5%	50.5%
12.	2035-36	47.0%			4.5%	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 10 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	238.15	200.37	4638.14	344.90	5421.56
2.	2026-27	336.38	228.81	5112.26	461.03	6138.46
3.	2027-28	434.70	251.95	5613.89	585.52	6886.06
4.	2028-29	543.66	261.69	6100.00	718.73	7622.23
5.	2029-30	665.97	254.52	6510.41	861.17	8292.06
6.	2030-31	8143.01			893.75	9036.76
7.	2031-32	8762.65			927.81	9690.46
8.	2032-33	9383.71			964.08	10347.79
9.	2033-34	10030.50			1003.05	11033.55
10.	2034-35	10683.04			1045.08	11728.12
11.	2035-36	11387.63			1090.31	12477.94

The year-wise total renewable energy, excluding DRE, met from the existing and planned capacity along with the deficit is shown in table below:

Table 11 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	5077	30.91%	4169	25.38%	-5.53%
2026-27	5677	33.25%	4389	25.70%	-7.55%
2027-28	6301	35.51%	4545	25.62%	-9.89%
2028-29	6905	37.47%	8807	47.79%	10.32%
2029-30	7431	38.83%	9776	51.08%	12.25%
2030-31	8143	41.00%	9822	49.46%	8.46%
2031-32	8763	42.50%	9857	47.81%	5.31%
2032-33	9384	43.80%	9846	45.96%	2.16%
2033-34	10031	45.00%	10305	46.23%	1.23%
2034-35	10683	46.00%	10715	46.14%	0.14%
2035-36	11388	47.00%	10715	44.22%	-2.78%

It may be noted that, for computing the RE generation to meet the RPO, the generation corresponding to the 750 MW/3000 MWh BESS component in the Solar + BESS contracts have been considered, since the battery charging as conveyed by the utility would be undertaken by the developer through RE sources and not through the utility contracts.

As indicated in the tables above, the utility will not be able to meet its RPO requirements from 2025-26 to 2027-28 and in 2035-36, based on the existing and planned contracts.

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 below:

Table 12 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	345	2.10%	307	1.87%	-0.23%
2026-27	461	2.70%	416	2.44%	-0.26%
2027-28	586	3.30%	532	3.00%	-0.30%
2028-29	719	3.90%	484	2.63%	-1.27%
2029-30	861	4.50%	566	2.96%	-1.54%
2030-31	894	4.50%	606	3.05%	-1.45%
2031-32	928	4.50%	640	3.10%	-1.40%
2032-33	964	4.50%	713	3.33%	-1.17%
2033-34	1003	4.50%	827	3.71%	-0.79%
2034-35	1045	4.50%	920	3.96%	-0.54%
2035-36	1090	4.50%	945	3.90%	-0.60%

7.0 Outcome of the Study

7.1 Unserved Electrical Energy Projections

Initially, the study has been carried out considering only the existing and planned capacity contracts, and does not include any banking arrangements or short-term contracts. The total unserved electrical energy for the year 2035-36 would be 5,809 MU. The year-wise likely unserved electrical energy with the planned capacities is given in Figure 7.

