सत्यमेव जयते

Report on Resource Adequacy Plan (Generation) for Himachal Pradesh (2025-26 to 2035-36) (Version 3.0)

December, 2025

Government of India
Ministry of Power
Central Electricity Authority

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Disclaimer

This Resource Adequacy Study for the state of Himachal Pradesh has been conducted based on data and inputs provided by the Himachal Pradesh State Electricity Board Ltd. (HPSEBL). 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 Himachal Pradesh in fulfilling this requirement.

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

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 2034-35, based on the data provided by HPSEBL 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 been assessed in accordance with the trajectory specified in the Ministry of Power's Office Memorandum dated 20th October, 2023.

The electrical energy requirement and peak electricity demand for Himachal Pradesh, as furnished by HPSEBL, are projected to increase with a CAGR of 6% and 5% 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 Himachal Pradesh is projected to increase with a CAGR of 4.63% and 3.71% respectively from 2025-26 to 2035-36. The study has been done considering the demand projections as per mid-term review of 20th EPS. 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 Himachal Pradesh carried out based on existing contracted capacity and planned capacity additions (excluding banking/STOA/MTOA arrangements), indicates that the available capacity may be insufficient to meet the projected electricity demand. In particular, the total unserved energy in the year 2035-36 is estimated to be approximately 6443 MU, accounting for around 28% of the projected annual electrical energy requirement 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 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 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 Himachal Pradesh along with RPO targets 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 reliably meet anticipated demand. Based on the study, the likely total projected contracted capacity for the year 2035-36 is around 11,524 MW which consists of 410 MW from coal; 4 MW from biomass; 55 MW from nuclear; 2,247 MW from hydro; 4,067 MW from solar; 900 MW from hybrid; 569 MW from hydro based Distributed Renewable Energy (DRE) source; 383 MW from solar based DRE; 448 MW from small hydro plant (SHP); 1,299 MW from Storage and 1143 MW of MTOA/STOA arrangements. 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 electricity 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 in 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 Himachal Pradesh based on inputs furnished by Himachal Pradesh. 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, variations in 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 2034-35, based on data furnished by HPSEBL.

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 2034-35. The fuel-wise contracted capacity of Himachal Pradesh as on 31st March, 2024, is given in Fig. 1.

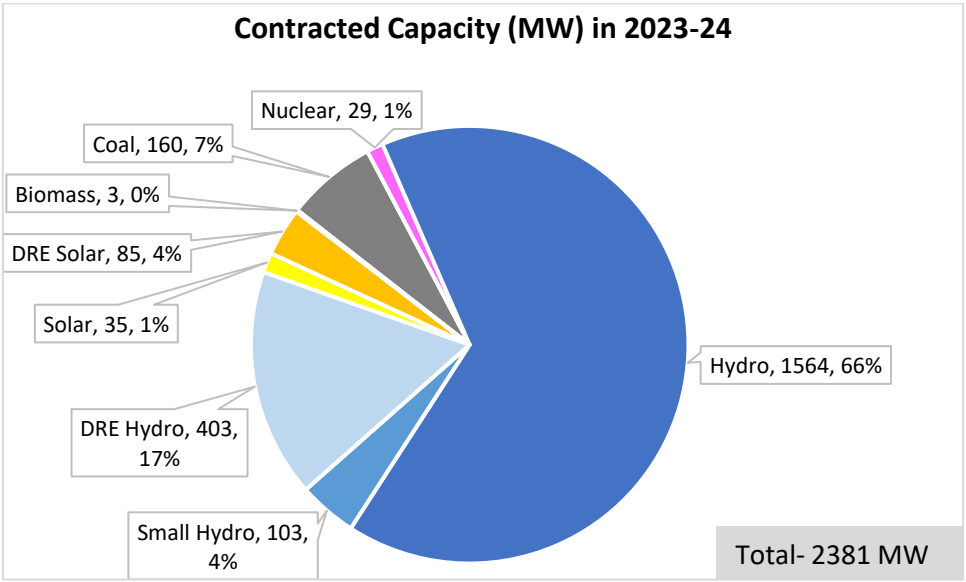


Figure 1: Fuel-wise Contracted Capacity (in MW) as on 31st March, 2024

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

Table 1: Peak electricity demand and electrical energy projections as per the utility

	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35
HPSEBL Energy Projections (in MU)	13,510	14,320	15,170	16,080	17,050	18,070	19,160	20,310	21,520	22,820	24,130
Year on Year Growth	-	6.0%	5.9%	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	5.7%
HPSEBL Peak Demand Projections (MW)	2,328	2,448	2,571	2,699	2,829	2,983	3,087	3,190	3,286	3,384	3,486
Year on Year Growth	-	5.2%	5.0%	5.0%	4.8%	5.4%	3.5%	3.3%	3.0%	3.0%	3.0%

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 (MW)

Year	Coal	Nuclear	Biomass	Hydro	Solar	Hybrid	DRE Hydro	DRE Solar	SHP	TOTAL	Storage (MW/MWh)	STOA/ MTOA
2024-25	160	42	3	1679	35	0	419	30	152	**2520**	0/0	1425
2025-26	160	55	3	1679	77	0	431	90	165	**2660**	0/0	1497
2026-27	160	55	3	1679	577	900	440	160	165	**4139**	0/0	1066
2027-28	160	55	3	2131	877	900	453	190	165	**4934**	0/0	1033
2028-29	160	55	3	2275	877	900	479	220	257	**5226**	0/0	1102
2029-30	410	55	3	2275	1640	900	542	250	275	**6350**	0/0	983
2030-31	410	55	3	2275	1940	900	548	250	341	**6722**	42/169	1098
2031-32	410	55	3	2275	2442	900	548	250	379	**7262**	319/1487	1100
2032-33	410	55	3	2275	2742	900	548	250	417	**7600**	341/1576	1300
2033-34	410	55	3	2304	3099	900	548	250	432	**8001**	464/2187	1430
2034-35	410	55	3	2304	3745	900	568	250	446	**8681**	1102/5678	1295

***** *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

FY	COAL	NUCLEAR	HYDRO	SOLAR		Hybrid
	Additional Requirement	Planned Contracts	Planned Contracts	Planned Contracts	Additional Requirement	Planned Contracts
2024-25	0	13	115	0	0	0
2025-26	0	13	0	42	0	0
2026-27	0	0	0	500	0	900
2027-28	0	0	453	300	0	0
2028-29	0	0	144	0	0	0
2029-30	250	0	0	0	763	0
2030-31	0	0	0	300	0	0
2031-32	0	0	0	300	201	0
2032-33	0	0	0	300	0	0
2033-34	0	0	39	0	358	0
2034-35	0	0	0	300	345	0

FY	DRE Hydro	DRE Solar	SHP	Total	
	Planned Contracts	Planned Contracts	Planned Contracts	Planned Contracts	Additional Requirement
2024-25	16	0	49	193	0
2025-26	12	60	13	140	0
2026-27	9	70	0	1479	0
2027-28	13	30	0	796	0
2028-29	26	30	92	292	0
2029-30	63	30	18	111	1013
2030-31	6	0	66	372	0
2031-32	0	0	38	338	201
2032-33	0	0	38	338	0
2033-34	0	0	15	54	358
2034-35	20	0	14	334	345

