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Report on Resource Adequacy Plan (Generation) for Bihar (2025-26 to 2035-36) (Version 2.0)

November, 2025

Government of India
Ministry of Power
Central Electricity Authority

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Disclaimer

This Resource Adequacy Study for the state of Bihar has been conducted based on data and inputs provided by the Bihar State Power Holding Company Limited (BSPHCL). The findings, analysis and conclusions presented in this report are contingent upon the accuracy, completeness and timeliness of the information furnished by the State. 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 the state of Bihar 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 the State.

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, 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 prepare a Resource Adequacy Plan (RAP) with a 10-year planning horizon, LT-DRAP to meet its own peak electricity demand and electrical energy requirement. This plan shall be vetted/validated by 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 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 energy consumption must be met from renewable energy sources.

To support the state in fulfilling this requirement, CEA, initially carried a Resource Adequacy (RA) study with a planning horizon up to FY 2033-34, based on the data provided by BSPHCL and in compliance with the RPO trajectory specified in the Ministry of Power's Office Memorandum 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 State and planning assumptions. The RPO requirement for the state has also been assessed in accordance with the recent gazette notified trajectory.

The electrical energy requirement and peak electricity demand for Bihar, as furnished by BSPHCL, are projected to increase with a CAGR of 5.10% and 5.55% respectively from 2025-26 to 2035-36. However, as per mid-term review of 20th EPS projections, the electricity energy requirement and peak electricity demand for Bihar is projected to increase with a CAGR of 5.40% and 4.38% respectively from 2025-26 to 2035-36. The study has been done considering the demand projections furnished by BSPHCL, as these projections are on the higher side as compared to the mid-term review projections. For satisfying resource adequacy i.e., meeting the electricity demand reliably and at affordable cost, the state needs to methodically plan its capacity expansion either by investing in new generation or by procuring power. In view of the reduction in cost of solar panels and newer technology options like battery energy storage systems, planning for long term optimal generation capacity mix gains tremendous importance so as the future generation capacity mix is cost effective as well as environment friendly.

The study for Bihar, based on existing contracted capacity and planned capacity additions, indicates that the available capacity may be insufficient to meet the projected future demand. In particular, the total unserved energy in the year 2035-36 is estimated to be approximately 1653 MU, accounting for around 1.9% of the projected annual energy demand for that year.

To find out the least cost option for generation capacity expansion for the period 2025-26 to 2035-36, generation expansion study has been carried out with an 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, RE generation 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 plan of Bihar along with RPO constraints for Solar, Wind and DRE technologies. The Renewable capacities have been assessed in view of adherence to RPO 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 shall be able to meet anticipated demand reliably at every instance. Based on the study, the likely total projected contracted capacity for the year 2035-36 is around 35,861 MW which consists of 12,622 MW from coal; 72 MW from biomass; 1,693 MW from hydro; 13,025 MW from solar; 5,281 MW from wind; 3,168 MW from Distributed Renewable Energy (DRE) source. In addition to the above, 5,290 MW from Storage (BESS or PSP) is projected to be required by 2035-36. 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 the existing/planned capacity to meet their RPO targets.

To support the state in fulfilling the Resource Adequacy Guidelines and complying with the Renewable Purchase Obligation (RPO) notification, CEA has carried out the RA study for the state of Bihar based on inputs furnished by Bihar. 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 outage of thermal capacities. The study also assesses the Planning Reserve Margin (PRM) required by the state 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 state up to FY 2033-34, based on data furnished by BSPHCL and in accordance with the RPO trajectory specified in the Ministry of Power's Office Memorandum 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 2022-23 was considered as the base year, and the study covered the period from 2024-25 to 2033-34. The fuel-wise contracted capacity of Bihar as on 31st March, 2023, is given in Fig. 1.

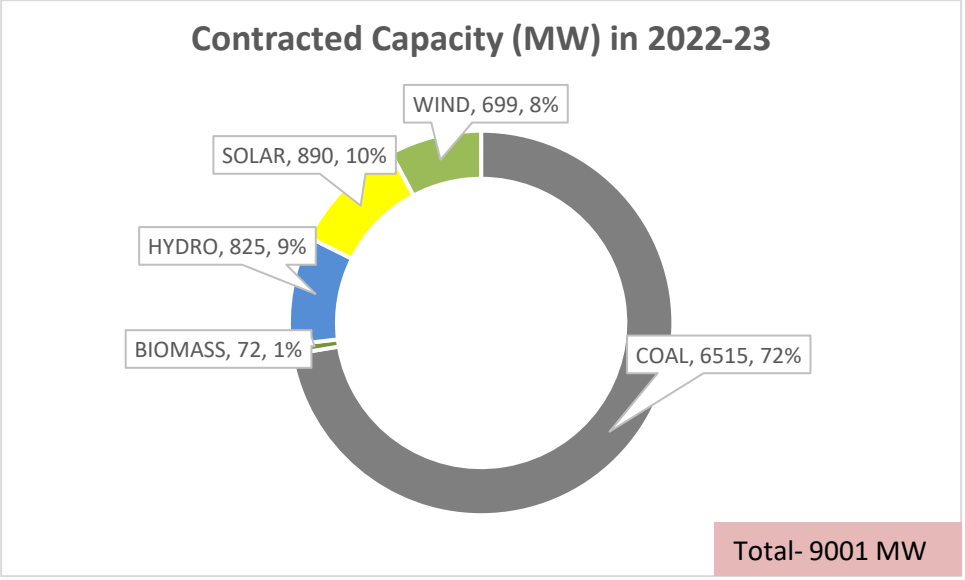


Figure 1: Fuel-wise Contracted Capacity (in MW) as on 31st March, 2023

2. The peak electricity demand and electrical energy projections that has been considered in the study is given in Table 1.

Table 1: Peak electricity demand & electrical energy projections as per 20th EPS Report

	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34
Electrical Energy Projections (MU)	49438	53920	58256	62871	67715	73241	78155	82876	87882	93190
Year on Year Growth		9.07%	8.04%	7.92%	7.70%	8.16%	6.71%	6.04%	6.04%	6.04%
Peak Electricity Demand Projections (MW)	8908	9743	10553	11416	12326	13360	14276	15159	16099	17097
Year on Year Growth		9.37%	8.31%	8.18%	7.97%	8.39%	6.86%	6.19%	6.20%	6.20%

3. 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 given in Table 2.

Table 2: Source-wise projected capacities

YEAR	COAL	BIOMASS	HYDRO	WIND	SOLAR	Storage(PSP/BESS)	DRE	SToA/ MToA*
2024-25	8227	72	925	699	2360	70	605	1917
2025-26	8608	72	925	1399	4522	115	923	2209
2026-27	8608	72	1325	2099	5343	529	1283	2163
2027-28	8608	72	1325	2799	6044	1137	1692	2220
2028-29	8758	72	1325	3499	6872	1937	2153	2022
2029-30	8759	72	1325	4199	7690	2737	2687	1900
2030-31	9046	72	1325	4899	8637	3537	3186	1800
2031-32	9619	72	1325	5599	9324	4337	3717	1700
2032-33	9619	72	1825	6299	9324	4834	4299	1600
2033-34	9758	72	1825	6999	9623	5634	4939	1500

*****_The SToA/MToA value represents the peak power requirement in MW and it was recommended that this requirement may be met through power procurement from the market or through bilateral agreements._

4. The year-wise planned and additional capacity contract addition (in MW) for the above tabulated cumulative capacity is given in Table 3.