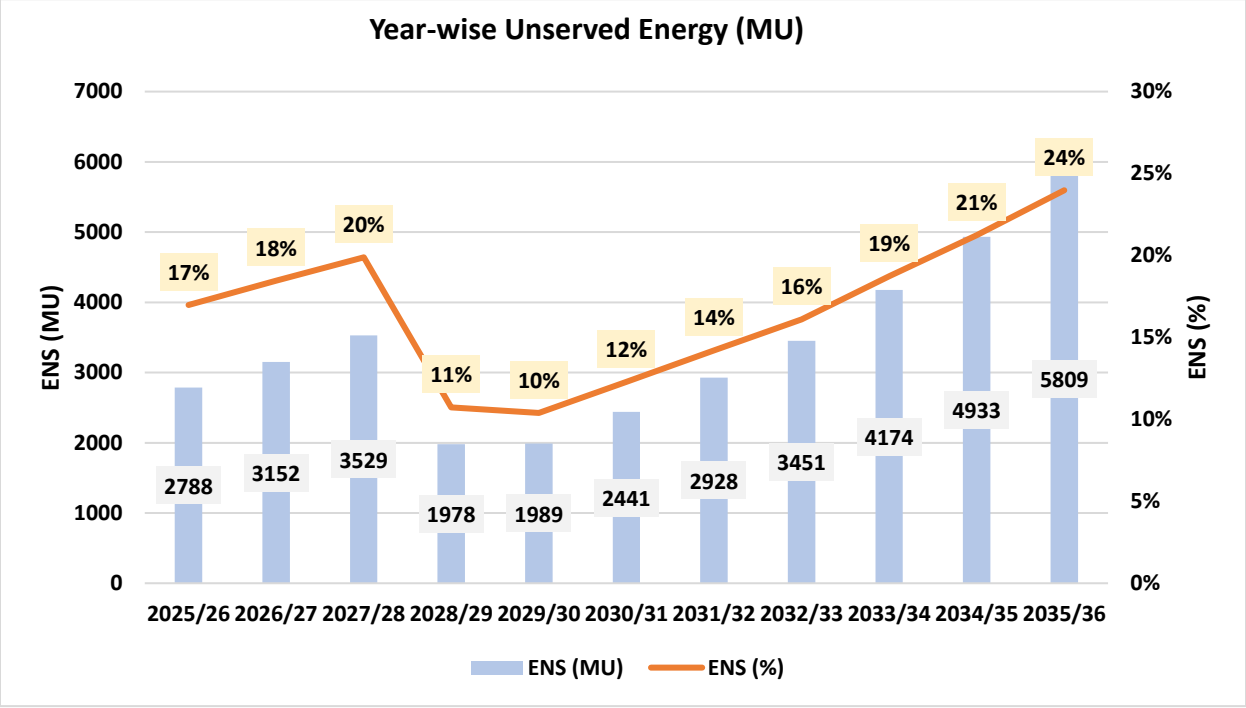


Figure 7 Yearly likely unserved electrical energy (in MU) with the existing and planned capacities

The study has also analyzed the daily and monthly pattern of unserved electrical energy in the year 2035-36.

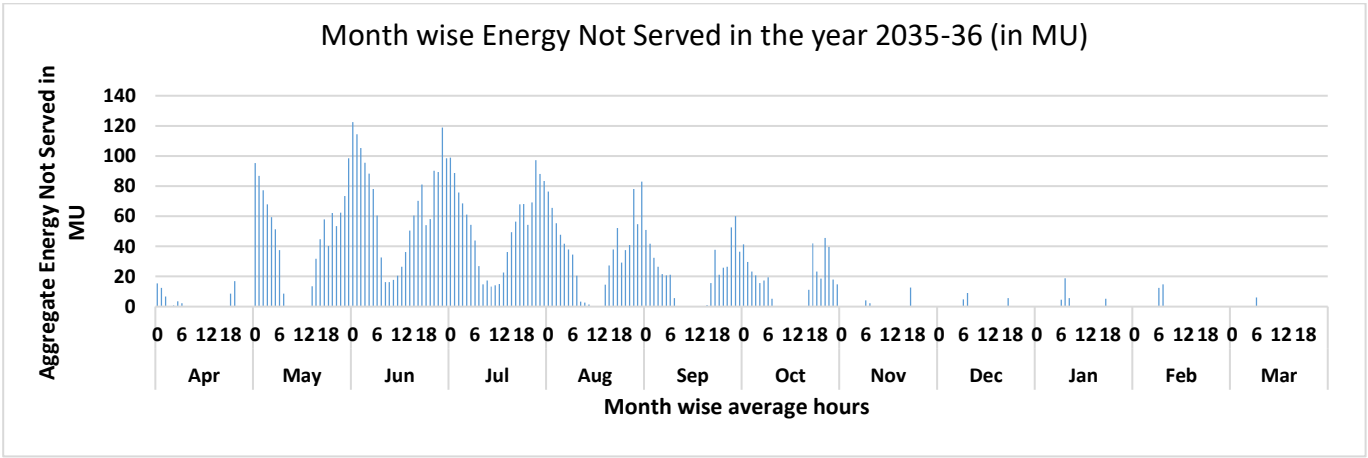


Figure 8 Block-wise Unserved Electrical Energy Pattern GWh (2035-36)

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 summer and monsoon months, when electricity demand is higher compared to other months.

7.2 Options to meet the unserved electrical energy

To meet this unserved electrical energy, candidate capacities have been given to the model to find the least cost optimal capacity mix required to meet the demand in compliance with the Renewable Purchase Obligation. It may be noted that different generating source-wise candidate capacities have been introduced from 2028-29 onwards, taking into account the utility's feasibility with respect to the contracts availability.

The candidate capacities incorporate the recent market price discoveries and are in line with the utility's decarbonization plan, as communicated in their letter to CEA dated 7th October 2024 (attached at **Annexure**). The capacity projections for BRPL are given below:

Table 13 Year-wise contracted capacity projections (existing, planned, to be tied up) (in MW)

FY	Coal	Gas	Nuclear	Biomass	Hydro	Wind	Solar	Hybrid	Solar + BESS		PSP	Storage * (MW/ MWh)	DRE	STOA/ MTOA/ Banking
									Solar compo-nent	4-hour BESS compo-nent				
2025-26	1171	648	102	28	397	350	580	0	0	0	0	20/40	271	1927
2026-27	1171	648	102	28	400	350	580	72	0	0	264	20/40	362	2159
2027-28	1171	648	102	28	443	350	580	72	0	0	264	20/40	459	2369
2028-29	1171	648	102	28	463	350	780	72	1500	750	264	339/1318	564	1813
2029-30	1171	648	102	28	501	350	980	72	1850	925	264	848/3354	676	1550
2030-31	1171	648	102	28	501	350	1180	72	1850	925	264	860/3403	701	1733
2031-32	1171	648	102	28	501	350	1380	72	1850	925	264	927/3668	728	1952
2032-33	1171	648	102	28	501	350	1580	72	1850	925	264	958/3795	757	2191
2033-34	1171	648	102	28	501	350	1580	72	1850	925	264	960/3803	787	2500
2034-35	1171	648	102	28	501	350	1580	72	1850	925	264	960/3803	820	2550
2035-36	1171	648	102	28	501	350	1580	72	1850	925	264	960/3803	856	2650

* The energy storage requirement as outline in the report may be fulfilled through any combination of energy storage systems (2 hrs, 4 hrs etc.) as deemed suitable by the utility.