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

3.1 Present Power Scenario in Himachal Pradesh

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

Table 4: Power Supply Position of Himachal Pradesh

Power Supply Position						
Year	**Energy required (MU)**	**Energy supplied (MU)**	**Gap (MU)**	**Peak Demand (MW)**	**Peak Met (MW)**	**Demand not met (MW)**
2020-21	10186	10130	56	1932	1932	0
2021-22	12115	12088	27	2030	2030	0
2022-23	12649	12542	107	2071	2071	0
2023-24	12805	12767	38	2181	2181	0
2024-25	13566	13526	40	2273	2273	0

As per the data provided by HPSEBL, as of March 2025, the total contracted capacity of Himachal Pradesh is 2,625 MW. Out of the total contracted capacity (CC), the share of non-fossil fuel-based CC is 94 %. 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	160	6.1%
Nuclear	55	2.1%
Biomass	4	0.1%
Hydro	1664	63.4%
Solar	67	2.6%
DRE Hydro	406	15.5%

DRE Solar	127	4.9%
Small Hydro	142	5.4%
Total	2625	

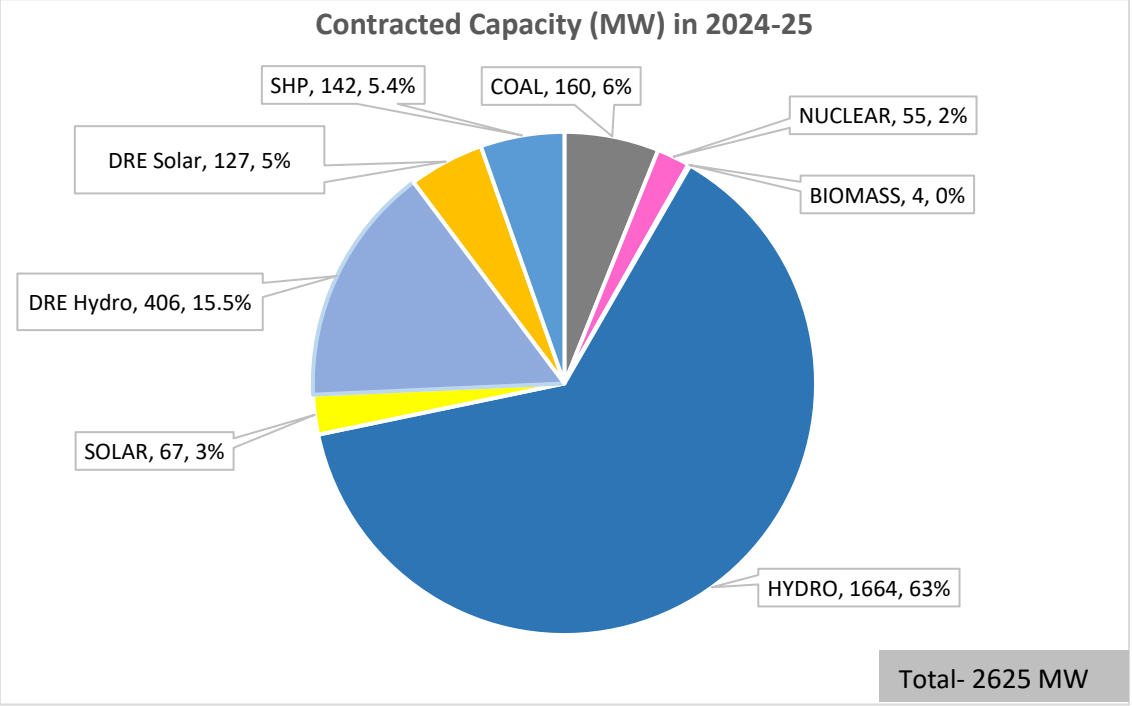


Figure 2: Fuel-wise Contracted Capacity (in MW) as on 31st March, 2025

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 Himachal Pradesh is typically during the winter months viz December, January and February. Peak electricity demand occurs during solar hours. The month-wise average hourly demand observed for the year 2024-25 is shown in Fig. 3.

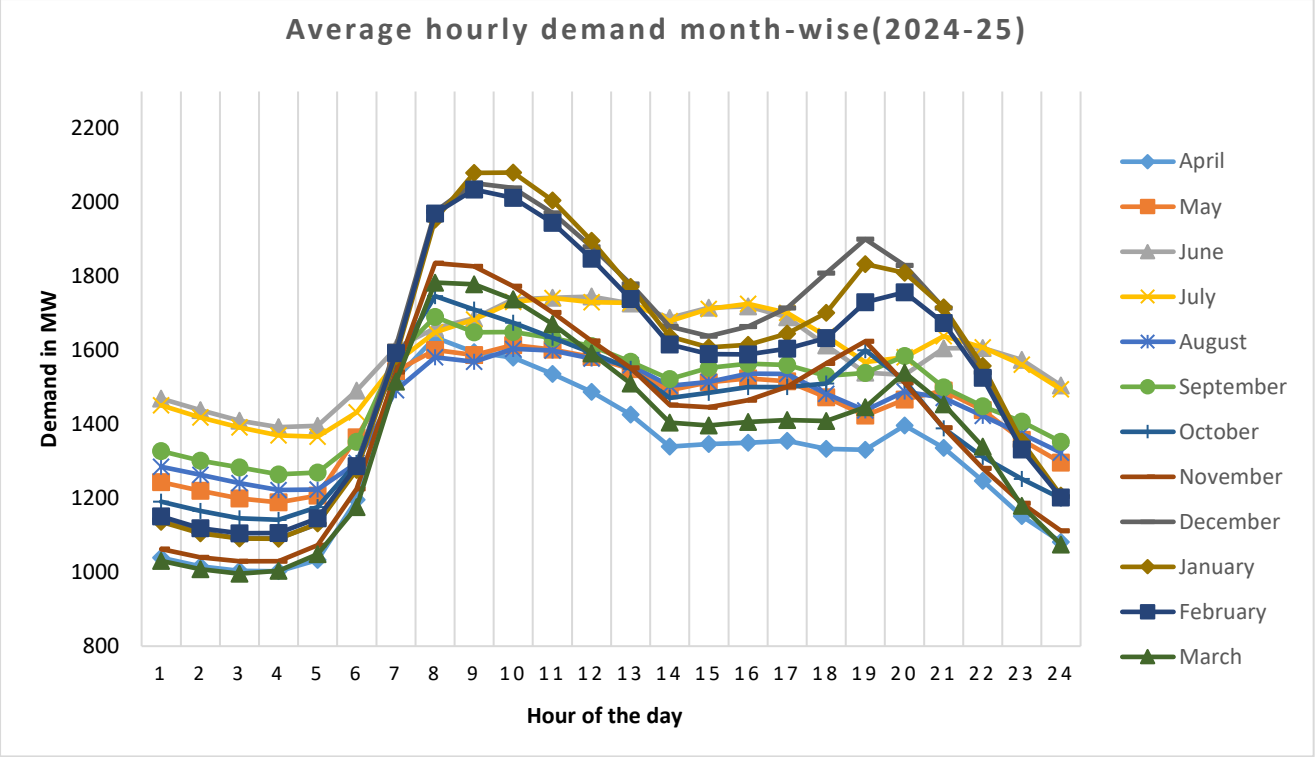


Figure 3: Average Hourly Demand Variation (Month-wise) for 2024-25

From the hourly demand data of 2024-25, the daily peak during solar hours and non-solar hours are plotted in Fig. 4.

