

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

(Version 2.0)

October, 2025

Government of India
Ministry of Power

Central Electricity Authority

Contents

Disclaimer i

Executive Summary ii

1.0 Introduction 1

2.0 Highlights of the Previous RA Study (up to FY 2033-34) 2

3.0 RA Study for BYPL (from 2025-26 to 2035-36) 4

3.1 Present Power Scenario in BYPL 4

3.2 Demand Analysis of the FY 2024-25 5

4.0 Principles of Generation Planning 7

4.1 Generation Expansion Planning Tool -ORDENA 7

5.0 Reliability Analysis 8

5.1 Demand variation 9

5.2 Variation in RE 10

5.3 Forced Outage of Thermal Generators 10

6.0 Inputs/Assumptions for the Study 10

7.0 Outcome of the model 14

7.1 Unserved Electrical Energy Projections 14

7.2 Options to meet the unserved electrical energy 15

7.3 Day-wise Surplus Capacity (in MW) 21

8.0 Conclusions 22

Disclaimer

This Resource Adequacy study for BSES Yamuna Power Limited (BYPL), a utility in Delhi, has been conducted based on the data and inputs provided by BYPL. The findings, analysis and conclusions presented in this report are contingent upon the accuracy, completeness and timeliness of the information furnished by BYPL. 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 Central Electricity Authority (CEA). CEA has facilitated this study and prepared the report solely to assist BYPL 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 rests entirely with BYPL.

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 BYPL is increasing with a CAGR of 1.5% and 4.1% respectively from 2025-26 to 2035-36 as forecasted by BYPL. 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 BYPL considering the existing contracted capacity and planned capacity addition. It was found that BYPL'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 887 MUs which is about 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, 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.

The Resource adequacy studies have projected 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 *5,183* MW which consists of 1023 MW from Coal, 374 MW from Gas, 37 MW from Nuclear, 28 MW from Biomass, 205 MW from Hydro, 150 MW from Wind, 1007 MW from Solar, 65 MW from Hybrid, 500 MW of Solar + BESS (i.e., with 250 MW / 1000 MWh of co-located BESS), 336 MW from Distributed Renewable Energy (DRE) sources, 152 MW of PSP, 322 MW/ 1287 MWh of Energy storage and 984 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, 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 BYPL 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 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 2033-34, based on inputs from BYPL 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 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:

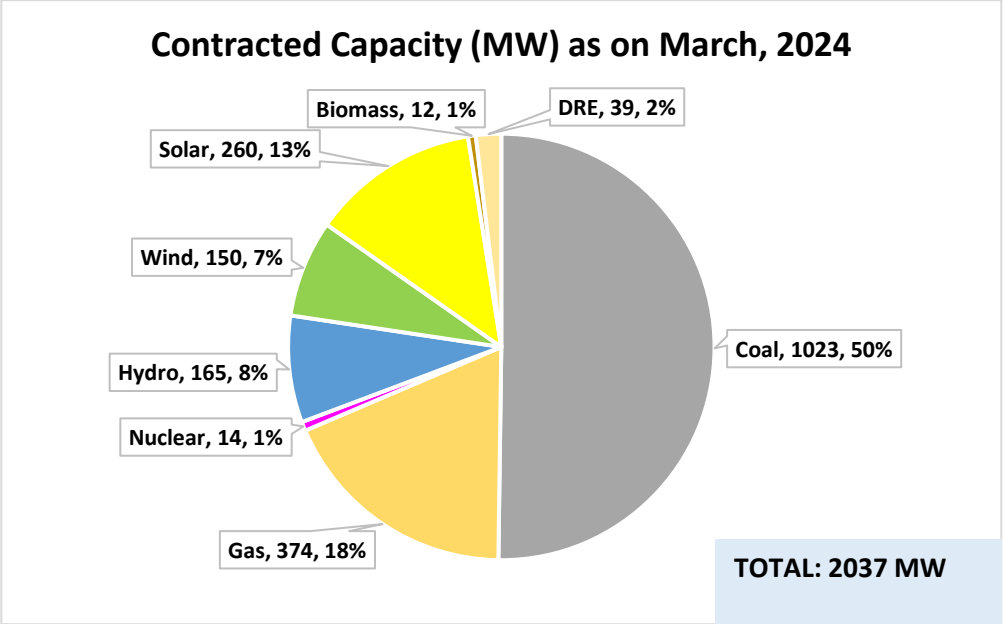


Figure 1 Fuel wise Contract Capacity (in MW) as on March 2024

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 BYPL 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

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)	7,682	7,797	7,914	8,072	8,234	8,399	8,567	8,738	8,956	9,180
Year on Year Growth *(Electrical Energy)*		4.1%	4.1%	4.1%	4.1%	4.1%	4.1%	4.1%	4.1%	4.1%
Peak electricity demand Projections (MW)	1,857	1,934	2,013	2,096	2,183	2,272	2,366	2,464	2,565	2,671
Year on Year Growth (Peak electricity demand)		1.5%	1.5%	2.0%	2.0%	2.0%	2.0%	2.0%	2.5%	2.5%

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	8,127	1,852

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	DRE	STORAGE	MTOA/ STOA
2024/25	1023	374	14	12	165	150	260	0	91	152/608	505
2025/26	1023	374	14	21	182	150	360	100	129	152/608	403
2026/27	1023	374	40	21	182	213	413	100	168	152/608	432
2027/28	1131	374	40	21	194	255	448	100	210	152/608	397
2028/29	1202	374	40	21	194	302	488	100	253	152/608	402
2029/30	1245	374	40	21	194	340	520	100	270	152/608	435
2030/31	1284	374	40	21	194	390	565	100	303	152/608	470
2031/32	1284	374	40	21	194	438	602	100	309	152/608	542
2032/33	1285	374	40	21	194	483	640	100	317	152/608	618
2033/34	1314	374	40	21	194	528	677	100	325	152/608	676

*****The STOA/MTOA value represents the peak electricity demand 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 BYPL (in MW)

	Coal	Nuclear	Biomass	Hydro	Wind	Solar		Hybrid	Storage	Distributed RE
Year	**Additional Requirement**	**Planned Contracts**	**Planned Contracts**	**Planned Contracts**	**Additional Requirement**	**Planned Contracts**	**Additional Requirement**	**Planned Contracts**	**Planned contracts**	**Additional Requirement**
2024-25	0	0	0	0	0	0	0	0	152	52
2025-26	0	0	9	17	0	100	0	100	0	38
2026-27	0	26	0	0	63	0	53	0	0	39
2027-28	107	0	0	11	42	0	35	0	0	42
2028-29	71	0	0	0	47	0	39	0	0	43
2029-30	43	0	0	0	38	0	32	0	0	17
2030-31	39	0	0	0	50	0	45	0	0	33
2031-32	0	0	0	0	48	0	36	0	0	6
2032-33	0	0	0	0	45	0	38	0	0	8
2033-34	29	0	0	0	45	0	38	0	0	8
TOTAL	**291**	**26**	**9**	**28**	**378**	**100**	**316**	**100**	**152**	**286**

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

3.1 Present Power Scenario in BYPL

As of March 2025, the total contracted capacity of BYPL is 2,042 MW including 44 MW DRE. Out of the total contracted capacity (CC), the share of non-fossil fuel-based CC is 31.5 %. Fuel-wise contracted capacity as on 31st March, 2025, is given in Table 5 and Figure 2:

Table 5: Fuel-wise Contracted Capacity as on March 2025

Source	Contracted Capacity (MW)	Percentage (%)
Coal	1023	50%
Gas	374	18%
Nuclear	14	1%
Hydro	165	8%
Wind	150	7%
Solar	260	13%
Biomass	12	1%
DRE	44	2%
Sub-Total	**2042**	100%

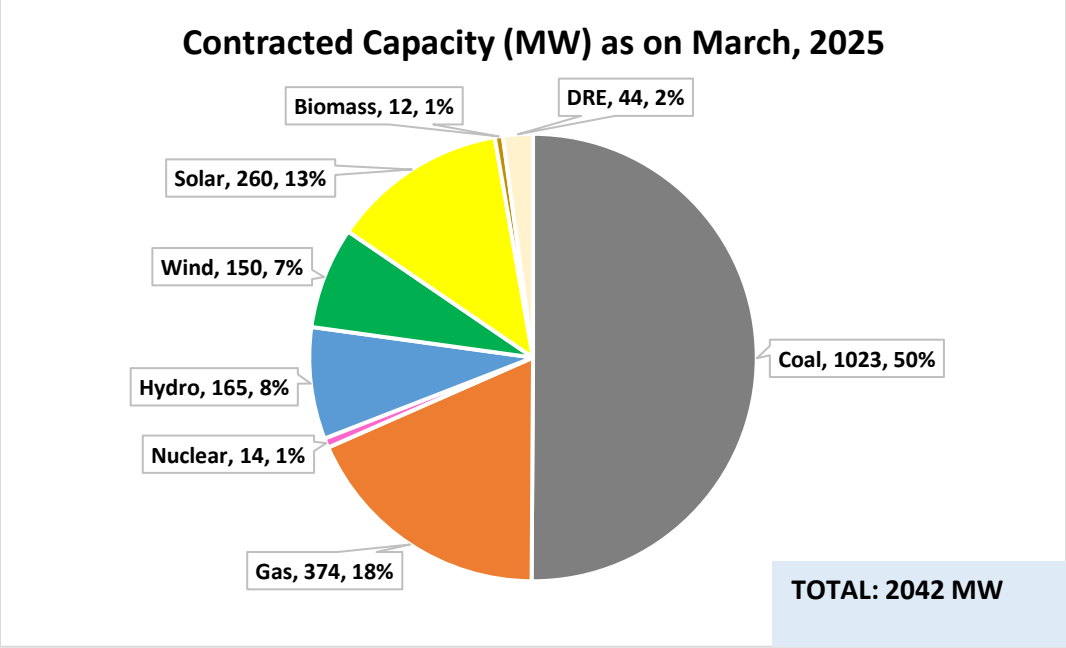


Figure 2 Fuel-wise Contracted Capacity (in MW) as on March, 2025

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 BYPL occurs during day time in June 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.

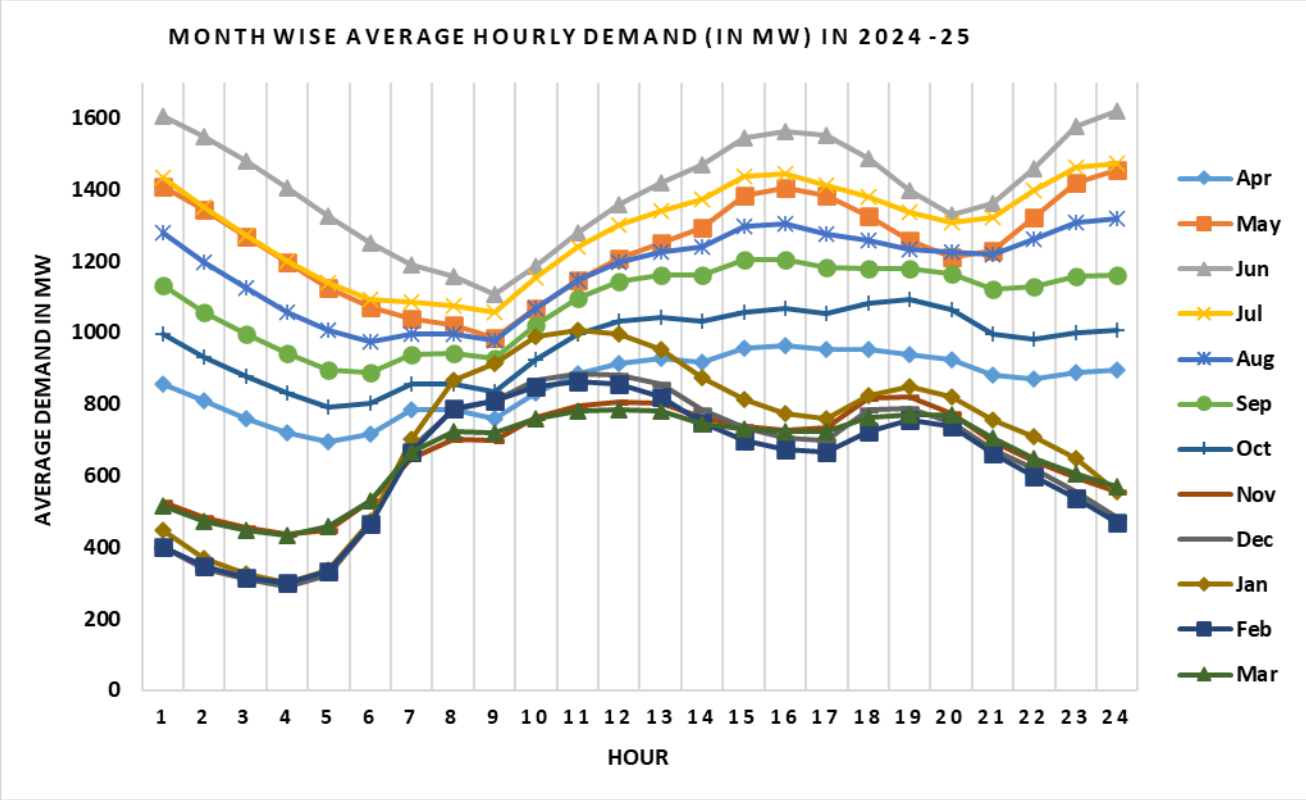


Figure 3 Average Hourly Demand Variation (Month-wise) for 2024-25

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.

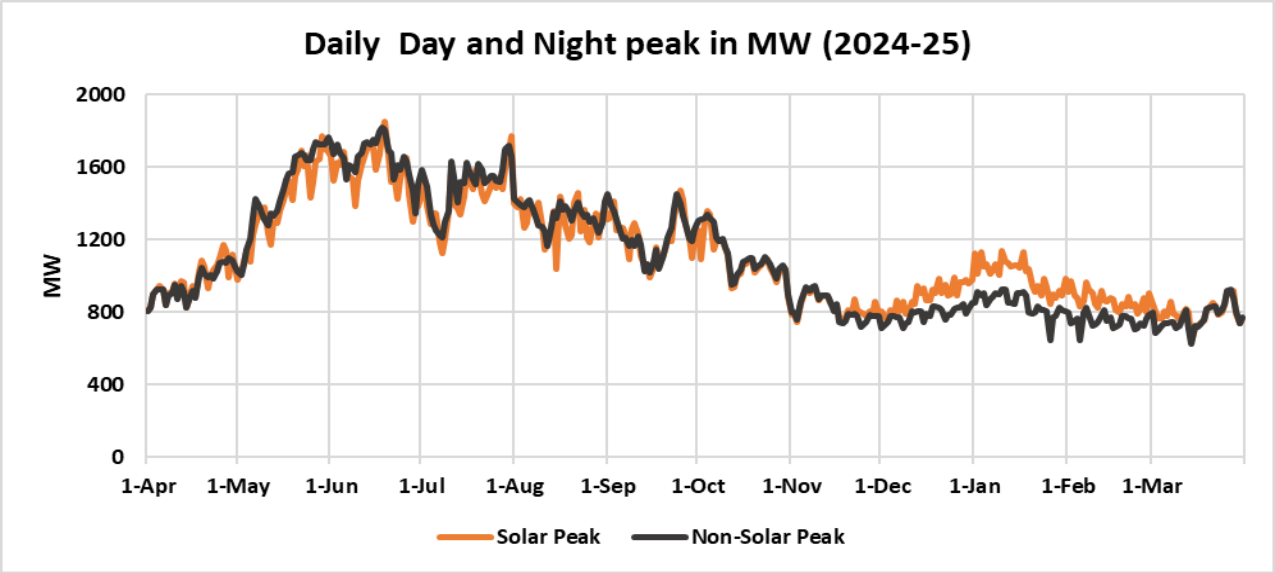


Figure 4 Day and Night Peak Electricity demand in MW for the year 2024-25

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.