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

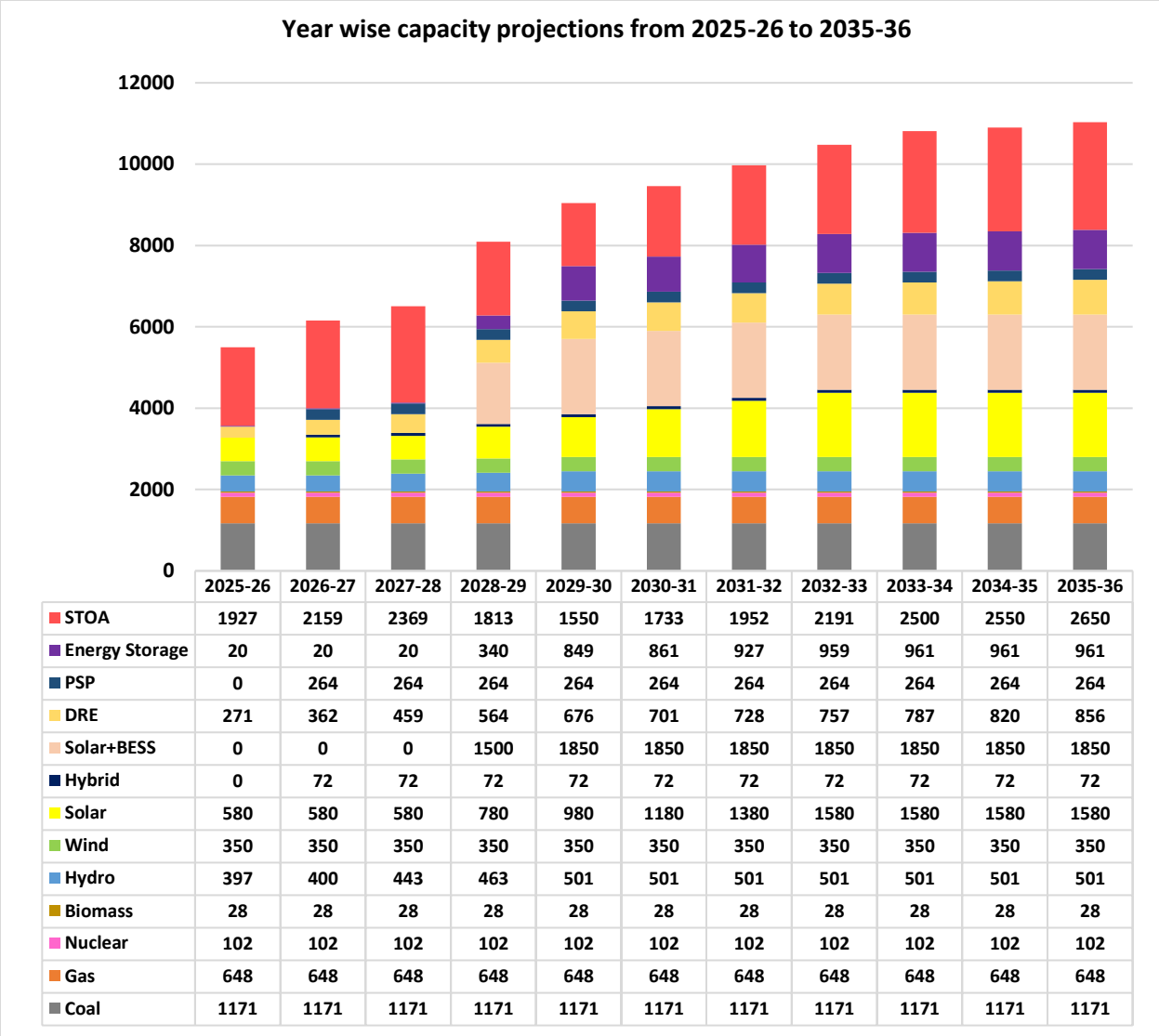
Table 14 Year wise Capacity Addition (in MW)

FY	Nuclear	Hydro	Hybrid	PSP	Solar	4h_Storage *	Solar + BESS #		DRE	
	Planned	Planned	Planned	Planned	Additional contracts	Additional contracts	Planned	Additional contracts	Planned	Additional contracts
2025-26	44	16	0	0	0	0	0	0	80	30
2026-27	0	3	72	264	0	0	0	0	86	5
2027-28	0	43	0	0	0	0	0	0	91	6
2028-29	0	20	0	0	200	320	1500	0	97	8
2029-30	0	38	0	0	200	509	0	350	103	9
2030-31	0	0	0	0	200	12	0	0	22	3
2031-32	0	0	0	0	200	66	0	0	23	4
2032-33	0	0	0	0	200	32	0	0	20	9
2033-34	0	0	0	0	0	2	0	0	20	10
2034-35	0	0	0	0	0	0	0	0	20	13
2035-36	0	0	0	0	0	0	0	0	20	16
TOTAL	**44**	**120**	**72**	**264**	**1000**	**941**	**1500**	**350**	**582**	**113**

* The energy storage requirement as outlined in the report may be fulfilled through any combination of energy storage systems (2 hrs, 4 hrs etc.) as deemed suitable by the utility.