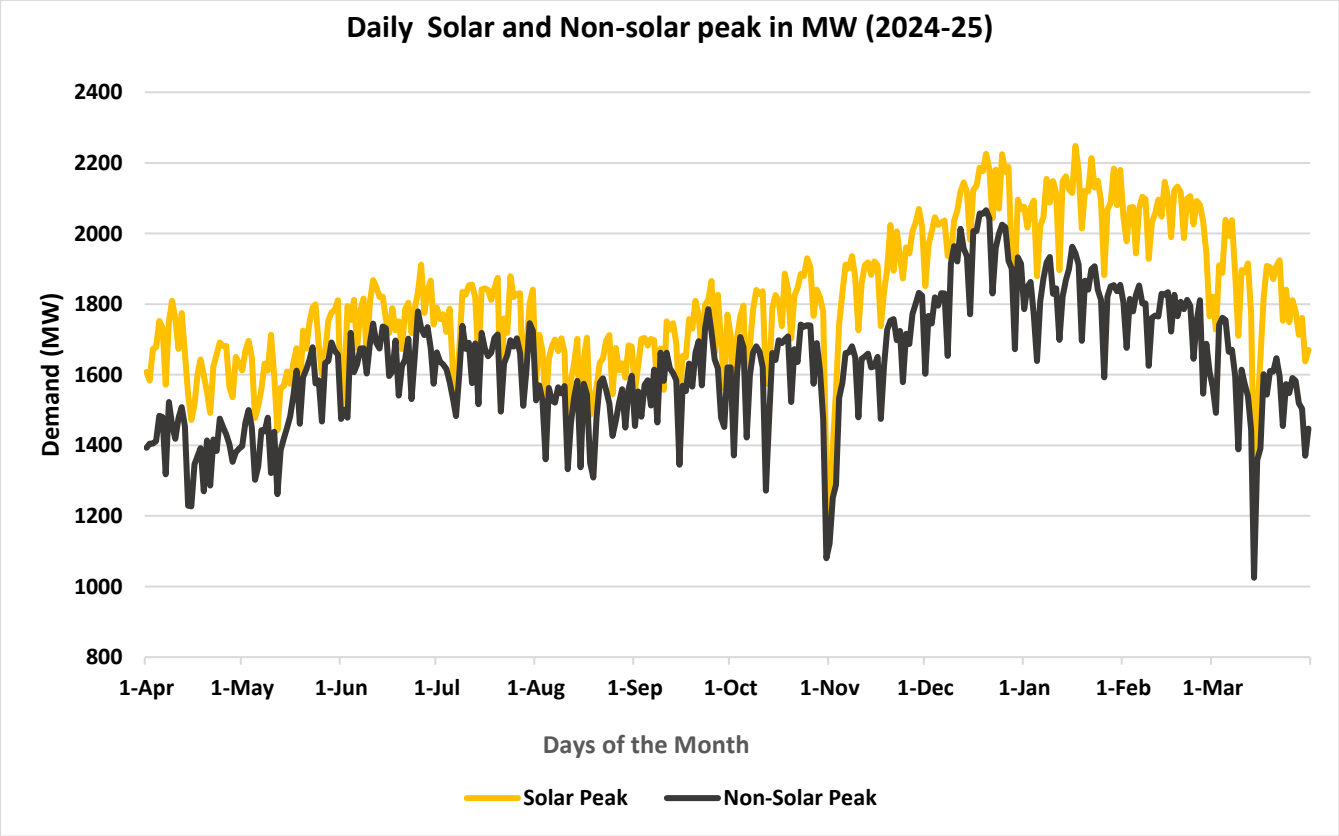


Figure 4: Solar and non-solar peak in MW for the year 2024-25

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.

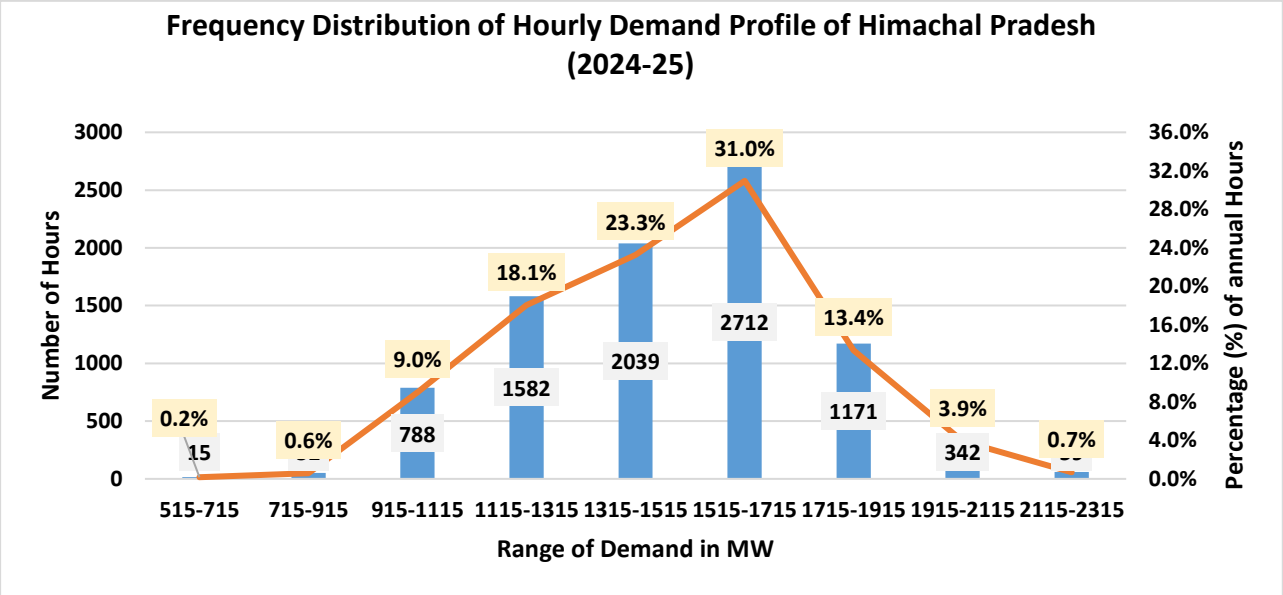


Figure 5: Frequency Distribution of Hourly Demand Profile of 2024-25

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.