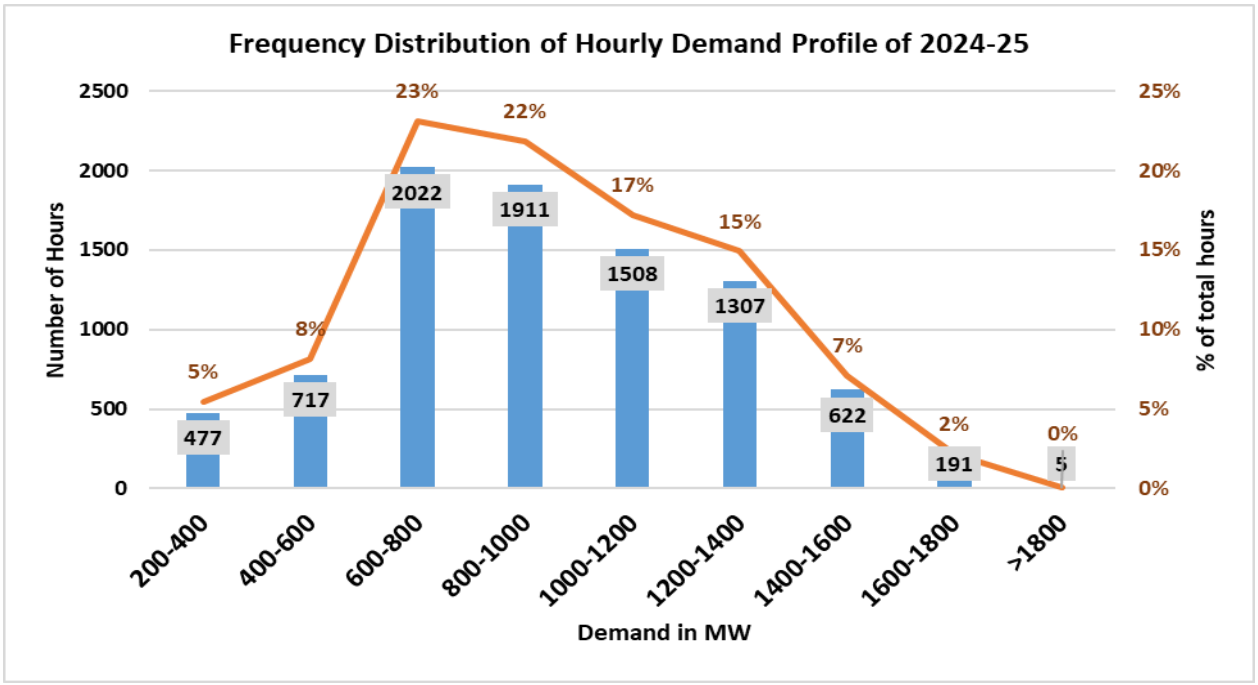


Figure 5 Frequency Distribution of Hourly Demand Profile of 2024-25

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.

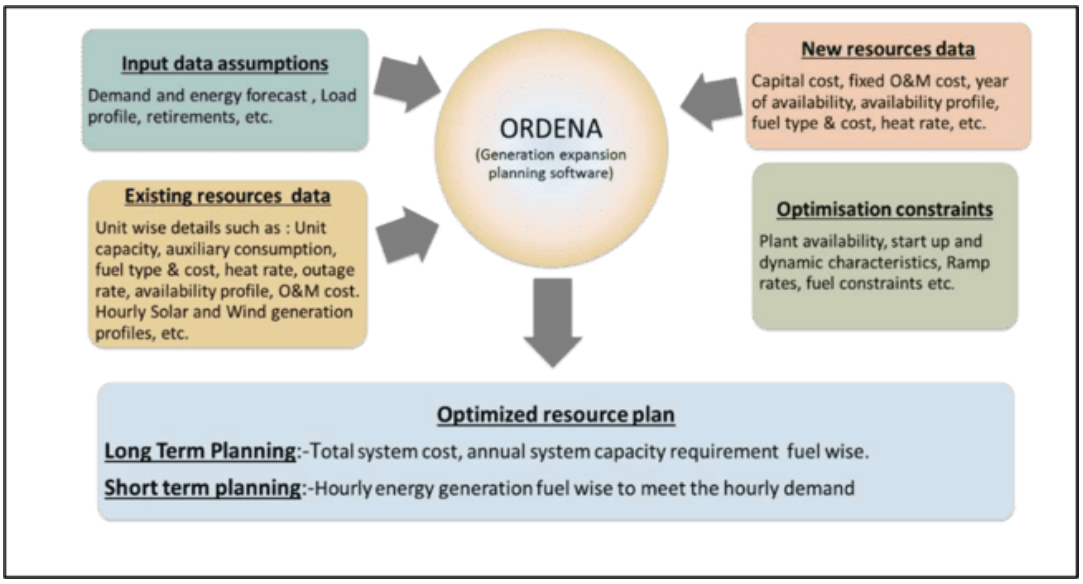


Exhibit : Schematic Diagram -Ordena

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 considering 2023-24 as base) has been analyzed. The demand pattern variation of 2023-24 and 2024-25 is shown below:

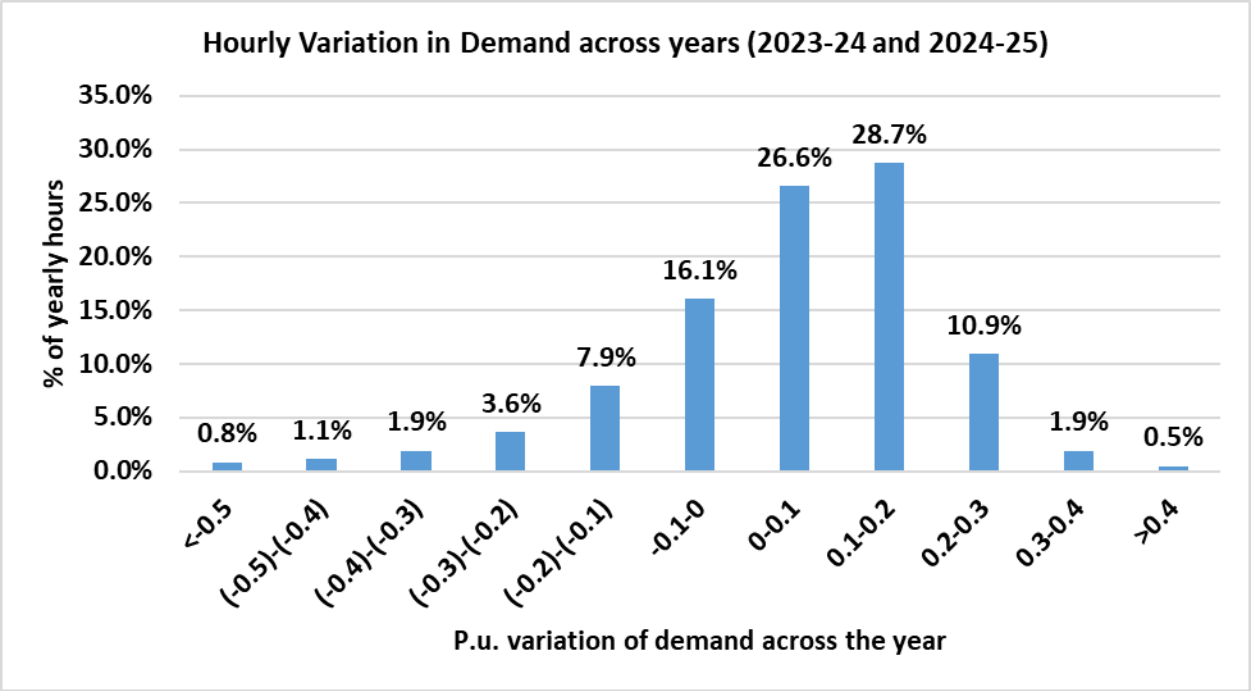


Figure 6 Hourly Variation in Demand across years

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 is considered based on the observed solar generation data to determine the optimal capacity mix. However, due to intermittent nature of these sources, the generation from these non-dispatchable sources may vary across years. As per the analyses carried out based on historical generation data, solar and hydro based generation has been varied by ± 10 % and wind generation has been varied by ± 50% to incorporate the variation in these generation sources and plan for requisite measures to mitigate such behavior.

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 projected electrical energy requirement and peak electricity demand as estimated by BYPL is given in Table 6.

Table 6: Electricity Demand Projection as provided by the utility

Year	Peak Electricity Demand (MW)	Electrical energy requirement (MU)
2025-26	1,934	8,181
2026-27	2,013	8,303
2027-28	2,096	8,428
2028-29	2,183	8,554
2029-30	2,272	8,683
2030-31	2,366	8,813
2031-32	2,464	8,945
2032-33	2,565	9,079
2033-34	2,671	9,215
2034-35	2,781	9,354
2035-36	2,895	9,494

Peak electricity demand and electrical energy requirement projections as per earlier report were updated with actual data of 2024-25. The electrical energy requirement and peak electricity demand projections are generally aligned with the earlier report.

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 BYPL, while the hydro generation profiles and PLFs have been taken from the National Electricity Plan 2023 (Vol. I - Generation).

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 BYPL. Source-wise planned capacity is given below:

Table 7 Source wise planned capacity addition

FY	Nuclear	Biomass	Hydro	Hybrid	PSP	Solar + BESS	DRE
2025-26	23	-	9	-	-	-	8
2026-27	-	4	2	65	152	-	8
2027-28	-	12	12	-	-	-	7
2028-29	-	-	13	-	-	500 MW Solar with 250 MW / 1000 MWh of BESS	7
2029-30	-	-	4	-	-	-	6
2030-31	-	-	-	-	-	-	6
2031-32	-	-	-	-	-	-	5
2032-33	-	-	-	-	-	-	5
2033-34	-	-	-	-	-	-	5
2034-35	-	-	-	-	-	-	5
2035-36	-	-	-	-	-	-	-
Total	**23**	**16**	**40**	**65**	**152**	**500**	**62**

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 has been 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 9.

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	118.62	99.80	2310.23	171.79	2700.45
2.	2026-27	163.58	111.27	2486.04	224.19	2985.08
3.	2027-28	206.49	119.68	2666.61	278.12	3270.89
4.	2028-29	252.35	121.47	2831.50	333.62	3538.09
5.	2029-30	302.16	115.48	2953.85	390.72	3762.21
6.	2030-31	3613.30			396.58	4009.89
7.	2031-32	3801.68			402.53	4204.21
8.	2032-33	3976.74			408.57	4385.31
9.	2033-34	4146.97			414.70	4561.67
10.	2034-35	4302.72			420.92	4723.63
11.	2035-36	4462.20			427.23	4889.43

The year-wise total renewable energy, excluding DRE, met from the existing and planned capacity along with the deficit is shown in Table 11.

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	2529	30.91%	1803	22.04%	-8.87%
2026-27	2761	33.25%	2036	24.52%	-8.73%
2027-28	2993	35.51%	2157	25.59%	-9.92%
2028-29	3205	37.47%	3804	44.47%	7.00%
2029-30	3371	38.83%	3819	43.98%	5.15%
2030-31	3613	41.00%	3819	43.33%	2.33%
2031-32	3802	42.50%	3819	42.69%	0.19%
2032-33	3977	43.80%	3819	42.06%	-1.74%
2033-34	4147	45.00%	3819	41.44%	-3.56%
2034-35	4303	46.00%	3819	40.83%	-5.17%
2035-36	4462	47.00%	3819	40.22%	-6.78%

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 from 2032-33 onwards, 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	172	2.10%	66	0.81%	-1.29%
2026-27	224	2.70%	76	0.92%	-1.78%
2027-28	278	3.30%	85	1.01%	-2.29%
2028-29	334	3.90%	94	1.10%	-2.80%
2029-30	391	4.50%	102	1.17%	-3.33%
2030-31	397	4.50%	109	1.24%	-3.26%
2031-32	403	4.50%	116	1.29%	-3.21%
2032-33	409	4.50%	122	1.35%	-3.15%
2033-34	415	4.50%	128	1.39%	-3.11%
2034-35	421	4.50%	135	1.44%	-3.06%
2035-36	427	4.50%	135	1.42%	-3.08%

7.0 Outcome of the model

7.1 Unserved Electrical Energy Projections

Initially, the study has been carried out considering only the existing and planned capacity contracts by BYPL, and does not include any banking arrangements or short-term contracts. The total unserved electrical energy for the year 2035-36 would be 887 MU. The year-wise likely unserved electrical energy with the planned capacities is given in Figure 7.