Table 3: Year-wise planned and additional capacity contract addition

	Coal		Hydro	Wind	Solar	
Year	Planned Contracts	Additional Requirement	Planned Contracts	Additional Requirement	Planned Contracts	Additional Requirement
2024-25	1712	0	100	0	1481	0
2025-26	381	0	0	700	151	2000
2026-27	0	0	400	700	0	820
2027-28	0	0	0	700	0	701
2028-29	150	0	0	700	0	828
2029-30	0	0	0	700	0	818
2030-31	0	287	0	700	0	947
2031-32	0	572	0	700	0	687
2032-33	0	0	500	700	0	0
2033-34	0	139	0	700	0	298

	Distributed RE	Storage (PSP/BESS)		STOA /MTOA*	Total	
Year	Additional Requirement	Planned Contracts	Additional Contract	Additional Contract	Planned Contracts	Additional Contract
2024-25	605	70	0	1917	3363	2522
2025-26	318	45	0	2209	577	5227
2026-27	360	0	414	2163	400	4457
2027-28	409	0	608	2220	0	4638
2028-29	461	0	800	2022	150	4811
2029-30	534	0	800	1900	0	4752
2030-31	499	0	800	1800	0	5033
2031-32	531	0	800	1700	0	4990
2032-33	582	0	496	1600	500	3378
2033-34	640	0	800	1500	0	4077

**Requirement is for a particular year*

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

3.1 Present Power Scenario in Bihar

The power supply position for Bihar from 2020-21 to 2024-25 is given in Table 4:

Table 4: Power Supply Position of Bihar

Power Supply Position						
Year	**Energy required (MU)**	**Energy supplied (MU)**	**Gap (MU)**	**Peak Demand (MW)**	**Peak Met (MW)**	**Demand not met (MW)**
2020-21	34171	34018	153	5995	5938	57
2021-22	36216	35761	455	7154	6490	664
2022-23	39545	38762	783	7852	6631	1221
2023-24	41514	40918	596	8049	7420	629
2024-25	44393	44217	176	8078	7852	226

The data in Table 4 indicates that over the past five years, Bihar's energy demand and peak electricity demand have increased at a Compound Annual Growth Rate (CAGR) of 6.76% and 7.74%, respectively.

As per the data provided by BSPHCL, as of March 2025, the total contracted capacity of Bihar is 11,236 MW. Out of the total contracted capacity (CC), the share of non-fossil fuel-based CC is 33 %.

The fuel-wise contracted capacity as on 31st March, 2025 is given in Table 5 and Fig. 2.

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

Source	Contracted Capacity (MW)	Percentage
Coal	7510	67%
Biomass	72	1%
Hydro	1034	9%
Wind	699	6%
Solar	1920	17%
Total	**11236**	**100.0%**

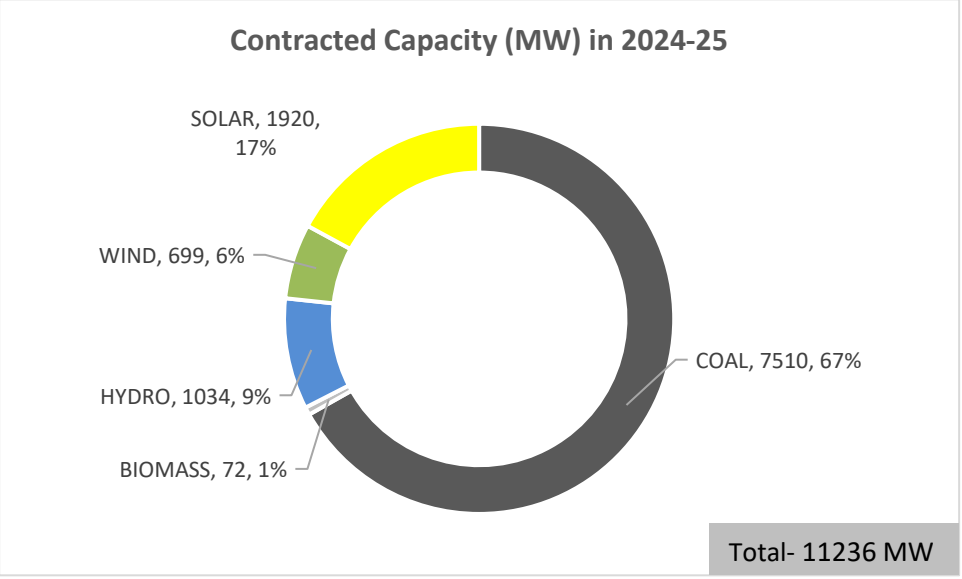


Figure 2: Fuel-wise Contracted Capacity (in MW) as on 31st March, 2025

3.2 Demand Analysis of the FY 2024-25

Hourly demand pattern of 2024-25 was analyzed and it was observed that the peak demand season for State of Bihar is typically during the months from April to September. Bihar witness peak electricity demand during non-solar hours.

The month-wise average hourly demand observed for the year 2024-25 is shown in Fig. 3.

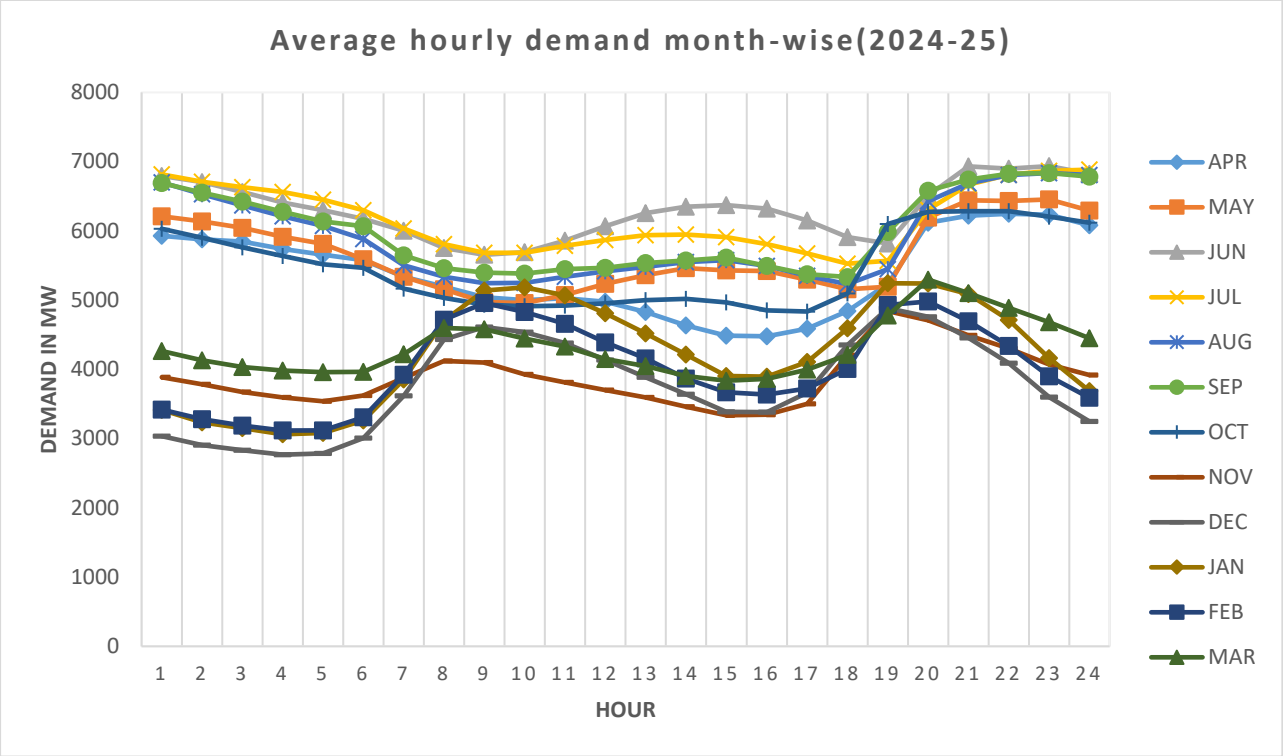


Figure 3: Average Hourly Demand Variation (Month-wise) for 2024-25

From the hourly demand data of 2024-25 the daily peak during solar hours (07:00 to 18:00 hrs) and non-solar hours are plotted in Fig. 4.