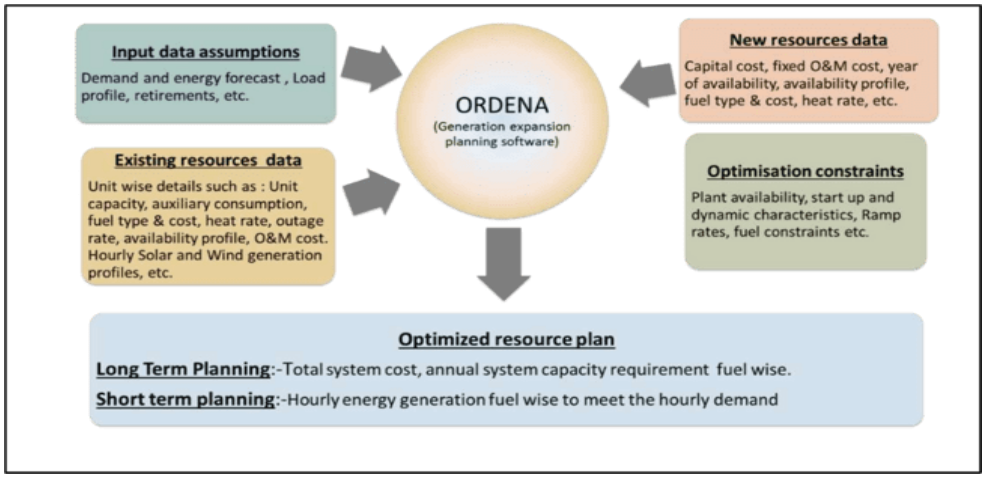


Figure 6: Schematic Diagram

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 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 generating plant. A large number 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 Variation in Electricity Demand

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.

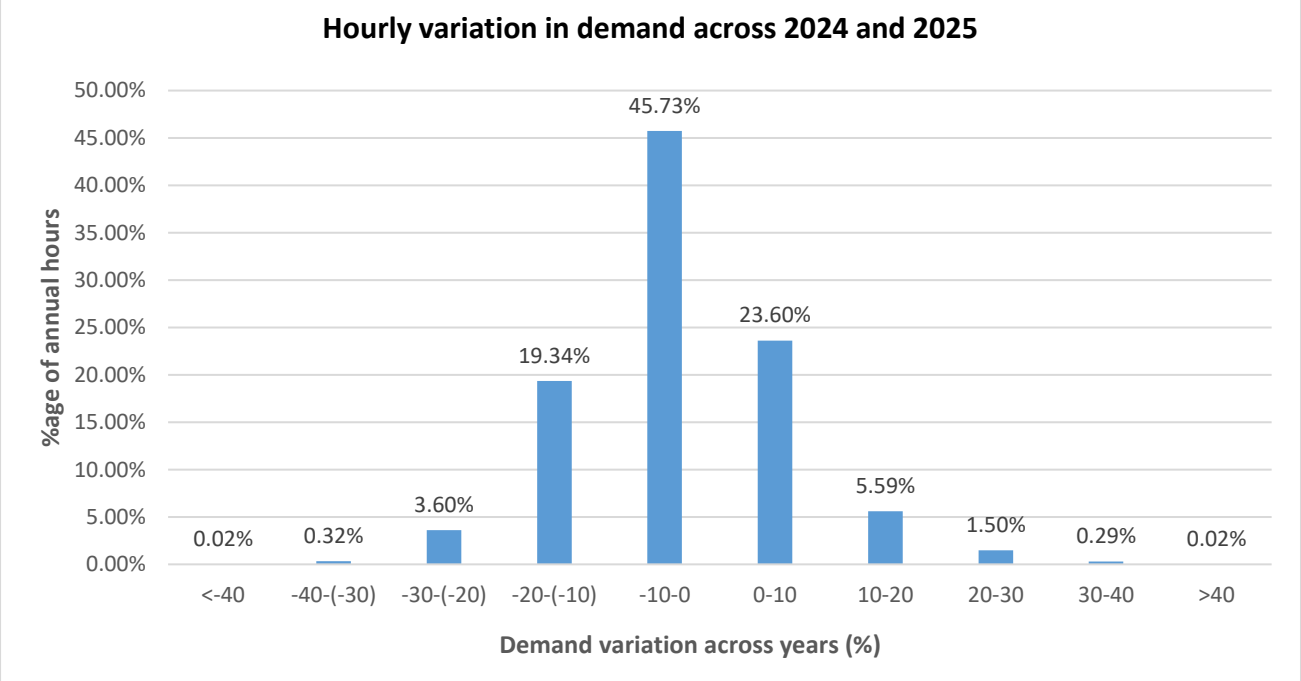


Figure 7: Hourly Variation in electricity demand across years

It can be observed that the hourly demand typically varies within ±10% for ~69% 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. Hydro based generation has also been varied by ± 5%.

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 Himachal Pradesh as per HPSEBL and mid-term review of 20th EPS Report is given in Table 6.

Table 6: Electricity demand projection

Year	Projections by HPSEBL, Himachal Pradesh				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	2387		15244		2568		14510	
2026-27	2506	5.00%	16158	6.00%	2729	6.27%	15417	6.25%
2027-28	2631	5.00%	17128	6.00%	2861	4.81%	16347	6.03%
2028-29	2763	5.00%	18156	6.00%	2993	4.61%	17297	5.81%
2029-30	2901	5.00%	19245	6.00%	3114	4.05%	18203	5.23%
2030-31	3046	5.00%	20400	6.00%	3222	3.48%	19048	4.64%
2031-32	3198	5.00%	21624	6.00%	3318	2.96%	19830	4.10%
2032-33	3358	5.00%	22921	6.00%	3418	3.04%	20657	4.17%
2033-34	3526	5.00%	24296	6.00%	3511	2.70%	21444	3.81%
2034-35	3702	5.00%	25754	6.00%	3593	2.35%	22185	3.45%
2035-36	3888	5.00%	27299	6.00%	3695	2.84%	22814	2.84%

Projections as per mid-term review of 20th EPS 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 considered as per data available with CEA.

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 Himachal Pradesh. 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	SOLAR	Hybrid	DRE Hydro	DRE Solar	SHP
2025-26	-	550	-	12	-	13
2026-27	-	550	900	9	140	-
2027-28	19	-	-	14	115	-
2028-29	563	-	-	40	-	92
2029-30	-	-	-	63	-	18
2030-31	-	-	-	6	-	66
2031-32	-	-	-	-	-	38
2032-33	-	-	-	-	-	38
2033-34	-	-	-	-	-	27
2034-35	-	-	-	20	-	14
2035-36	-	-	-	-	-	-
Total	**583**	**1100**	**900**	**163**	**256**	**306**

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	28.11	0.75	29.91
2.	2025-26	1.45	1.22	29.29	1.05	33.01
3.	2026-27	1.97	1.34	31.29	1.35	35.95
4.	2027-28	2.45	1.42	33.29	1.65	38.81
5.	2028-29	2.95	1.42	35.04	1.95	41.36
6.	2029-30	3.48	1.33	36.27	2.25	43.33

The notification also states that the distributed renewable energy component for hilly state namely Himachal Pradesh, shall be half of the DRE component as notified and the remaining component shall be included in the other renewable energy sources.