 # Solar + BESS implies 1500 MW Solar with 750 MW / 3000 MWh BESS in the year 2028-29 and 350 MW Solar with 175 MW / 600 MWh of BESS in 2029-30.

It is important to mention that, in the previous RA study up to FY 2033-34, the additional coal-based contracts were proposed to be around 1900 MW by the end of 2033-34 accompanied by 400 MW of additional solar and 583 MW of additional wind-based contracts and no additional storage-based contracts. BRPL, in its letter dated 7th October 2024, has communicated its intent towards the decarbonization plan and to green its power purchase portfolio. In line with this intent, BRPL has opted for greater penetration of renewable energy (RE) sources, particularly through the adoption of the Solar + BESS product, which has been observed to be well-suited to BRPL's diurnal and seasonal demand profile. Taking these factors in to account the projected contracted capacity mix, year-wise is given in the figure below:



	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35	2035-36
STOA	1927	2159	2369	1813	1550	1733	1952	2191	2500	2550	2650
Energy Storage	20	20	20	340	849	861	927	959	961	961	961
PSP	0	264	264	264	264	264	264	264	264	264	264
DRE	271	362	459	564	676	701	728	757	787	820	856
Solar+BESS	0	0	0	1500	1850	1850	1850	1850	1850	1850	1850
Hybrid	0	72	72	72	72	72	72	72	72	72	72
Solar	580	580	580	780	980	1180	1380	1580	1580	1580	1580
Wind	350	350	350	350	350	350	350	350	350	350	350
Hydro	397	400	443	463	501	501	501	501	501	501	501
Biomass	28	28	28	28	28	28	28	28	28	28	28
Nuclear	102	102	102	102	102	102	102	102	102	102	102
Gas	648	648	648	648	648	648	648	648	648	648	648
Coal	1171	1171	1171	1171	1171	1171	1171	1171	1171	1171	1171

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

The STOA/MTOA requirement can be fulfilled through power procurement from markets or bilateral agreements. The STOA/MTOA value reflects the year-wise peak requirement/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 Normalised energy Not-Served (NENS) remaining within the permissible limits of 0.2% and 0.05% respectively.

As per the Resource Adequacy studies, the likely total projected contracted capacity for the year 2035-36 is around 11,034 MW which consists of 1171 MW from Coal, 648 MW from Gas, 102 MW from Nuclear, 28 MW from Biomass, 501 MW from Hydro, 350 MW from Wind, 1580 MW

from Solar, 72 MW from Hybrid, 1850 MW Solar + BESS (i.e., with 925 MW co-located BESS), 856 MW from Distributed Renewable Energy (DRE) sources, 264 MW of PSP, 960 MW/3803 MWh from Energy Storage System (ESS) and 2650 MW of MTOA/STOA arrangement will be required. This capacity shall be able to meet the projected demand with prescribed reliability criteria. The Planning Reserve Margin (PRM) for BRPL has been assessed as 12%.

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.

Furthermore, the projected contracted capacity is in compliance with the stipulated Renewable Purchase Obligation (RPO) targets from 2028-29 onwards. The projected capacity and generation mix presented in the report adequately meet the utility's RPO requirements for the period 2028-29 to 2035-36. This is on account of the fact that investment options have been introduced only from 2028-29 onwards, in line with the availability of contracts as observed by the utility. For the year 2025-26 to 2027-28 the utility may endeavor short-term, banking or medium-term power purchase agreements, or through any other appropriate mechanisms deemed suitable by the utility in order to meet the RPO trajectory.