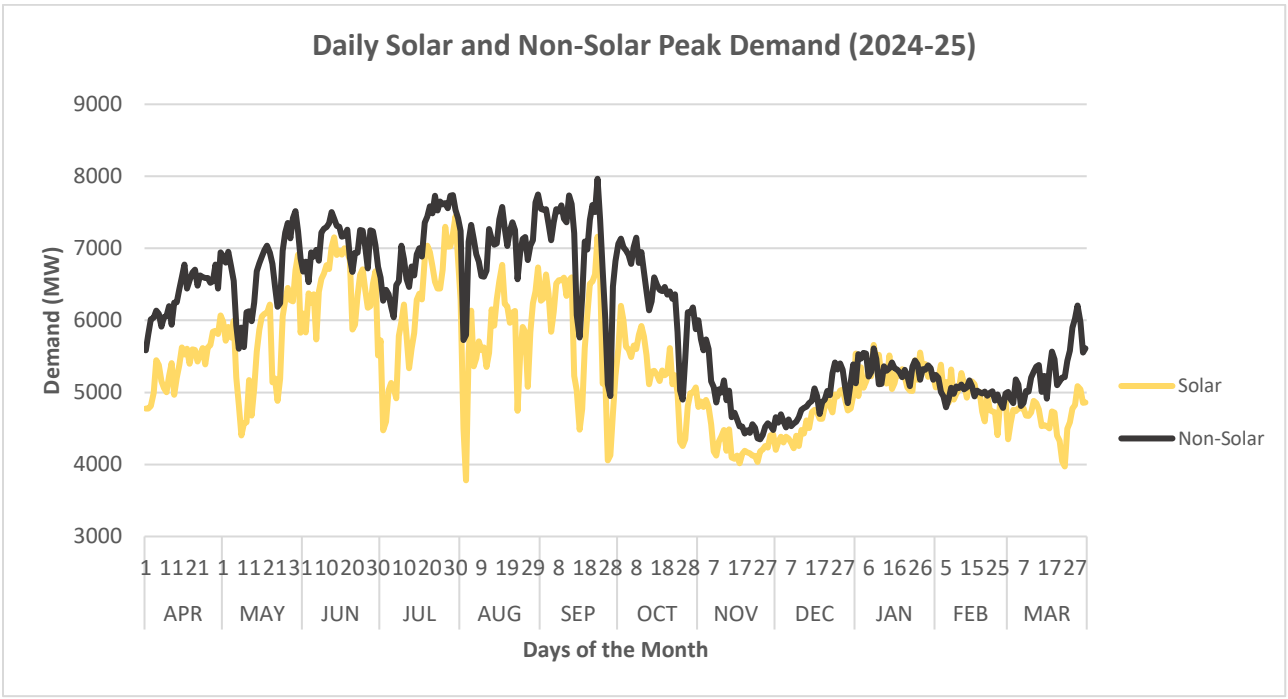


Figure 4: Solar and non-solar peak in MW for the year 2024-25

The hourly demand pattern of 2024-25 was analysed for finding out the number of occurrences of the peak and near peak 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. Frequency Distribution of hourly demand profile for 2024-25 is shown in Fig. 5.

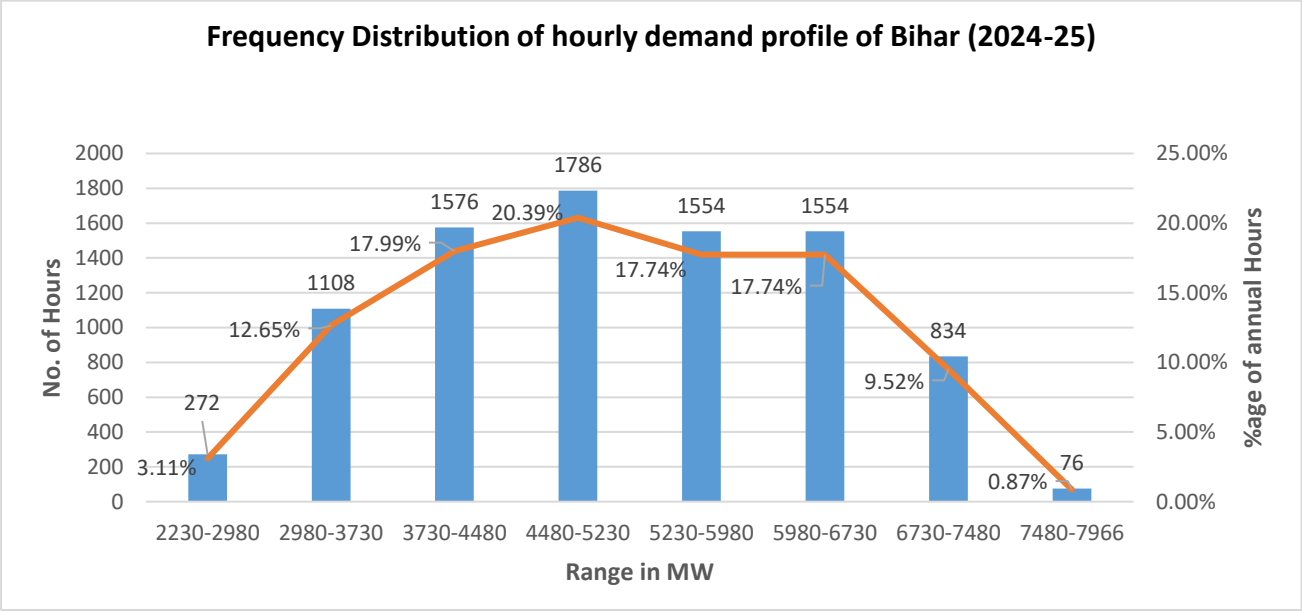


Figure 5: Frequency Distribution of Hourly Demand Profile of 2024-25

4.0 Principles of Generation Planning

The objective of Generation Planning process is to obtain an optimal generation capacity mix in the least cost manner to meet the electricity demand at every instance of time while ensuring the most efficient use of resources.

The major aspects considered in the planning process are:

i) To Supply 24x7 reliable power to the consumers
ii) To achieve objectives of all policies of the Government of India such as RPO trajectory, RE capacity addition plan 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 have been 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 supply and demand, 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 Fig. 6.

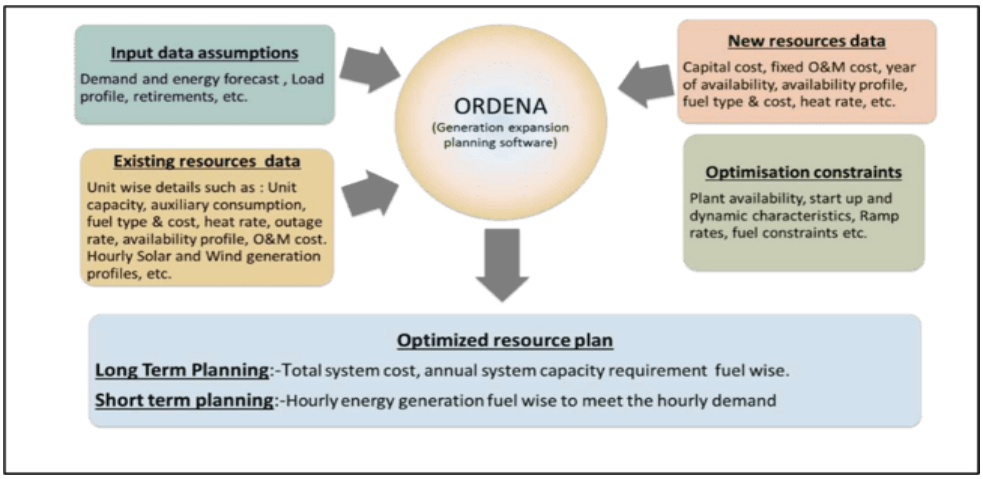


Figure 6: Schematic Diagram

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 total system 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 no. of random samples of these variables is 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 margins need 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 generally expressed as a certain percent of the projected peak electricity demand.

5.1 Demand variation

The variation in demand pattern for last two years viz. 2023-24 and 2024-25 (considering 2023-24 as the base year) has been analyzed. The demand pattern variation across 2023-24 and 2024-25 is shown in Fig. 7.