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 and the DRE percentage has been assumed to be 2.25 % beyond 2029-30. Hence, the suggested trajectory of Renewable Purchase Requirement for Himachal Pradesh 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	28.11	0.75	29.91
2.	2025-26	1.45	1.22	29.29	1.05	33.01
3.	2026-27	1.97	1.34	31.29	1.35	35.95
4.	2027-28	2.45	1.42	33.29	1.65	38.81
5.	2028-29	2.95	1.42	35.04	1.95	41.36
6.	2029-30	3.48	1.33	36.27	2.25	43.33
7.	2030-31	43.25			2.25	45.50
8.	2031-32	44.75			2.25	47.00
9.	2032-33	46.05			2.25	48.30
10.	2033-34	47.25			2.25	49.50
11.	2034-35	48.25			2.25	50.50
12.	2035-36	49.25			2.25	51.50

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**	210.40	177.02	4250.00	152.36	4789.78
2.	**2026-27**	303.72	206.59	4823.99	208.13	5542.42
3.	**2027-28**	400.51	232.13	5442.00	269.73	6344.36
4.	**2028-29**	510.27	245.62	6060.96	337.30	7154.14
5.	**2029-30**	633.46	242.10	6602.13	409.56	7887.25
6.	**2030-31**	8238.17			428.58	8666.75
7.	**2031-32**	8873.77			446.17	9319.94
8.	**2032-33**	9512.34			464.77	9977.11
9.	**2033-34**	10132.35			482.49	10614.85
10.	**2034-35**	10704.27			499.16	11203.43
11.	**2035-36**	11236.01			513.32	11749.33

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

Table 11 (a): Renewable Energy Surplus/Deficit

FY	RE Generation required to meet RPO (excluding DRE)		RE Generation excluding DRE available or met from existing and planned contracts		RE Generation Surplus (+)/ Deficit (-) (excluding DRE)
	(MU)	(%)	(MU)	(%)	(%)
2025-26	4637	31.96%	7195	49.45%	17.63%
2026-27	5334	34.60%	10410	67.53%	32.92%
2027-28	6075	37.16%	10563	64.62%	27.46%
2028-29	6817	39.41%	11864	70.58%	29.18%
2029-30	7478	41.08%	12133	69.25%	25.57%
2030-31	8238	43.25%	12410	67.65%	21.90%
2031-32	8874	44.75%	12605	66.33%	18.81%
2032-33	9512	46.05%	12748	64.53%	15.67%
2033-34	10132	47.25%	12820	62.84%	12.53%
2034-35	10704	48.25%	12855	61.00%	9.69%
2035-36	11236	49.25%	12855	59.38%	7.10%

Similarly, the year-wise total renewable energy for Distributed Renewable Energy (DRE) met from the existing and planned capacity along with the surplus/deficit is shown in Table 11(b).

Table 11 (b): Distributed Renewable Energy (DRE) Surplus/ Deficit

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	152	1.05%	881	6.07%	5.02%
2026-27	208	1.35%	935	6.07%	4.72%
2027-28	270	1.65%	1127	6.89%	5.24%
2028-29	337	1.95%	1216	7.03%	5.08%
2029-30	410	2.25%	1350	7.42%	5.17%
2030-31	429	2.25%	1387	7.28%	5.03%
2031-32	446	2.25%	1402	7.07%	4.82%
2032-33	465	2.25%	1409	6.82%	4.57%
2033-34	482	2.25%	1409	6.57%	4.32%
2034-35	499	2.25%	1443	6.51%	4.26%
2035-36	513	2.25%	1443	6.33%	4.08%

As indicated in the tables above, the state will be able to meet its RPO requirements based on the existing and planned contracts. Further, the utility will also be able to meet its RPO requirements from DRE as well.

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 6443 MUs which is about 28% of the electrical energy requirement in 2035-36. The year-wise likely unserved energy with the existing and planned capacities is given in Fig 8.

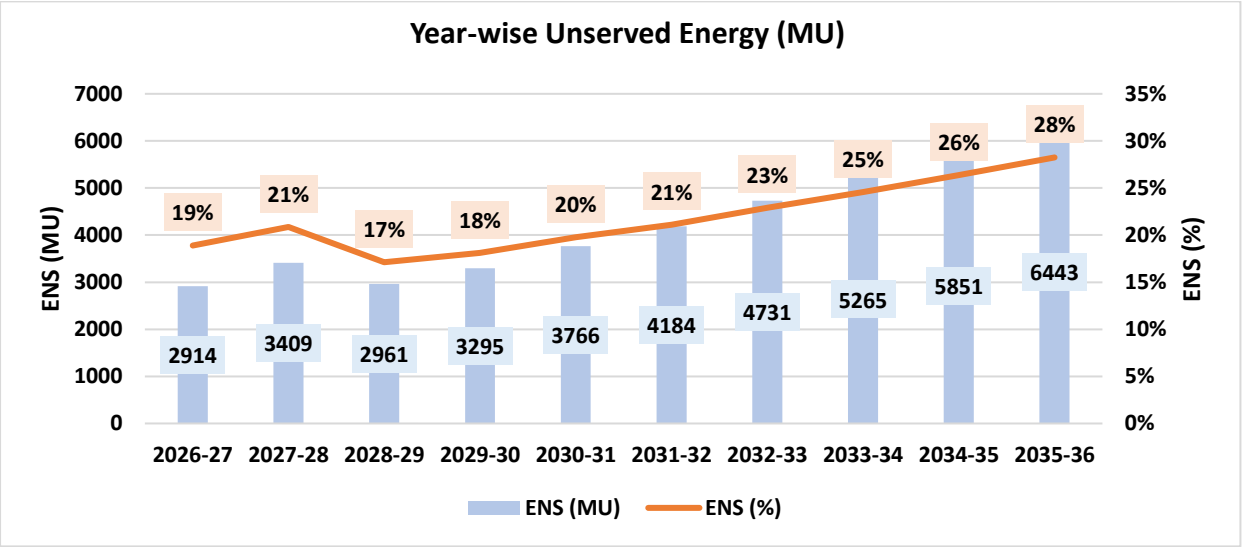


Figure 8: Yearly likely unserved energy (in MU) with the existing and planned capacities

The study has also analyzed the daily and monthly pattern of unserved energy in the year 2035-36 and it can be seen that contracted capacity (present and planned) is unable to meet the demand. Further, it is mentioned that the unserved energy in the year 2035-36 is high because the banking/STOA/MTOA arrangements have not been considered while calculating ENS. Details are shown in Fig. 9.