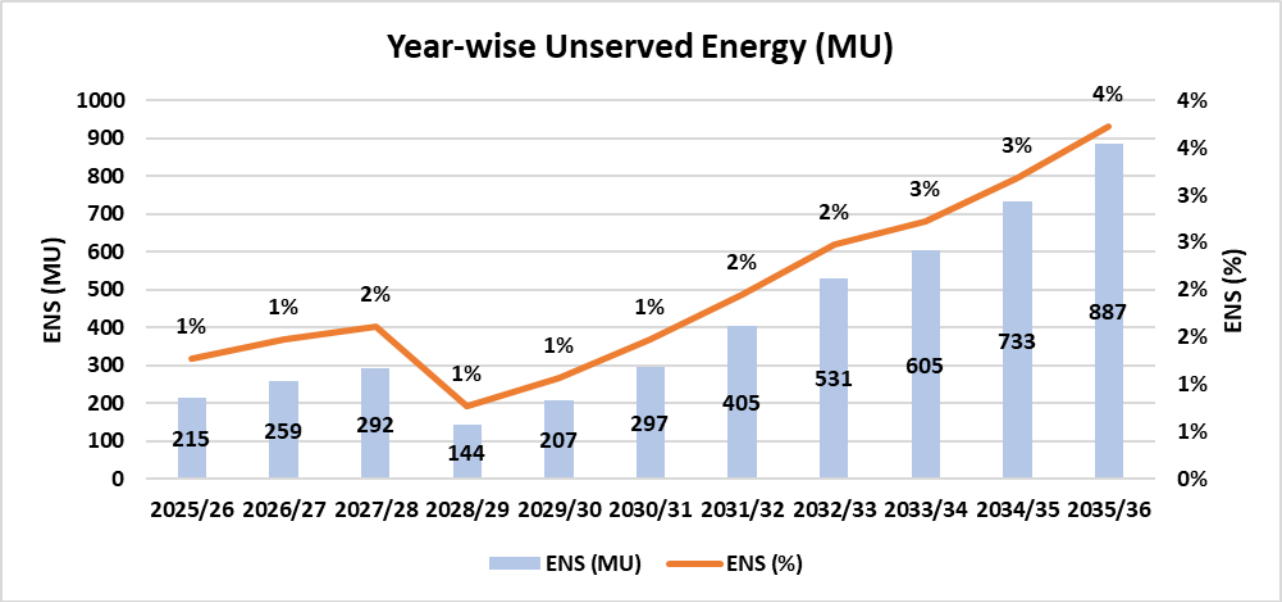


Figure 7 Yearly likely unserved electrical energy (in MU) with the existing and planned capacities

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

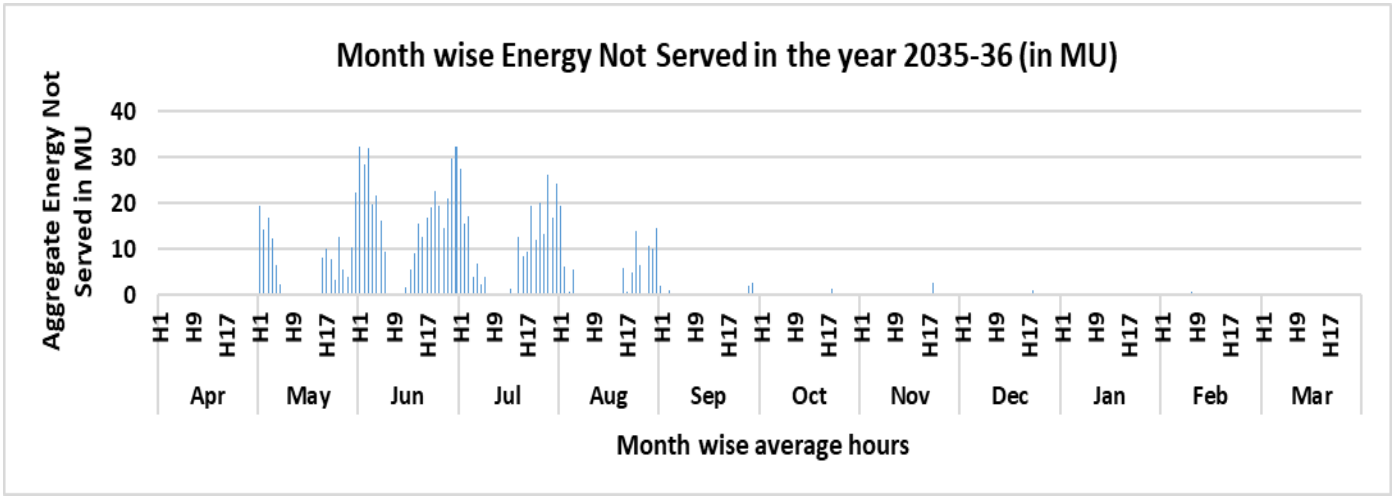


Figure 8 Block-wise Unserved Electrical Energy Pattern GWh (2035-36)

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. To meet unserved energy, the utility needs to tie up additional capacity.

7.2 Options to meet the unserved electrical energy

To meet 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 contracts availability.

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

Table 13 Likely requirement of contracted capacity (existing+planned+additional) (in MW)

FY	Coal	Gas	Nuclear	Biomass	Hydro	Wind	Solar	Hybrid	Solar + BESS		PSP	Storage # (MW / MWh)	DRE	MTOA /STOA
									Solar compo-nent	4-hour BESS compo-nent				
2025-26	1023	374	37	12	174	150	260	0	0	0	0	0/0	135	509
2026-27	1023	374	37	16	176	150	260	65	0	0	152	0/0	176	573
2027-28	1023	374	37	28	188	150	260	65	0	0	152	0/0	219	638
2028-29	1023	374	37	28	201	150	260	65	500	250	152	0/0	262	590
2029-30	1023	374	37	28	205	150	315	65	500	250	152	0/0	307	676
2030-31	1023	374	37	28	205	150	467	65	500	250	152	59/237	313	712
2031-32	1023	374	37	28	205	150	592	65	500	250	152	109/438	318	761
2032-33	1023	374	37	28	205	150	702	65	500	250	152	169/677	323	803
2033-34	1023	374	37	28	205	150	818	65	500	250	152	225/901	328	854
2034-35	1023	374	37	28	205	150	909	65	500	250	152	290/1161	333	901
2035-36	1023	374	37	28	205	150	1007	65	500	250	152	321/1287	336	984

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.

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

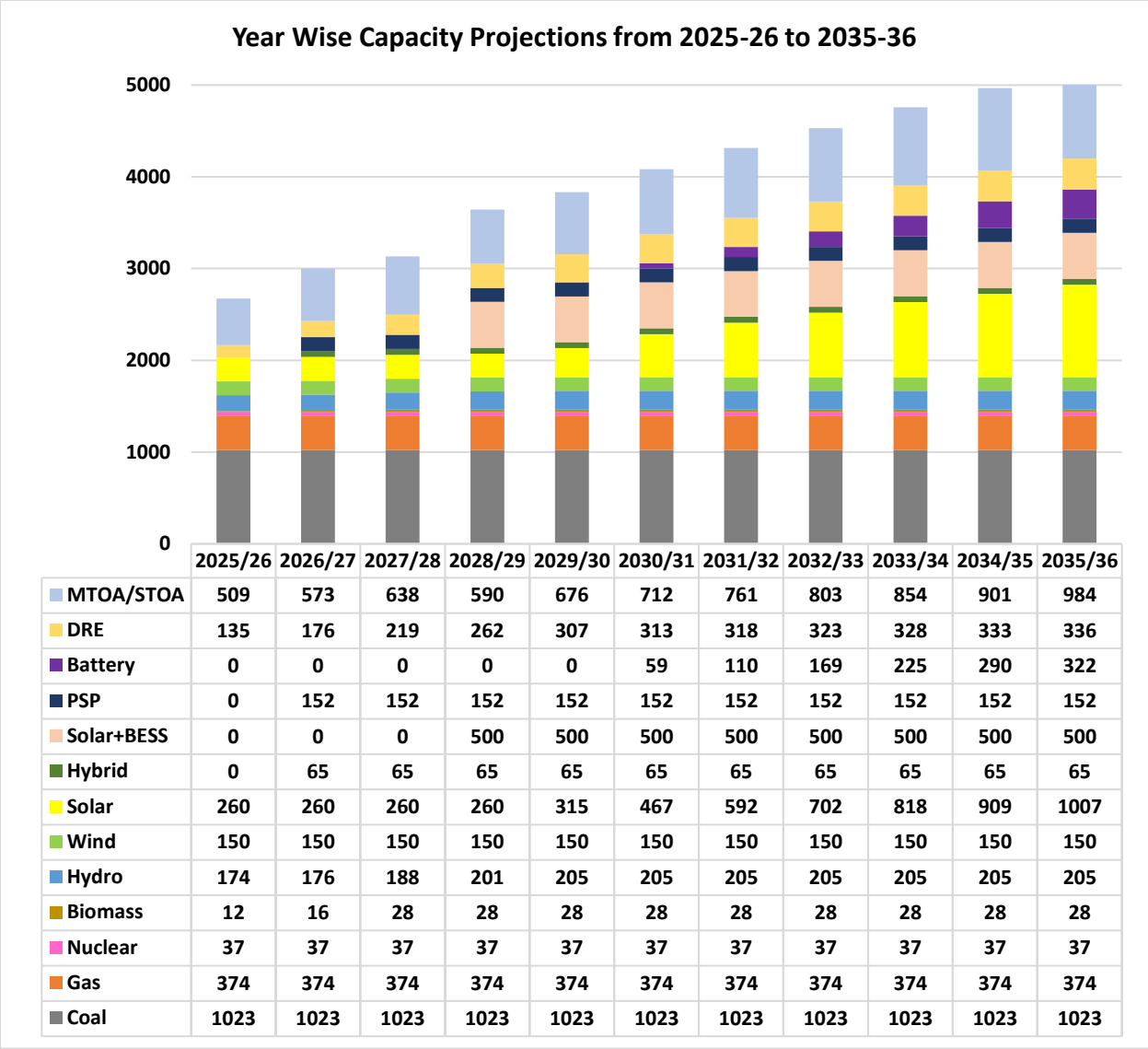
Table 14 Likely planned capacity and capacity to be contracted by the utility (in MW)