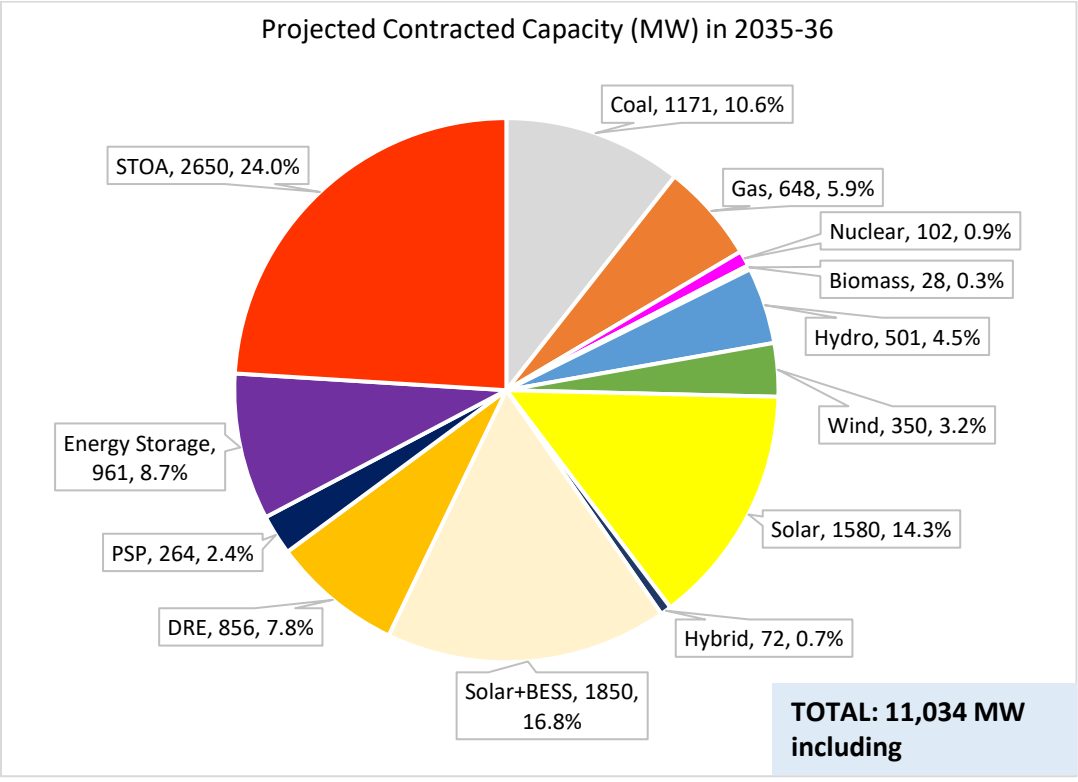


Figure 10 Contracted Capacity Mix in 2035-36

The projected gross generation mix for the utility is shown in Figure 12.