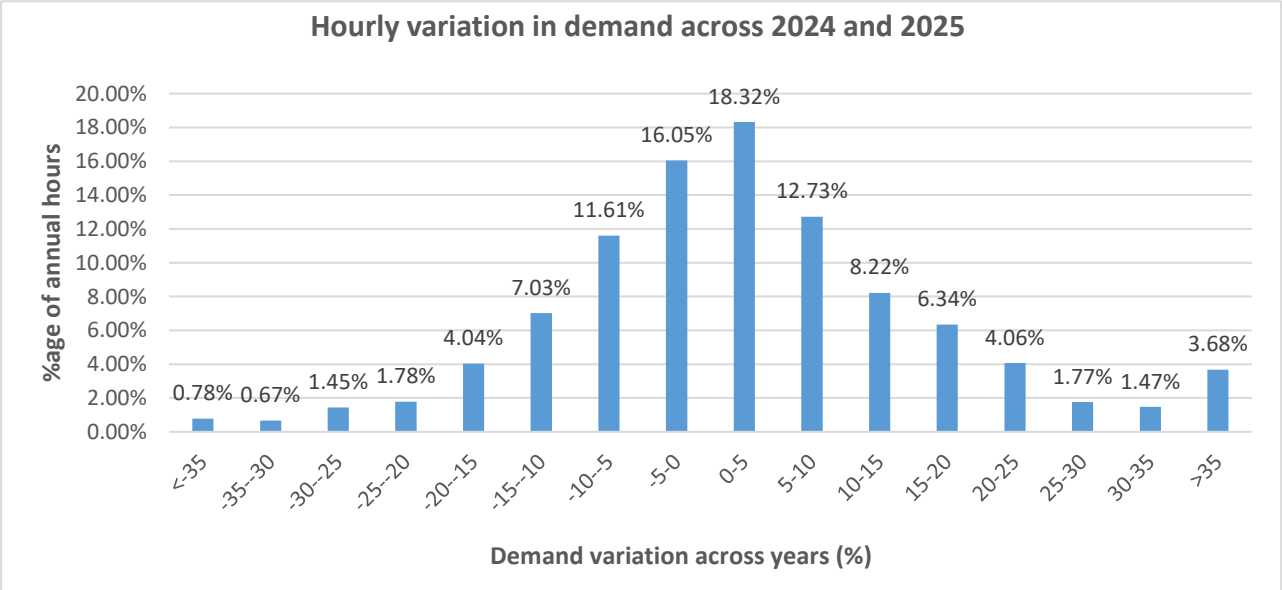


Figure 7: Hourly Variation in electricity demand across years

It can be observed that the hourly demand typically varies within ±10% for ~58% of instances. This variation is primarily due to temperature, weather parameter or any random outages of transmission line and generating units etc. This variation has been captured in the reliability study by incorporating a variation of ±10% in the projected hourly demand for the future years 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 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-based generation has been varied by ± 10% and ± 50% respectively to incorporate the variation in these generation sources and plan for requisite measures to mitigate such behavior.

5.3 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 have been carried out to ascertain robustness of the system.

6.0 Inputs/Assumptions for the Study

i) The peak electricity demand and electrical energy requirement of Bihar as per BSPHCL and mid-term review of 20th EPS Report is given in Table 6.

Table 6: Electricity demand projection

Year	Projections by BSPHCL, Bihar				Projections as per Mid-term review of 20th EPS			
	Peak Electricity Demand		Electrical Energy Requirement		Peak Electricity Demand		Electrical Energy Requirement	
	Projections (in MW)	Y-o-Y Growth	Projections (in MU)	Y-o-Y Growth	Projections (in MW)	Y-o-Y Growth	Projections (in MU)	Y-o-Y Growth
2025-26	8878		52518		9348		48051	
2026-27	9602	8.16%	56181	6.97%	10016	7.15%	51479	7.13%
2027-28	10366	7.96%	60030	6.85%	10569	5.52%	55014	6.87%
2028-29	11002	6.14%	63218	5.31%	11125	5.26%	58638	6.59%
2029-30	11615	5.57%	66383	5.01%	11658	4.79%	62215	6.10%
2030-31	12159	4.68%	69214	4.26%	12129	4.04%	65523	5.32%
2031-32	12643	3.98%	71966	3.98%	12554	3.51%	68646	4.77%
2032-33	13165	4.13%	74629	3.70%	13017	3.69%	72031	4.93%
2033-34	13810	4.90%	78517	5.21%	13454	3.35%	75331	4.58%

2034-35	14458	4.69%	82461	5.02%	13860	3.02%	78519	4.23%
2035-36	15233	5.36%	86337	4.70%	14354	3.56%	81318	3.56%

Projections as per BSPHCL has been considered in the study.

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, wind and hydro generation profiles and CUFs have been referred from National Electricity Plan 2023 (Vol I Generation).

iv) The capital cost of candidate plants for coal, solar, and battery/PSP technologies is detailed in the Annexure and are in alignment with current market trends and recent price discovery.

v) The planned capacity has been considered based on the tie-up information as furnished by Bihar. The same is summarised in Table 7 and details are furnished in Annexure.

Table 7: Source-wise planned capacity addition

Fig.in MW

FY	HYDRO (Conventional/Small)	Thermal	Solar	DRE	Wind	PSP	Battery (MW/MWh)
2025-26	217	1122	337	-	-	70	45.4/181.6
2026-27	140	-	716	255.47	-		50.5/202
2027-28	32	-	-	-	582		125/500
2028-29	46	150	-	-	-		-
2029-30	-	800	-	-	-		-
2030-31	-	1600	-	-	-		-
2031-32	224	1440	-				
Total	**659**	**5112**	**1053**	**255.47**	**582**	**70**	**221/884**

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 as given in Table 8.

Table 8: Renewable Purchase Obligation (RPO) trajectory (%)

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. Further, the DRE percentage has been assumed to be 4.5 % beyond 2029-30. Hence, the suggested trajectory of Renewable Purchase Requirement up to FY 2035-36 is given in Table 9.

Table 9: Renewable Purchase Obligation (RPO) trajectory (in %) considered for the study

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	1.50	29.91
2.	2025-26	1.45	1.22	28.24	2.10	33.01
3.	2026-27	1.97	1.34	29.94	2.70	35.95
4.	2027-28	2.45	1.42	31.64	3.30	38.81
5.	2028-29	2.95	1.42	33.10	3.90	41.36
6.	2029-30	3.48	1.33	34.02	4.50	43.33
7.	2030-31	41.00			4.50	45.50
8.	2031-32	42.50			4.50	47.00
9.	2032-33	43.80			4.50	48.30
10.	2033-34	45.00			4.50	49.50
11.	2034-35	46.50			4.50	51.00
12.	2035-36	47.50			4.50	52.00

Based on the trajectory specified, RPO quantum in million units (MUs) from hydro, wind, other (Solar, biomass etc.) and distributed renewable energy (DRE) is calculated and given in Table 10.

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)	(2)	(3)	(4)	(5)	(6)	(7)
1.	**2025-26**	761.5	640.7	15382.5	1102.9	17336.2
2.	**2026-27**	1106.8	752.8	17579.0	1516.9	20197.1
3.	**2027-28**	1470.7	852.4	19984.0	1981.0	23297.6
4.	**2028-29**	1864.9	897.7	22157.9	2465.5	26147.0
5.	**2029-30**	2310.1	882.9	24077.1	2987.2	28763.8
6.	**2030-31**	29935.1			3114.6	31492.4
7.	**2031-32**	32204.8			3238.5	33824.0
8.	**2032-33**	34366.7			3358.3	36045.8
9.	**2033-34**	37099.3			3533.3	38865.9
10.	**2034-35**	40199.7			3710.7	42055.1
11.	**2035-36**	41010.1			3885.2	44895.2

As indicated in Table 11, the state with its existing and envisaged future capacity additions will not be able to meet its RPO requirements from the year 2025-26 onwards.

Table 11: Renewable Energy Deficit/Surplus

FY	RE Generation required to meet RPO		RE Generation available/met (From existing/ planned contracts)		RPO Surplus (+)/ Deficit (-)
	(MU)	(%)	(MU)	(%)	(%)
2025-26	17336.2	33.01	9304	17.7	-15.3
2026-27	20197.1	35.95	11598	20.6	-15.4
2027-28	23297.6	38.81	12957	21.6	-17.2
2028-29	26147.0	41.36	13134	20.8	-20.6
2029-30	28763.8	43.33	13133	19.8	-23.5
2030-31	31492.4	45.5	13101	18.9	-26.6
2031-32	33824.0	47.0	13806	19.2	-27.8
2032-33	36045.8	48.3	13810	18.5	-29.8
2033-34	38865.9	49.5	13805	17.6	-31.9
2034-35	42055.1	51.0	13826	16.8	-34.2
2035-36	44895.2	52.0	13854	16.0	-36.0

7.0 Outcome of the model

7.1 Unserved Energy Projections

Initially, the study has been carried out considering only the existing and planned capacity contracts. The projected total unserved energy (ENS) for the year 2035-36 is about 1653 MUs which is about 2% of the energy demand in 2035-36. The year-wise likely unserved energy with the existing and planned capacities is given in Fig 8.