FY	Nuclear	Biomass	Hydro	Hybrid	PSP	Solar	Storage#	Solar + BESS *	DRE	
	Planned	Planned	Planned	Planned	Planned	Additional contracts	Additional contracts	Planned	Planned	Additional contracts
2025-26	23	0	9	0	0	0	0	0	8	83
2026-27	0	4	2	65	152	0	0	0	8	33
2027-28	0	12	12	0	0	0	0	0	7	36
2028-29	0	0	13	0	0	0	0	500	7	36
2029-30	0	0	4	0	0	55	0	0	6	39
2030-31	0	0	0	0	0	152	59/237	0	6	0
2031-32	0	0	0	0	0	125	50/200	0	5	0
2032-33	0	0	0	0	0	111	59/239	0	5	0
2033-34	0	0	0	0	0	116	55/223	0	5	0
2034-35	0	0	0	0	0	91	64/259	0	5	0
2035-36	0	0	0	0	0	99	31/126	0	0	3
TOTAL	**23**	**16**	**40**	**65**	**152**	**747**	**321/1287**	**500**	**62**	**230**

***** **Solar + BESS** implies 500 MW Solar with 250 MW / 1000 MWh BESS in the year 2028-29.

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.

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 291 MW by the end of 2033-34 accompanied by 316 MW of additional solar and 378 MW of additional wind-based contracts and no additional storage-based contracts. BSES group, 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, BYPL 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 BYPL'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
MTOA/STOA	509	573	638	590	676	712	761	803	854	901	984
DRE	135	176	219	262	307	313	318	323	328	333	336
Battery	0	0	0	0	0	59	110	169	225	290	322
PSP	0	152	152	152	152	152	152	152	152	152	152
Solar+BESS	0	0	0	500	500	500	500	500	500	500	500
Hybrid	0	65	65	65	65	65	65	65	65	65	65
Solar	260	260	260	260	315	467	592	702	818	909	1007
Wind	150	150	150	150	150	150	150	150	150	150	150
Hydro	174	176	188	201	205	205	205	205	205	205	205
Biomass	12	16	28	28	28	28	28	28	28	28	28
Nuclear	37	37	37	37	37	37	37	37	37	37	37
Gas	374	374	374	374	374	374	374	374	374	374	374
Coal	1023	1023	1023	1023	1023	1023	1023	1023	1023	1023	1023

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 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 5,183 MW which consists of 1023 MW from Coal, 374 MW from Gas, 37 MW

from Nuclear, 28 MW from Biomass, 205 MW from Hydro, 150 MW from Wind, 1007 MW from Solar, 65 MW from Hybrid, 500 MW of Solar + BESS (i.e., with 250 MW / 1000 MWh of co-located BESS), 336 MW from Distributed Renewable Energy (DRE) sources, 152 MW of PSP, 322 MW/ 1287 MWh of Energy storage and 984 MW of MTOA/STOA arrangement 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 BYPL has been assessed as 8% during solar hours wherein the peak electricity demand during solar hours is observed with higher availability of solar and wind generation but without the availability of storage contracts and during the non-solar hours as 6%, when the peak electricity demand during non-solar hours is observed with higher availability of storage-based contracts. The availability of large hydro, conventional generating sources, and short-term market arrangements (such as MTOA/STOA and power exchanges) has been assumed to remain uniform across both peak electricity demand periods.

Furthermore, 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. 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 in order to meet the RPO trajectory.

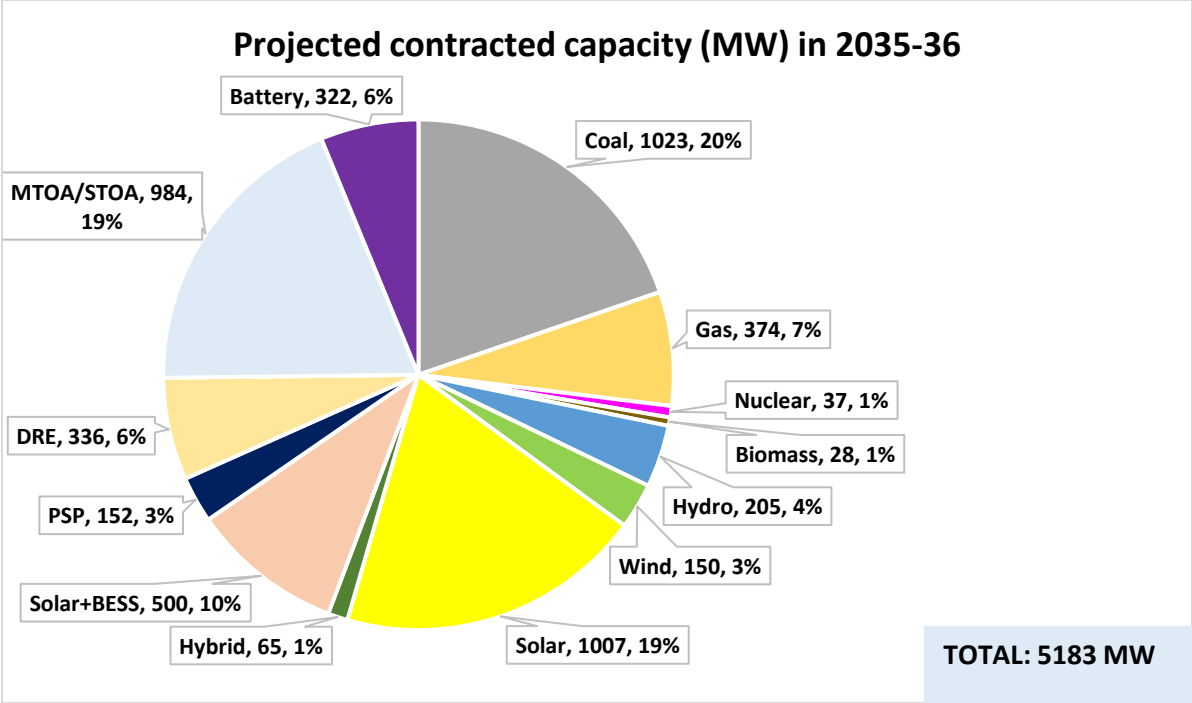


Figure 10 Contracted Capacity Mix in 2035-36

The share of non-fossil fuel-based capacity is projected to increase to around 45% by 2035-36 from 32% in 2024-25. Further, the share of non-fossil fuel-based generation will be around 57% in the year 2035-36. The projected gross generation mix for the utility is shown in Figure 12.