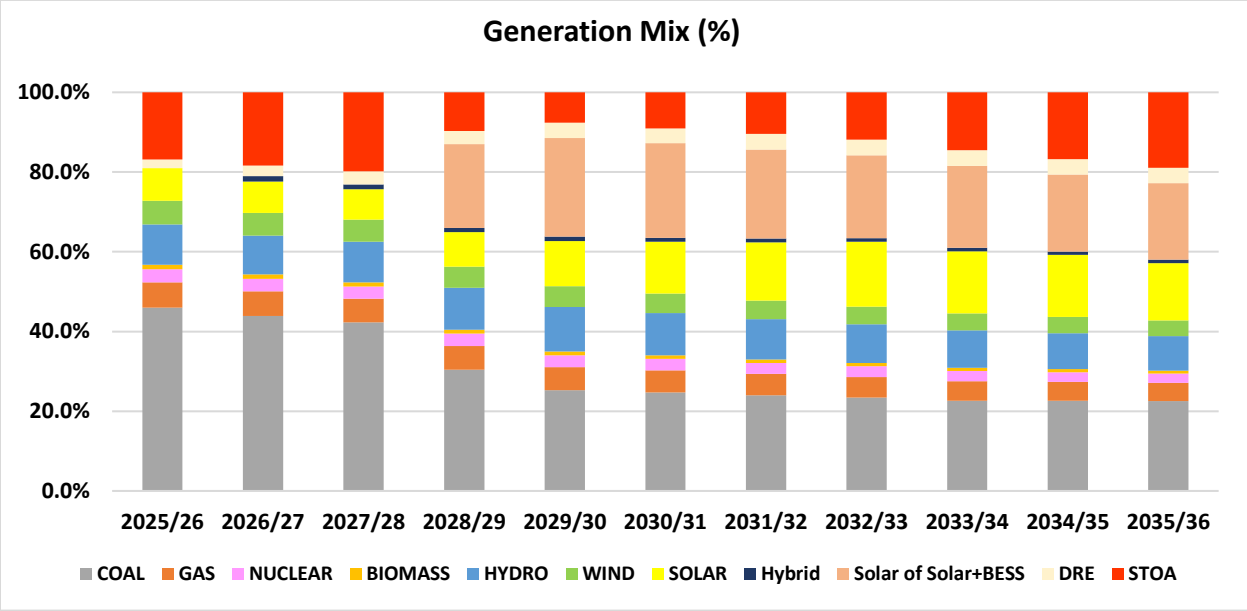
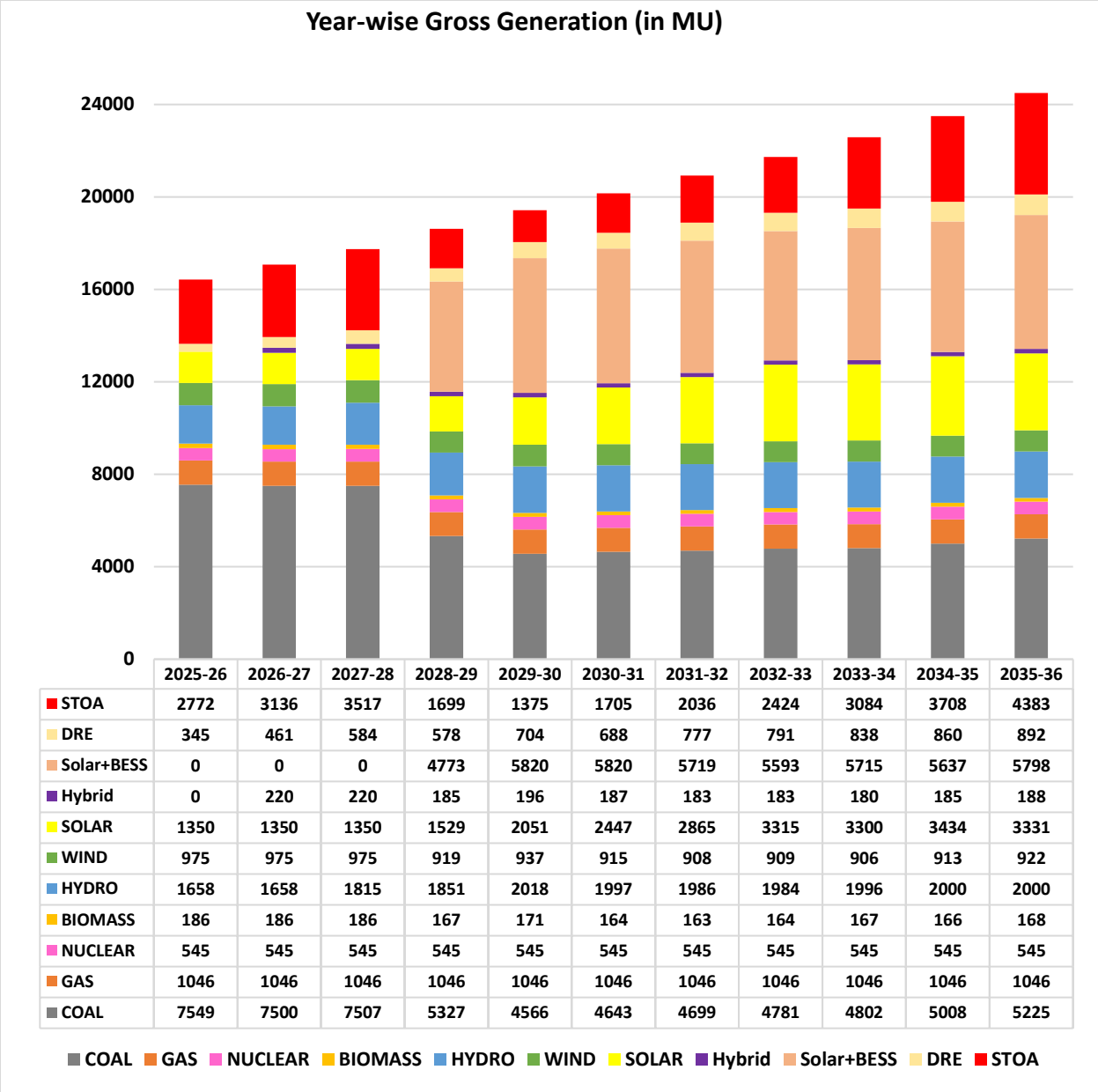


Figure 11 Year-wise projected gross generation mix (in %)

The years-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	2772	3136	3517	1699	1375	1705	2036	2424	3084	3708	4383
DRE	345	461	584	578	704	688	777	791	838	860	892
Solar+BESS	0	0	0	4773	5820	5820	5719	5593	5715	5637	5798
Hybrid	0	220	220	185	196	187	183	183	180	185	188
SOLAR	1350	1350	1350	1529	2051	2447	2865	3315	3300	3434	3331
WIND	975	975	975	919	937	915	908	909	906	913	922
HYDRO	1658	1658	1815	1851	2018	1997	1986	1984	1996	2000	2000
BIOMASS	186	186	186	167	171	164	163	164	167	166	168
NUCLEAR	545	545	545	545	545	545	545	545	545	545	545
GAS	1046	1046	1046	1046	1046	1046	1046	1046	1046	1046	1046
COAL	7549	7500	7507	5327	4566	4643	4699	4781	4802	5008	5225

Figure 12 Year-wise projected gross 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 of 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 reduction in the cost for consumer. BRPL is likely to have surplus capacity during the off-peak electricity demand months (November to March), which can be shared with other states. With the introduction of Solar + BESS and additional solar contracts accompanied by storage from 2028-29 onwards, coal-based surplus capacity is likely to increase, as reflected in the figure. Specifically, the utility is likely to have a surplus of around 400 MW to 680 MW during November to April in 2028-29, which can be shared with other states/Discoms.