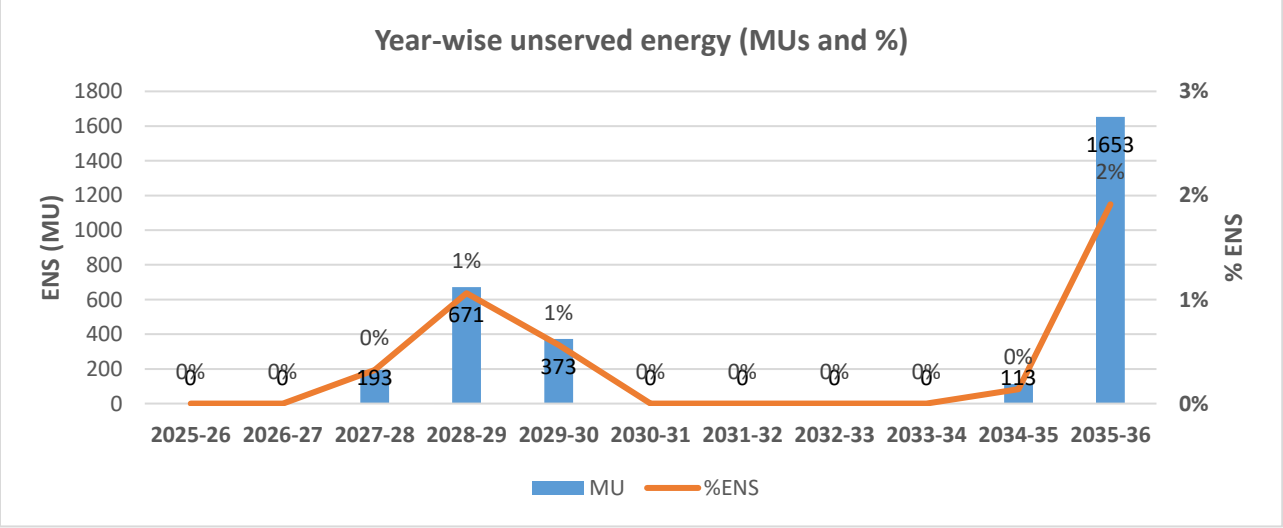


Figure 8: Yearly likely unserved energy (in MU) with the existing and planned capacities

The study has also analyzed the daily and monthly pattern of unserved energy in the year 2035-36, it can be seen that contracted capacity (present and planned) is unable to meet the demand. Details are shown in Fig. 9.

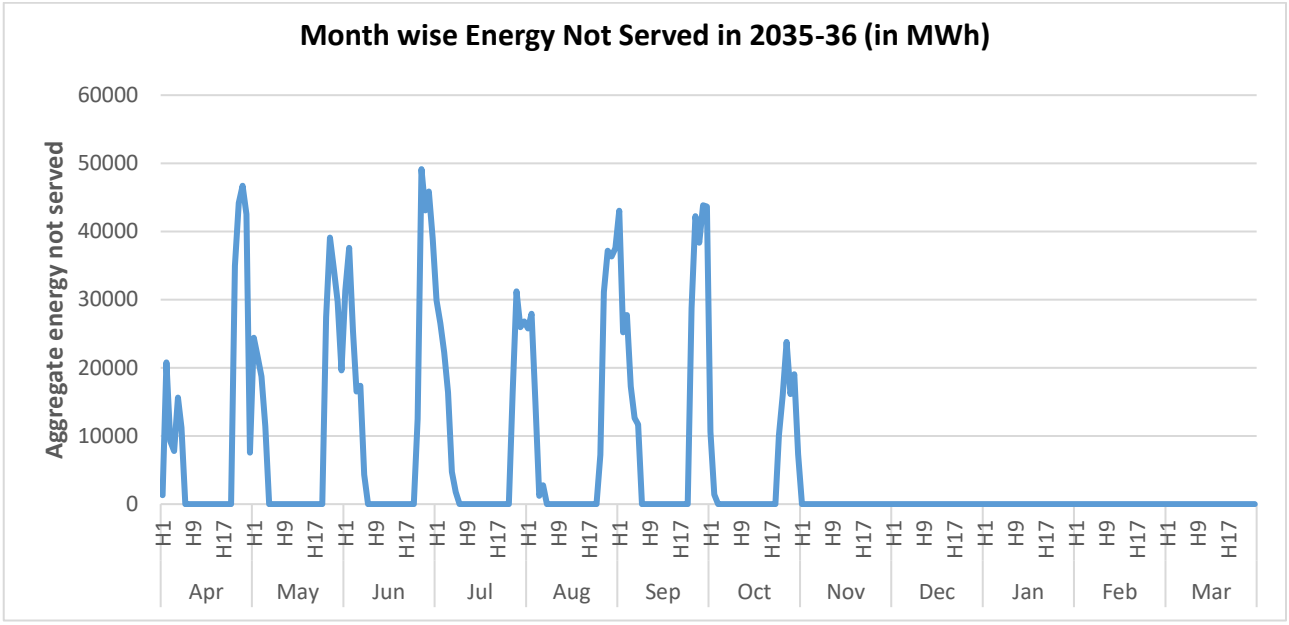


Figure 9: Block-wise Unserved Energy Pattern MWh (2035-36)

From the above figure, it can be seen that unserved energy is high during high demand season viz. April to October and is typically observed during non-solar hours.

7.2 Investment options to meet the unserved energy

To meet this unserved energy, energy investment options (i.e., candidate capacities) have been given to the model to find the least cost optimal capacity mix required to meet the electricity demand while fulfilling the RPO obligations. The capacity projections (existing, planned, to be tied up) for Bihar are given in Table 12.

Table 12: Year-wise contracted capacity projections (in MW)

Year	Coal	Biomass	Hydro	Wind	Solar	Storage (PSP/BESS)	DRE	SToA/MToA
2025-26	8632	72	1251	699	2257	115	0	0
2026-27	8632	72	1391	1349	5473	1365	1237	294
2027-28	8632	72	1423	2581	6004	1490	1615	570
2028-29	8782	72	1469	3231	6499	1551	2010	737
2029-30	9582	72	1469	3881	6870	1714	2436	343
2030-31	11182	72	1469	4531	7513	2049	2540	0
2031-32	12622	72	1693	5181	7517	2049	2641	0
2032-33	12622	72	1693	5281	8480	2632	2738	0
2033-34	12622	72	1693	5281	9733	3639	2881	0
2034-35	12622	72	1693	5281	11194	4770	3026	0
2035-36	12622	72	1693	5281	13025	5290	3168	0

The projected contracted capacity mix, year-wise is given in Figure 10.