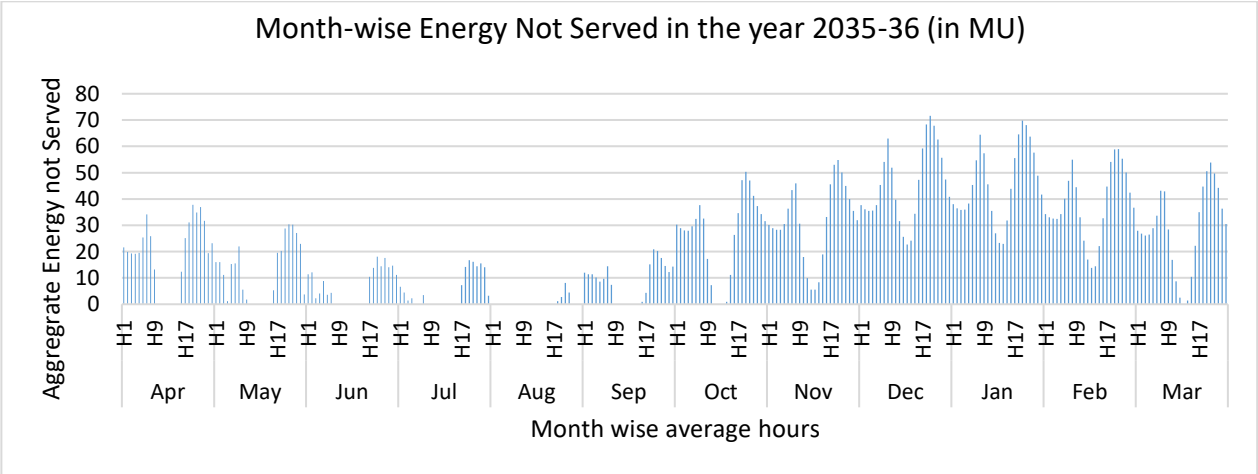


Figure 9: Block-wise Unserved Energy Pattern MU (2035-36)

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

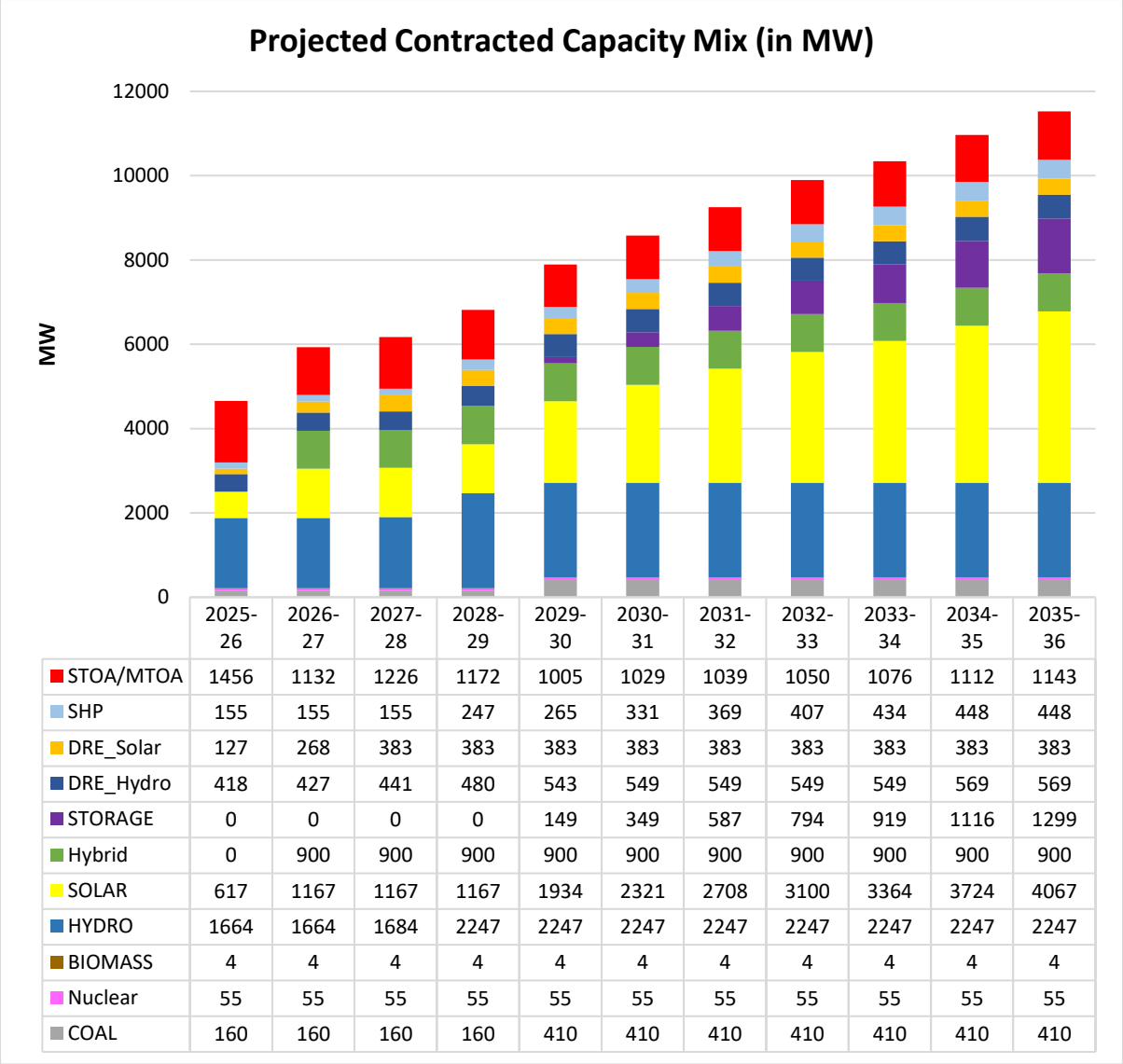
7.2 Investment options to meet the unserved energy

To meet this unserved 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 Himachal Pradesh are given in Table 12.

Table 12: Year-wise contracted capacity (existing, planned, to be tied up) projections (in MW)

Year	Coal	Nuclear	Biomass	Hydro	Solar	Hybrid	Storage	DRE Hydro	DRE Solar	SHP	STOA/ MTOA
2025-26	160	55	4	1664	617	0	0	418	127	155	1456
2026-27	160	55	4	1664	1167	900	0	427	268	155	1132
2027-28	160	55	4	1684	1167	900	0	441	383	155	1226
2028-29	160	55	4	2247	1167	900	0	480	383	247	1172
2029-30	410	55	4	2247	1934	900	149	543	383	265	1005
2030-31	410	55	4	2247	2321	900	349	549	383	331	1029
2031-32	410	55	4	2247	2708	900	587	549	383	369	1039
2032-33	410	55	4	2247	3100	900	794	549	383	407	1050
2033-34	410	55	4	2247	3364	900	919	549	383	434	1076
2034-35	410	55	4	2247	3724	900	1116	569	383	448	1112
2035-36	410	55	4	2247	4067	900	1299	569	383	448	1143

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



	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35	2035-36
STOA/MTOA	1456	1132	1226	1172	1005	1029	1039	1050	1076	1112	1143
SHP	155	155	155	247	265	331	369	407	434	448	448
DRE_Solar	127	268	383	383	383	383	383	383	383	383	383
DRE_Hydro	418	427	441	480	543	549	549	549	549	569	569
STORAGE	0	0	0	0	149	349	587	794	919	1116	1299
Hybrid	0	900	900	900	900	900	900	900	900	900	900
SOLAR	617	1167	1167	1167	1934	2321	2708	3100	3364	3724	4067
HYDRO	1664	1664	1684	2247	2247	2247	2247	2247	2247	2247	2247
BIOMASS	4	4	4	4	4	4	4	4	4	4	4
Nuclear	55	55	55	55	55	55	55	55	55	55	55
COAL	160	160	160	160	410	410	410	410	410	410	410

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 Normalised Energy Not Served (NENS) remaining within the permissible limits of 0.2% and 0.05% respectively.