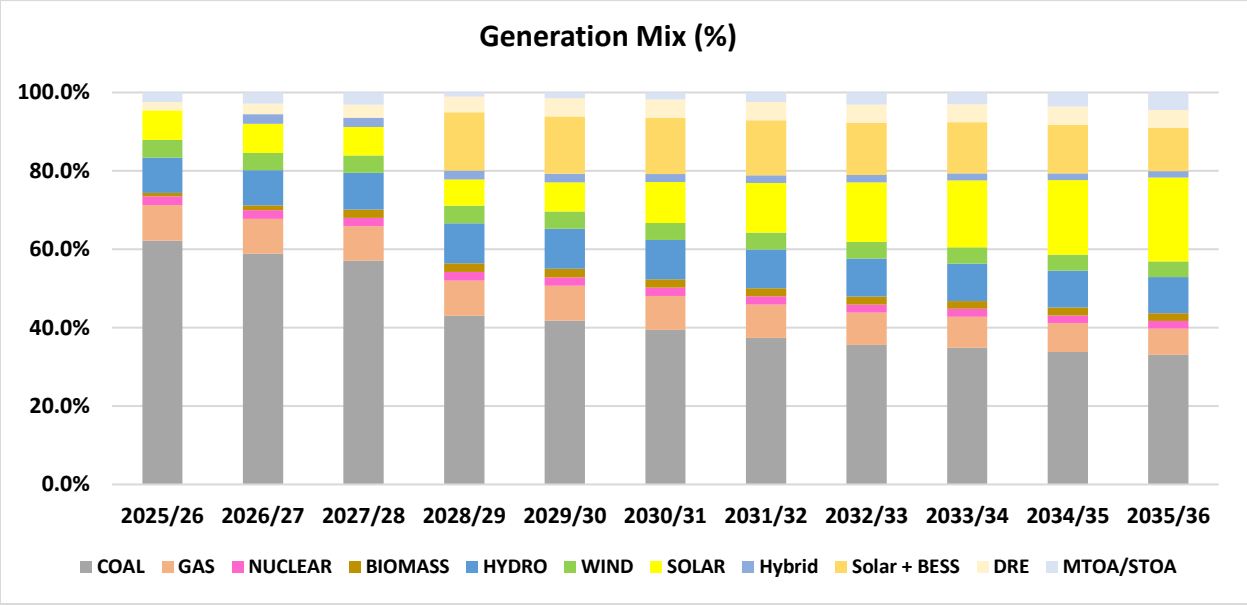


Figure 11 Year-wise projected gross generation mix (in %)

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

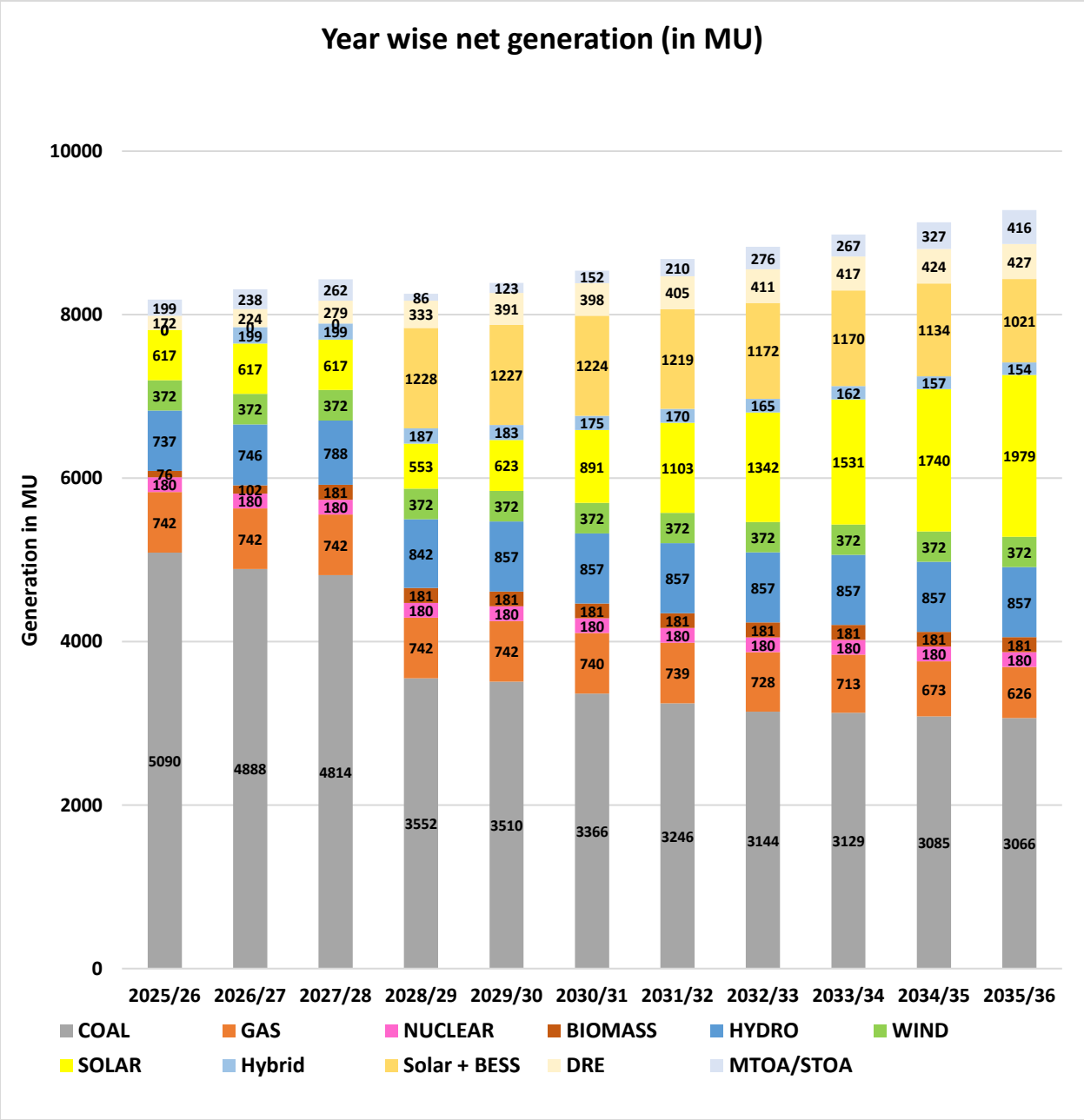


Figure 12 Year-wise projected gross generation (in GWh)

7.3 Day-wise Surplus Capacity (in MW)

The pattern of surplus capacities has been observed as given in Figure 15. 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. BYPL 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 minimum surplus of around 250 MW to 650 MW during September to April in 2028-29, which can be shared with other states/Discoms.