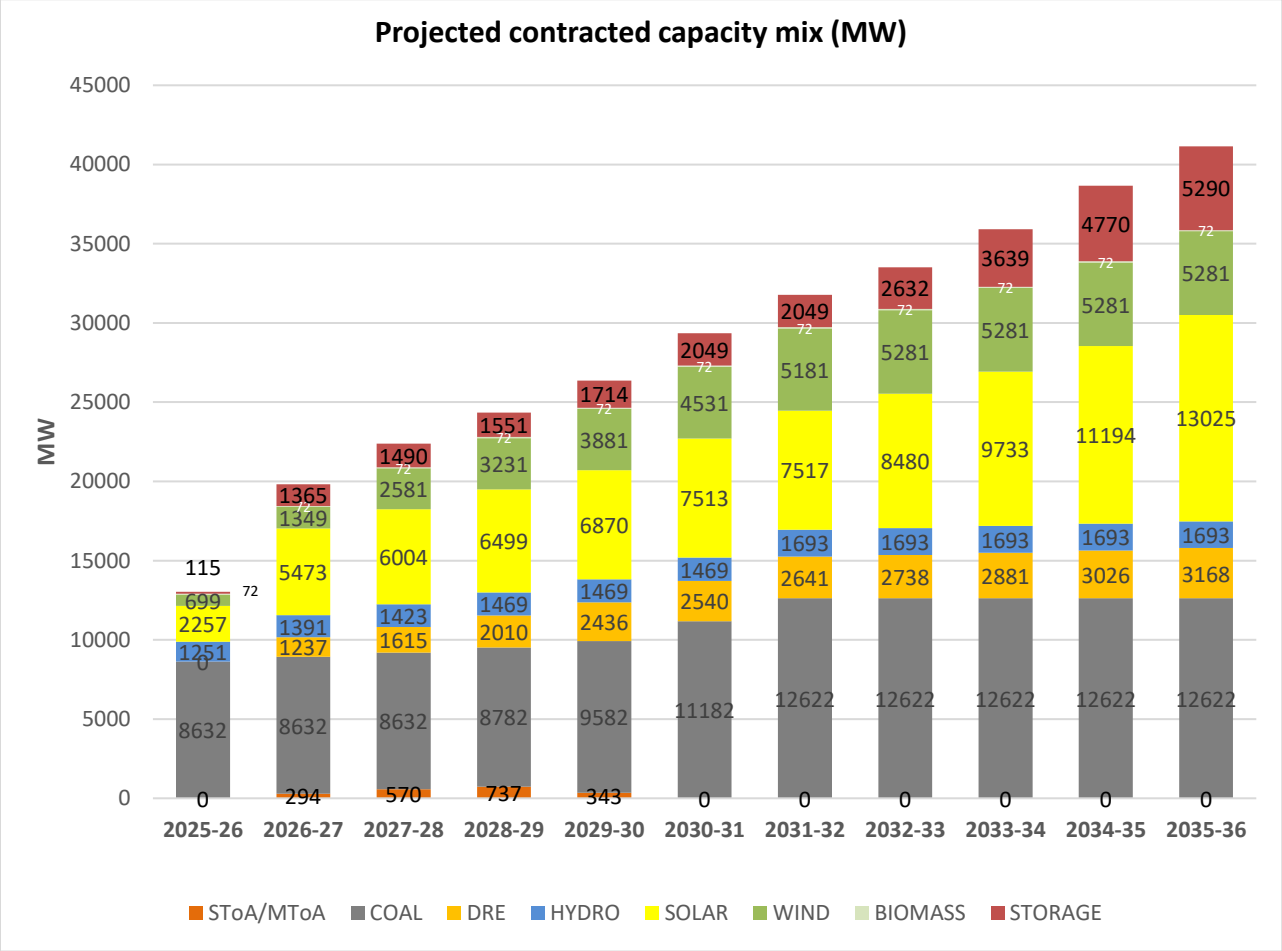


Figure 10: Year-wise Projected Contracted Capacity Mix (MW)

The SToA/MToA requirement can be fulfilled through power procurement from market or bilateral agreements. The SToA/MToA value reflects the peak 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 35,861 MW which consists of 12,622 MW from coal; 72 MW from biomass; 1,693 MW from hydro; 13,025 MW from solar; 5,281 MW from wind; 3,168 MW from Distributed Renewable Energy (DRE) source. In addition to the above, 5,290 MW from Storage (PSP or BESS) is projected to be required by 2035-36. This capacity shall be able to meet the projected demand with prescribed reliability criteria and to comply with the stipulated Renewable Purchase Obligation (RPO) targets. Based on the capacity addition, the planning reserve margin works out to be about 14%. Capacity mix required by 2035-36 is shown in Figure 11.

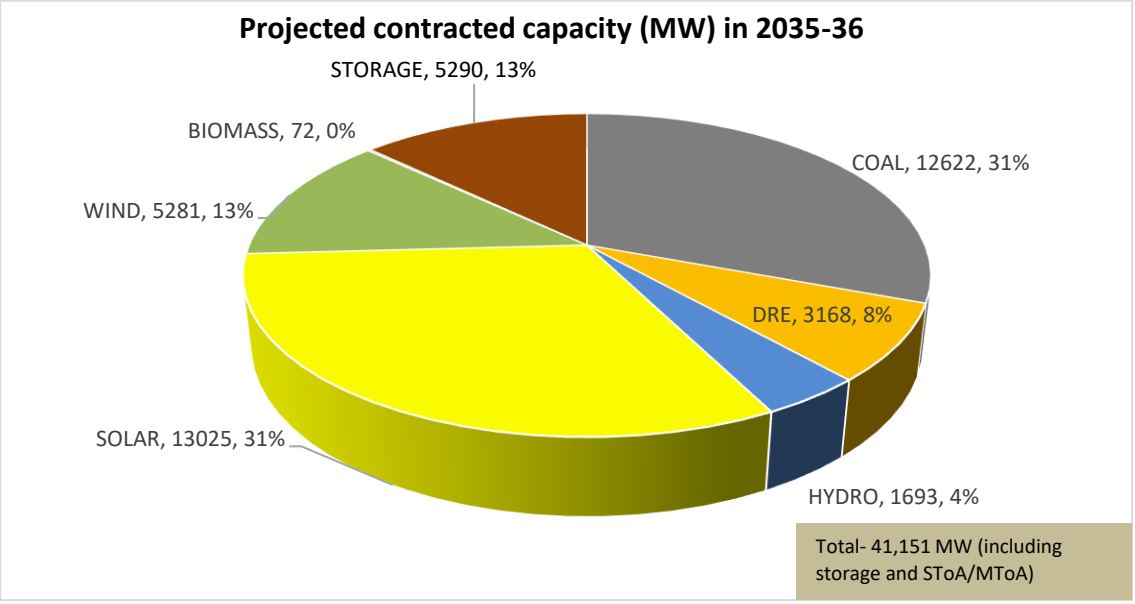


Figure 11: Contracted Capacity Mix in 2035-36

It is important to note that any deviations in the commissioning schedule of the planned capacity could result in a situation where the state 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 meeting the state's power demand reliably.

As per the study, the state likely needs to contract the following capacities (planned and additional) every year till 2035-36 to meet its demand reliably as shown in Table 13.

Table 13: Year-wise Capacity Addition (in MW)

	Coal	**Hydro**	**Wind**		**Solar**	
Year	Planned Contracts	Planned Contracts	Planned Contracts	Additional Requirement	Planned Contracts	Additional Requirement
2025-26	1122	217	0	0	337	0
2026-27	0	140	0	650	716	2500
2027-28	0	32	582	650	0	531
2028-29	150	46	0	650	0	495
2029-30	800	0	0	650	0	371
2030-31	1600	0	0	650	0	643
2031-32	1440	224	0	650	0	4
2032-33	0	0	0	100	0	964
2033-34	0	0	0	0	0	1252
2034-35	0	0	0	0	0	1462
2035-36	0	0	0	0	0	1830
Total	**5112**	**659**	**582**	**4000**	**1053**	**10052**

	Distributed RE#	**Storage (PSP/BESS)**		**TOTAL**		**SToA /MToA***
Year	Additional Requirement	Planned Contracts	Additional Requirement	Planned Contracts	Additional Requirement	Additional Requirement
2025-26	0	115	0	1791	0	0
2026-27	1237	50	1200	906	5587	294
2027-28	378	125	0	739	1559	570
2028-29	395	0	0	196	1540	737
2029-30	425	0	363	800	1809	343
2030-31	104	0	406	1600	1803	0
2031-32	101	0	0	1664	755	0
2032-33	98	0	509	0	1671	0
2033-34	143	0	1126	0	2521	0
2034-35	145	0	1200	0	2807	0
2035-36	142	0	195	0	2167	0
Total	**3168**	**290**	**5000**	**7696**	**22219**	

*Yearly requirement

#inclusive of Planned DRE of 255 MW

The projected gross generation mix for the state is shown in Figure 12 and 13.