As per the resource adequacy study, the likely total projected contracted capacity for the year 2035-36 is around 11,524 MW which consists of 410 MW from coal; 4 MW from biomass; 55 MW from nuclear; 2,247 MW from hydro; 4,067 MW from solar; 900 MW from hybrid; 569 MW from hydro based Distributed Renewable Energy (DRE) source; 383 MW from solar based DRE; 448 MW from small hydro plant (SHP); 1,299 MW from Storage and 1143 MW of MTOA/STOA arrangement. 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. The storage requirement can be met from PSP, combination of 2 hr/4 hr BESS or combination of PSP and BESS. Based on the capacity addition, the planning reserve margin works out to be about 5%. Projected Contracted Capacity required in 2035-36 is shown in Figure 11.

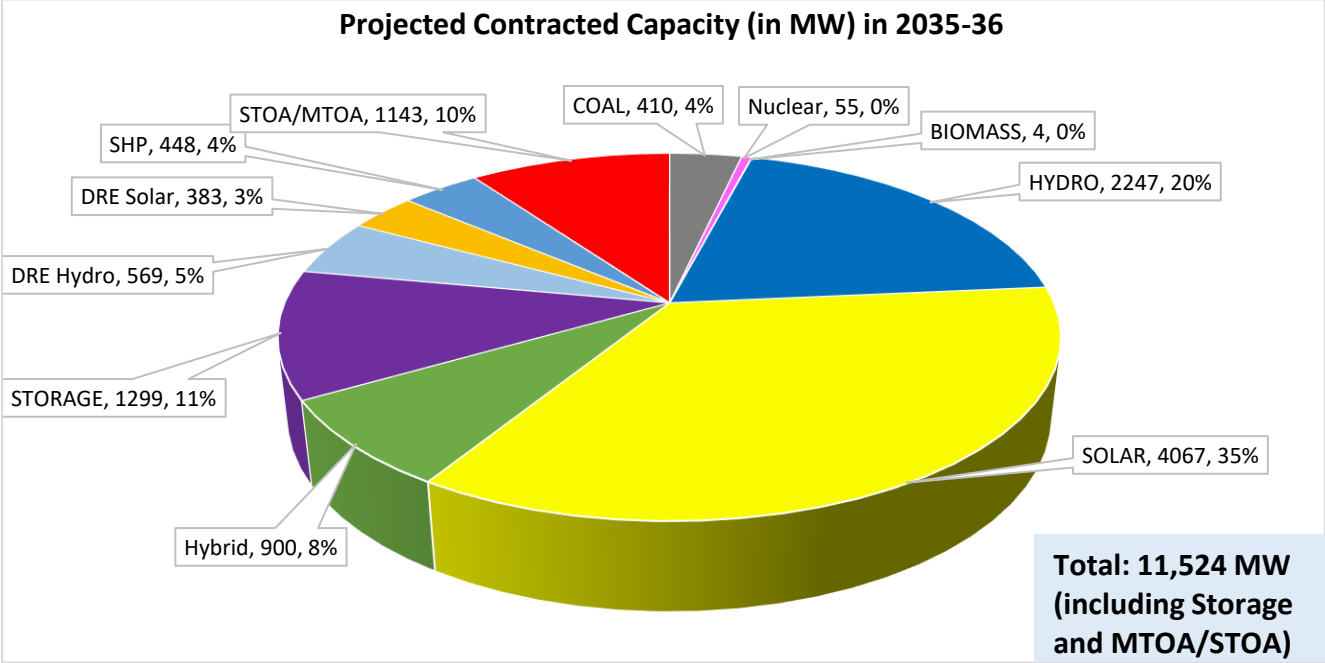


Figure 11: Contracted Capacity Mix in 2035-36

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 reliably meet its electricity demand as shown in Table 13.

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

FY	COAL	HYDRO	SOLAR		Hybrid
	Additional Contracts	Planned Contracts	Planned Contracts	Additional Contracts	Planned Contracts
2025-26	0	0	550	0	0
2026-27	0	0	550	0	900
2027-28	0	19	0	0	0
2028-29	0	563	0	0	0
2029-30	250	0	0	767	0
2030-31	0	0	0	387	0
2031-32	0	0	0	387	0
2032-33	0	0	0	392	0
2033-34	0	0	0	264	0
2034-35	0	0	0	360	0
2035-36	0	0	0	344	0
Total	**250**	**583**	**1100**	**2900**	**900**
FY	**DRE Hydro**	**DRE Solar**	**SHP**	**STORAGE**	**STOA/MTOA**
	Planned Contracts	Planned Contracts	Planned Contracts	Additional Contracts	*Requirement
2025-26	12	0	13	0	1456
2026-27	9	140	0	0	1132
2027-28	14	115	0	0	1226
2028-29	40	0	92	0	1172
2029-30	63	0	18	149	1005
2030-31	6	0	66	200	1029
2031-32	0	0	38	238	1039
2032-33	0	0	38	207	1050
2033-34	0	0	27	125	1076
2034-35	20	0	14	197	1112
2035-36	0	0	0	182	1143
Total	**163**	**256**	**306**	**1299**	