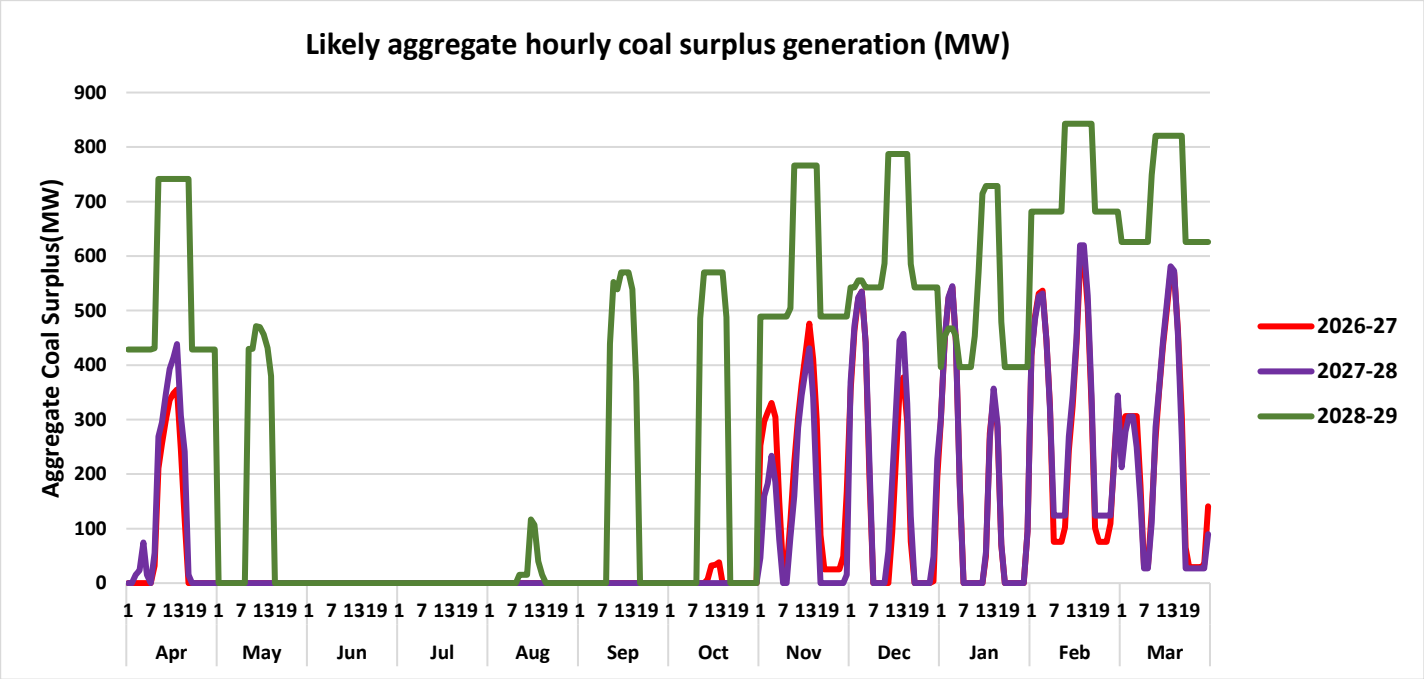


Figure 13 Surplus Coal Capacity Year-wise (MW)

8.0 Conclusions

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

1. The study has been carried out considered the electrical energy requirement projections and peak electricity demand projections as per BRPL. The electrical energy requirement of the utility is likely to grow at a CAGR of 4% while the peak electricity demand for the utility is likely to grow at a CAGR of 5.9% for the period of 2025-26 to 2035-36.
2. Based on the demand pattern of last few years, it is seen that the high electricity demand is typically from June to July with peak electricity demand occurring during night time. The demand during the months from October to March remains significantly low as compared to other months, reflecting the seasonality in demand, largely driven by the high proportion of domestic consumers in the overall mix. 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.
3. BRPL is likely to witness energy deficit ranging from 1978 MUs to 5809 MUs in different years from 2025-26 to 2035-36 with the existing and planned capacity addition only. This deficit may reduce depending upon the banking arrangement etc.
4. As per the Resource Adequacy studies, the likely total projected contracted capacity for the year 2035-36 is around 11,034 MW which consists of 1171 MW from Coal, 648 MW from Gas, 102 MW from Nuclear, 28 MW from Biomass, 501 MW from Hydro, 350 MW from Wind, 1580 MW from Solar, 72 MW from Hybrid, 1850 MW Solar + BESS (i.e., with 925 MW co-located BESS), 856 MW from Distributed Renewable Energy (DRE) sources, 264 MW of PSP, 960 MW/3803 MWh from Energy Storage System (ESS) and 2650 MW of MTOA/STOA arrangement will be required. This capacity shall be able to meet the projected demand with prescribed reliability criteria. The Planning Reserve Margin (PRM) for BRPL has been assessed as 12%.
5. The projected capacity and generation mix outlined in the report meet the utility's RPO requirements for the years 2028-29 to 2035-36. To meet the RPO trajectory for the year 2025-26 to 2027-28, the utility may endeavor short-term or medium-term power purchase agreements, or through any other appropriate mechanisms deemed suitable by the utility.
6. The electrical energy requirement to be met from STOA/MTOA (short term/medium term/market-based contracts) ranges from 10% to 20% of the total electrical energy requirement, indicating the need for seasonal banking arrangements as also being practiced by the utility.