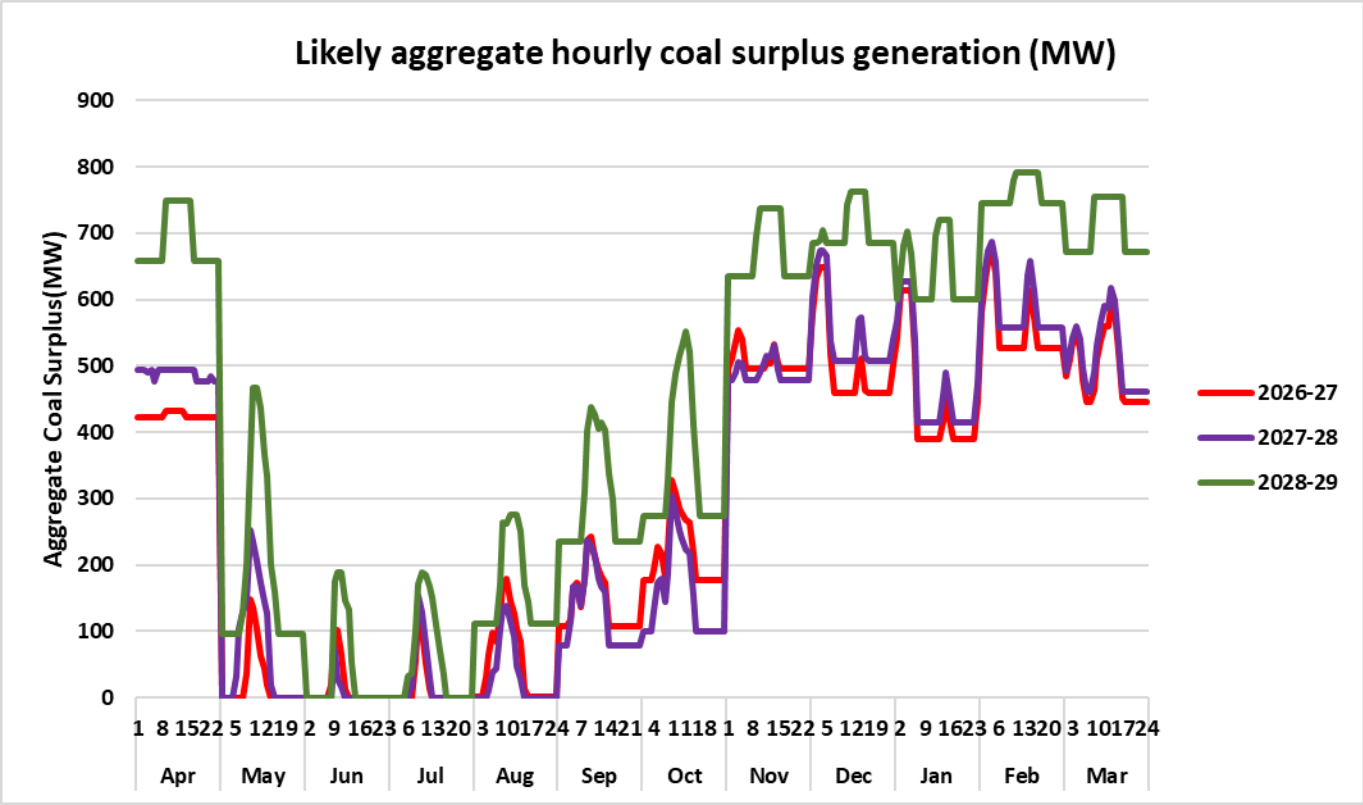


Figure 13 Surplus Coal Capacity Year-wise (MW)

8.0 Conclusions

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

1. 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 day 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 MTOA/STOA as currently practiced for managing the seasonal variation in demand is one of the effective ways for ensuring resource adequacy in such periods.
2. The study has considered electrical energy requirement projections and peak electricity demand projections as prepared by BYPL which envisages that the annual electrical energy requirement of the utility is likely to grow at a CAGR of 1.5% while the peak electricity demand for the utility is likely to grow at a CAGR of 4.1% for the period of 2025-26 to 2035-36.
3. BYPL is likely to witness energy deficit ranging from 144 MUs to 887 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 arrangement etc.
4. BYPL is likely to have unserved electrical energy in coming years and needs to contract additional renewable capacities including Solar and Standalone Energy Storage for meeting electrical energy requirements other than the planned capacities. In addition to this, the utility will likely require MTOA/ STOA arrangement ranging from around 500 MW to 1000 MW in different years as outlined in the report. The STOA/MTOA requirement can be fulfilled through power procurement from market or bilateral/banking agreements. The electrical energy requirement to be met from STOA/MTOA (short term/medium term/market-based contracts) ranges from 1% to 5% of the total electrical energy requirement, indicating short term arrangement required to meet the peak electricity demand.
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 current capacity mix of the utility has 68% of contracted capacity from fossil fuel sources (Coal + Gas). The share of fossil fuel-based capacity is likely to reduce to 37% in 2035-36. In 2035-36, the RE based contract capacity (that includes hydro, solar, wind, biomass and Solar of Solar + BESS) are likely to constitute around 61% of the total contract capacity.

7. The Planning Reserve Margin (PRM) for BYPL has been assessed as 8% during solar hours and 6% during non-solar hours. Further, the study indicates year-wise short-term/medium-term/bilateral requirements to meet the demand optimally.
8. It is likely that BYPL may have surplus capacity available during the months from September to April which can be shared with other utilities/states through banking/bilateral arrangements, including Pushp portal.
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 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	BYPL share (in MW)
1.	RAPP 7 & 8	Nuclear	2025-26	23.2
2.	Parbati-II	Hydro		9
3.	Delhi MSW Solutions Limited	Biomass	2026-27	3.94
4.	Rangit-IV	Hydro		2
5.	Hybrid Tranche	Hybrid		65
6.	Tehri PSP	PSP		152
7.	Delhi MSW Solutions Limited	Biomass	2027-28	12.06
8.	Kiru	Hydro		7.41
9.	Pakal Dul	Hydro		4.15
10.	Kwar	Hydro	2028-29	7
11.	Teesta VI	Hydro		6
12.	Solar + BESS	Solar + BESS		500 MW + 250 MW/ 1000 MWh
13.	Ratle	Hydro	2029-30	4

Assumption for Resource Adequacy Studies

1. Electrical energy requirement & peak electricity demand requirement: As per projections of BYPL.
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
44-46 %	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. (%)	Min. online time (hr)	Min. offline time (hr)
		At max loading	At min loading			
Coal	Existing/ Planned	2300 to 2879	2438 to 3052	7.0	6	4
	Candidate (SC & USC)	2060 to 2125	2183 to 2253	6.5	6	4
Gas	Existing	2000 to 2900	2260 to 3277	2.5	4	3
Nuclear	Existing/ Planned	2777	2777	10	6	4
	Candidate	2777	2777	10	-	-
Biomass	Existing/ Planned	4200	4450	8	6	4
	Candidate	4200	4450	8	6	4

Technology	Type	Heat Rate (MCal/MWh)		Aux. Consum. (%)	Min. online time (hr)	Min. offline time (hr)
		At max loading	At min loading			
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)	O&M Fixed Cost (in ₹/MW)	Construction Time (in years)	Amortization /Life time (in years)
Coal	11.5 Cr	19.54 Lakh	4	25
Solar	5 Cr	1 % of Capex	0.5	25
Battery Energy Storage (4-Hour)	8.22 Cr to 4.72 Cr	1 % of Capex	0.5	14

BSES letter to CEA dated 7th October 2024

BSES Rajdhani Power Limited
BSES Bhawan, Nehru Place,
New Delhi - 110 019, India.
CIN : U40109DL2001PLC111527
GST : 07AAGCS3187H2Z3
Tel. : +91 11 4920 9999
Fax : +91 11 4920 7888
www.bsesdelhi.com

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