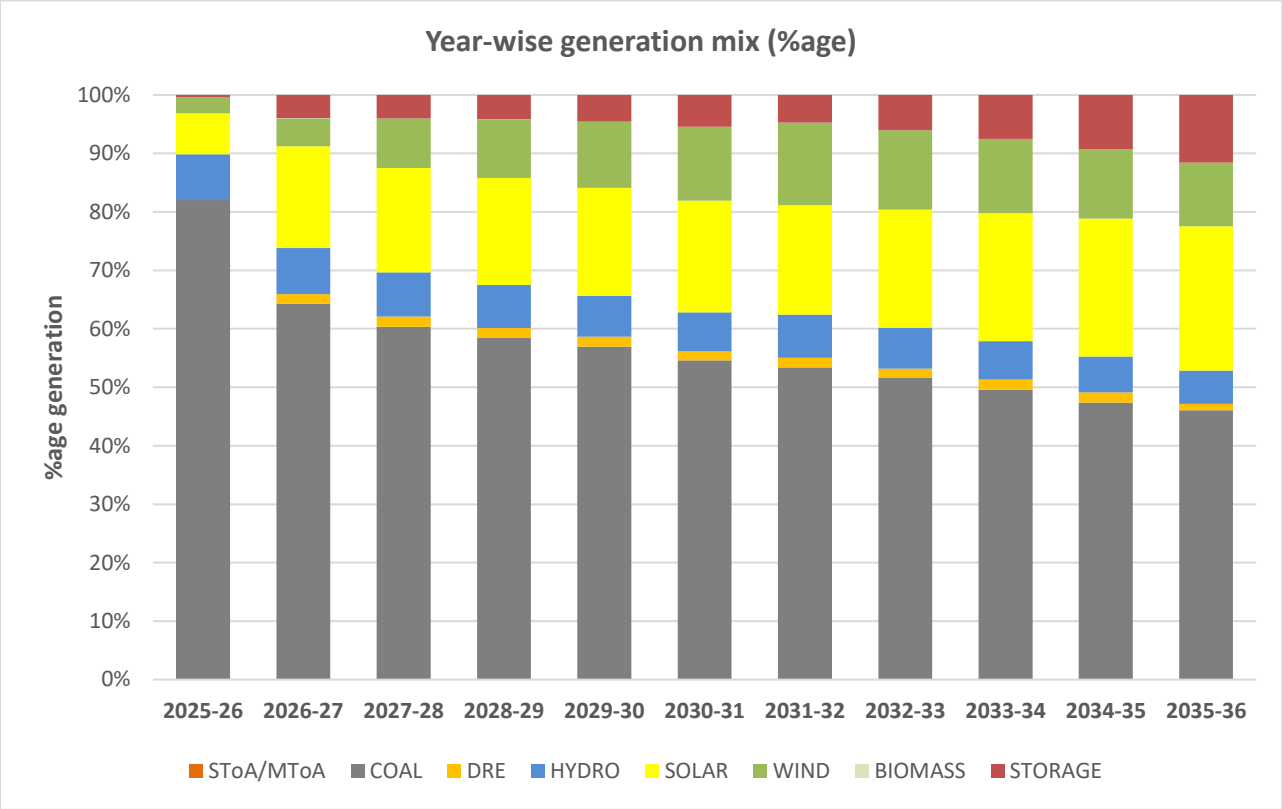
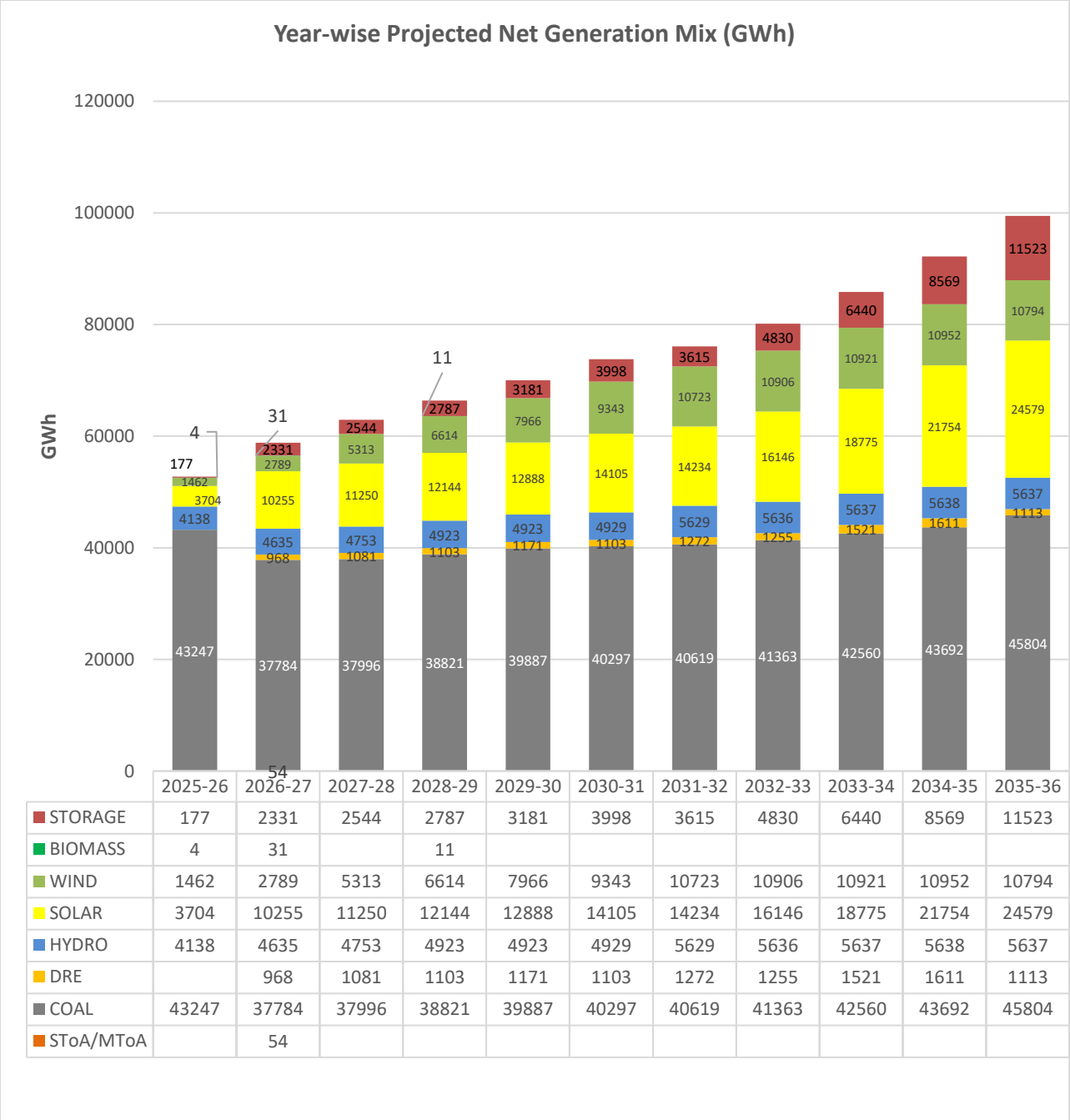


Figure 12: Year-wise projected net generation mix (in %)



	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35	2035-36
STORAGE	177	2331	2544	2787	3181	3998	3615	4830	6440	8569	11523
BIOMASS	4	31		11							
WIND	1462	2789	5313	6614	7966	9343	10723	10906	10921	10952	10794
SOLAR	3704	10255	11250	12144	12888	14105	14234	16146	18775	21754	24579
HYDRO	4138	4635	4753	4923	4923	4929	5629	5636	5637	5638	5637
DRE		968	1081	1103	1171	1103	1272	1255	1521	1611	1113
COAL	43247	37784	37996	38821	39887	40297	40619	41363	42560	43692	45804
SToA/MToA		54									

Figure 13: Year-wise projected net generation (in GWh)

7.3 Surplus Coal Capacity (in MW)

Generally, surplus capacity is available with the state due to variation in electricity demand, RE availability etc. The pattern of surplus capacities has been observed as shown in Figure 14. From the figure below, it is observed that Bihar is expected to have a minimum surplus coal-based capacity

ranging between 400 MW and 2000 MW during the period from May to March. This surplus capacity may be banked or shared with other states whose demand profile complements that of Bihar.