7. It is likely that BRPL may have surplus capacity available during the months from October to March which can be shared with other utilities/states through banking/bilateral arrangements, including Pushp portal.
8. 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.
9. Timely commissioning of planned capacities is critical to ensuring 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

Planned Future Contracted (MW) considered in the study

S No	Tied capacity name	Type of generation	Expected CoD	BRPL share (in MW)
1.	RAPP 7 & 8	Nuclear	2025-26	44.5
2.	Parbati-II	Hydro		16
3.	Rangit-IV	Hydro	2026-27	3
4.	Hybrid Tranche	Hybrid		72
5.	Tehri PSP	PSP		264
6.	Kiru	Hydro	2027-28	12
7.	Pakaldul	Hydro		7
8.	Vishnugad Pipalkoti	Hydro		23.6
9.	Kwar	Hydro	2028-29	10
10.	Teesta VI	Hydro		10
11.	Solar + BESS	Solar + BESS		1500 MW + 750 MW/ 3000 MWh
12.	Ratle	Hydro	2029-30	7
13.	Tapovan Vishnugad	Hydro		31.32

Assumption for Resource Adequacy Studies

1. The electrical energy requirement projections and peak demand projections as estimated by CEA, after considering the projections of BRPL.
2. Demand Profile: Based on 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 National Electricity Plan and recent market trends.

RE CUF considered

Hydro	Wind	Solar	DRE
38 %	31%	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. (%)
		At max loading	At min loading	
Coal	Existing/ Planned	2300 to 2879	2438 to 3052	7.0
	Candidate (SC & USC)	2060 to 2125	2183 to 2253	6.5
Gas	Existing	2000 to 2900	2260 to 3277	2.5
Nuclear	Existing/ Planned	2777	2777	10
	Candidate	2777	2777	10
Biomass	Existing/ Planned	4200	4450	8
	Candidate	4200	4450	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. Inter State ATC limit has not been considered in the study. Additionally, for modelling the charged BESS under the Solar + BESS configuration, the BESS capacity has been created at a separate node, with its charging arranged by the generator, unlike in the standalone BESS setup.

Financial Parameters

Following cost parameters have been assumed:

Resource	Capex* (in ₹/MW)	Fixed O&M Cost (in ₹/MW)	Construction Time (in years)	Amortization /Life time (in years)
Coal	12 Cr	30 Lakh	4	25
Solar	4.5 Cr	1 % of Capex	1	25
Battery Energy Storage (4-Hour)	4.98 Cr to 3 Cr	5.9 Lakh	1	15
PSP	6 Cr	30 Lakh	4	40

BRPL letter to CEA dated 7th October 2024

BSES Rajdhani Power Limited
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No. HOD (PMG)/BRPL/2024-25/416 **Date: 07.10.2024**

To,
Chief Engineer - IRP,
Central Electricity Authority,
Sewa Bhawan, New Delhi

Subject: Carbon-neutral and Decarbonisation plan for BSES Rajdhani Power Limited (BRPL)

Ref: CEA's Resource Adequacy Study vide letter dated 02.09.2024

Dear Madam,

1. This has reference to the Resource Adequacy Study conducted by CEA vide reference mentioned above. We are very thankful for your guidance, and support extended by your team for preparing this report.
2. As per the RA report dated 02.09.2024, we have assumed the future Renewable capacity requirements based on the RPO targets as per Energy Conservation Act.
3. The National Electricity Policy (NEP) outlines the Government of India's emphasis on increasing the share of renewable energy in the power mix, in line with the country's commitment to sustainability and climate change mitigation. Considering the National Target of achieving 500 GW non-fossil fuel-based installed capacity by 2030 and carbon neutral by 2070, we are further evaluating the option of increasing the share of Renewables in our portfolio.
4. Tariff discovered in recent tenders are very competitive in view of fall in solar module and energy storage system prices. Further, recent renewable energy tenders are also offering new renewable mix combinations (like the recent FDRE tenders, an alternative to thermal power) duly providing reliability while maintaining its competitiveness over fossil fuel sources.
5. In view of the above, we seek your support and guidance in developing a road map for BRPL to achieve carbon neutrality and moving forward to establish a comprehensive decarbonisation plan that ensures both reliability and sustainability.

Registered Office: **BSES Rajdhani Power Limited** - BSES Bhawan, Nehru Place, New Delhi -110 019.

6. In this regard, we request you that as an alternative plan with the objective of greening the power purchase portfolio, CEA may kindly undertake a study of Resource Adequacy Plan with an objective to achieve carbon neutrality and progressively adopting Green Energy & phasing out thermal capacity to achieve decarbonisation of our power purchase portfolio.

7. We will be happy to provide any necessary support / information as may be required to conduct this study and finalising the report.

You're sincerely,

For **BSES Rajdhani Power Ltd**

Sanjay Srivastav
(Head PMG)

CC: Chairman, CEA