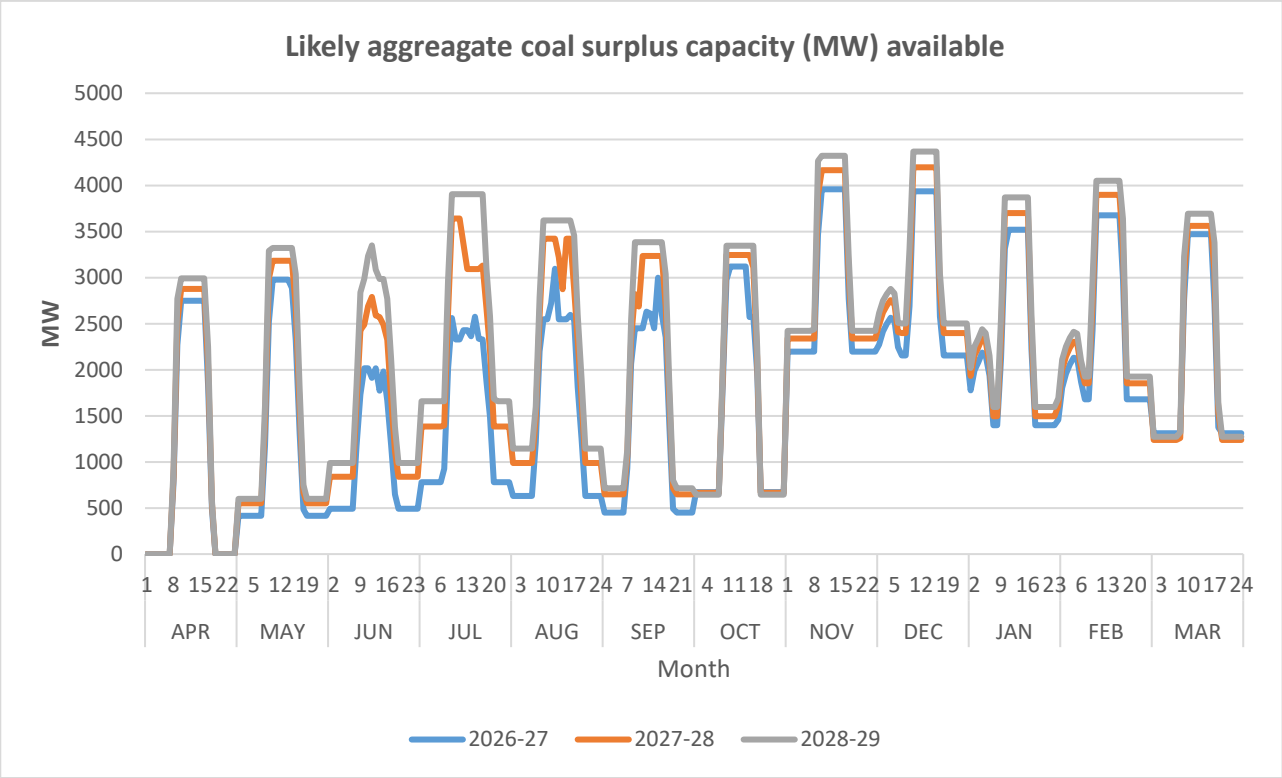


Figure 14: Surplus Coal Capacity Year-wise (MW)

8.0 Conclusions

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

1. The study has been done based on the hourly electricity demand pattern of the year 2024-25. It has been observed that the peak demand season is typically from April to September with peak demand occurring during non-solar hours.
2. The study has considered energy requirement projections as per the projections furnished by BSPHCL (Bihar), which envisages that the annual energy requirement of the state is likely to grow at a CAGR of 5.10% while the peak electricity demand for the state is likely to grow at a CAGR of 5.55% for the period of 2025-26 to 2035-36.
3. Bihar, with its existing and planned capacity addition only, is likely to witness energy deficit ranging from 113 to 1653 MUs in different years from 2027-28 to 2029-30 and in 2035-36.
4. The state is projected to face unserved energy in the coming years and will need to contract additional solar, wind and storage capacities beyond those already planned. In addition to the existing and already planned contracts, the state needs to tie up approximately 10,000 MW of

solar-based capacity, 4000 MW of wind-based capacity and 5000 MW of Storage (PSP or BESS) by 2035–36 (refer Table 13). Additionally, there will be a requirement for Medium-Term Open Access (MToA) and Short-Term Open Access (SToA) ranging from around 294 MW to 737 MW in different years, as detailed in the report. These MToA/SToA needs can be met through power procurement from market or through bilateral agreements. The MToA/SToA values represent peak electricity demand requirements as well as seasonal banking needs, expressed in terms of megawatts (MW). The projected capacity and generation mix outlined in the report meet the state's RPO requirements for the years 2026-27 to 2035-36.

5. As per studies, the state is expected to have a minimum surplus coal-based capacity ranging between 400 MW and 2000 MW during the period from May to March. This surplus capacity may be banked or shared with other states whose demand profile complements that of Bihar.
6. The Planning Reserve Margin (PRM) for Bihar has been assessed at about 14%. Further, the study indicates year-wise short-term/medium-term/bilateral requirements inclusive of the PRM capacity to optimally meet the demand.
7. Timely commissioning of planned capacities is critical for ensuring that the state meets its projected peak electricity demand and electrical energy requirements reliably. Any deviation from the planned schedule may lead to resource shortfalls and could significantly increase the cost of reliably meeting the state’s power demand.

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Annexure

Details of upcoming considered in the study

Sl. No.	Tied capacity name	Type of generation	Expected COD	Bihar's share (in MW)
1.	Buxar Thermal Power Station Unit 1	Thermal	2025-26	561
2.	Buxar Thermal Power Station Unit 2	Thermal	2025-26	561
3.	Darlipalli Stage II	Thermal	2028-29	150
4.	Nabinagar Stage II	Thermal	2031-32	1440
5.	Pirpainti Unit 1	Thermal	2029-30	800
6.	Pirpainti Unit 2 and 3	Thermal	2030-31	1600
7.	Punatsangchhu	Hydro	2025-26	117
8.	Arun-3	Hydro	2026-27	23
9.	Kiru	Hydro	2026-27	19
10.	Teesta VI	Hydro	2027-28	13
11.	Rattle	Hydro	2027-28	26
12.	Heo	Hydro	2028-29	20
13.	Tato-I	Hydro	2028-29	120
14.	Kalai II	Hydro	2031-32	104
15.	Dibang	Hydro	2031-32	117
16.	Wind	Wind	2027-28	582
17.	Solar	Solar	2025-26	337
18.	Solar	Solar	2026-27	716
19.	PM KUSUM Phase I	DRE	2026-27	17
20.	PM KUSUM Phase II	DRE	2026-27	238
21.	Greenko PSP	PSP	2025-26	70
22.	Kajra Phase I BESS	BESS	2025-26	45.4
23.	Kajra Phase II BESS	BESS	2026-27	50.5
24.	Standalone BESS at different GSS	BESS	2027-28	125

Assumption for Resource Adequacy Studies

1. Electricity Demand & peak requirement: As per information furnished by the State.
2. Demand Profile: Based on hourly demand profile of 2024-25.
3. Existing & Planned Capacity: As per the information shared by the state.
4. Cost parameters: based on information in National Electricity Plan.

RE CUF considered

Hydro	Wind	Solar (existing)	Solar (planned)	DRE

38 %	24%	18%	23.5	14%

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. Interstate ATC limit has not been considered in the study.

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 (2-Hour)	5.13 Cr to 3.13 Cr	1 % of Capex	0.5	14
Battery Energy Storage (4-Hour)	8.22 Cr to 4.72 Cr	1 % of Capex	0.5	14
Battery Energy Storage (5-Hour)	9.77Cr to 5.51 Cr	1 % of Capex	0.5	14
Battery Energy Storage (6-Hour)	11.31 Cr to 6.30 Cr	1 % of Capex	0.5	14