**The STOA/MTOA requirement is for a particular year.*

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

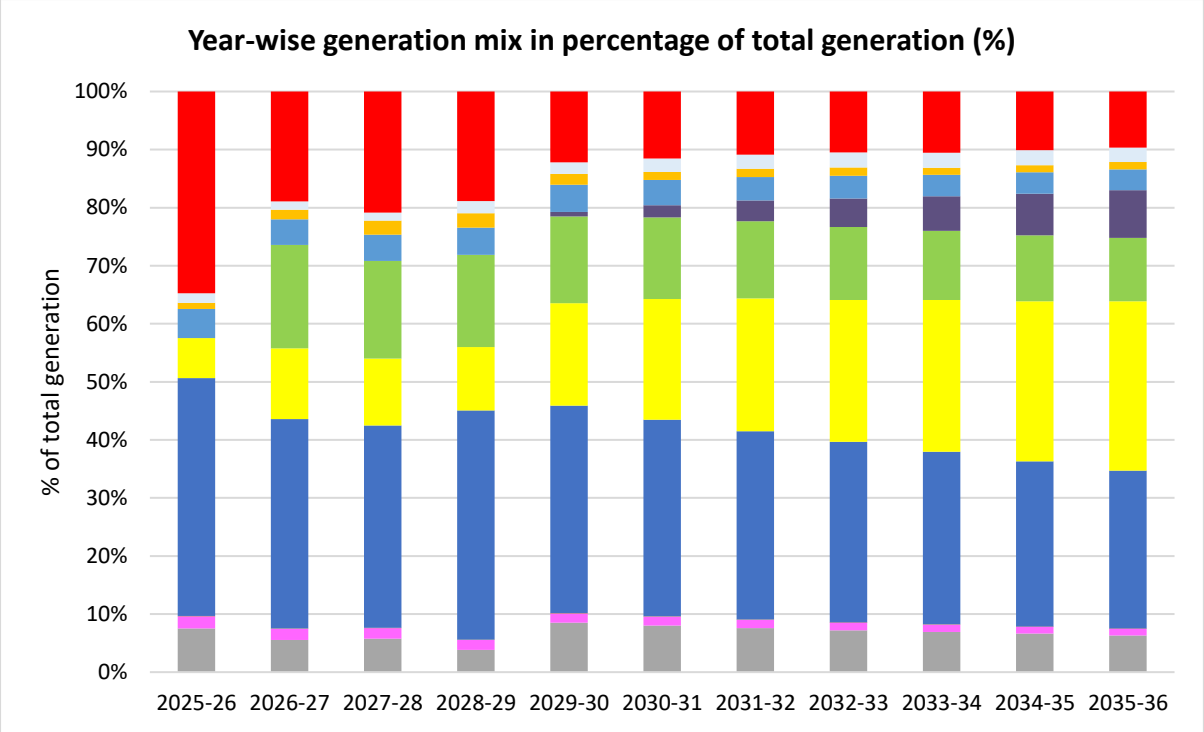
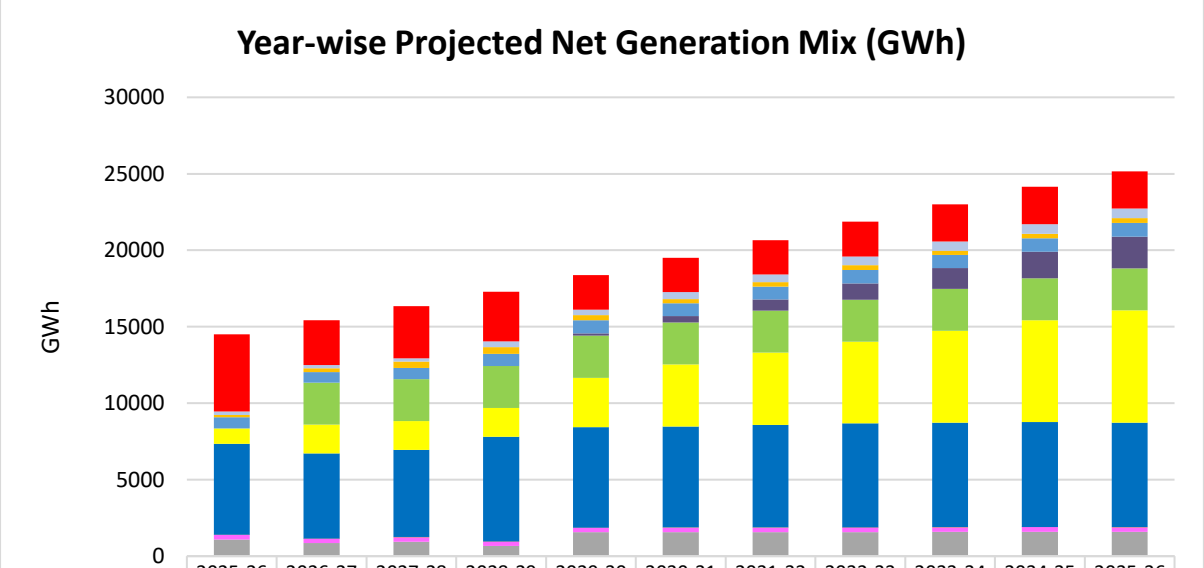


Figure 12: Year-wise projected net generation mix (in %)



	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35	2035-36
STOA/MTOA	5041	2914	3410	3259	2244	2254	2246	2291	2421	2436	2430
SHP	244	220	221	371	362	446	505	567	596	625	628
DRE_Solar	148	256	404	429	344	276	291	310	279	294	314
DRE_Hydro	732	685	738	808	858	845	837	868	855	896	900
STORAGE	0	0	0	0	145	409	734	1074	1362	1725	2065
Hybrid	0	2747	2747	2747	2747	2747	2747	2747	2747	2747	2747
SOLAR	997	1871	1884	1884	3238	4053	4728	5341	5998	6662	7350
HYDRO	5942	5563	5693	6833	6566	6610	6702	6796	6839	6857	6830
BIOMASS	12	8	9	6	7	7	7	7	7	7	7
Nuclear	297	297	297	297	297	297	297	297	297	297	297
COAL	1096	855	945	661	1560	1569	1571	1577	1590	1599	1593

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

7.3 Surplus Coal Capacity

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 Himachal Pradesh is expected to have a surplus coal-based capacity available during non-winter months namely June to September of around 125 MW for 2028-29. This surplus capacity may be banked or shared with other states whose demand profile complements that of Himachal Pradesh.

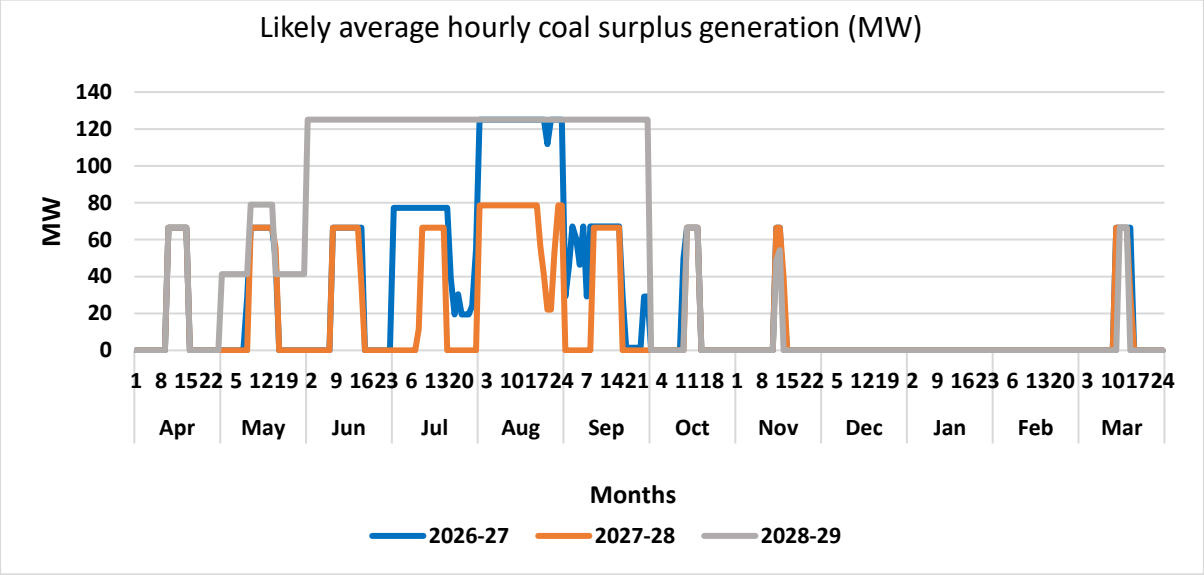


Figure 14: Surplus Coal Capacity Year-wise (MW)

8.0 Conclusions

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

1. The study has been carried out considering electricity demand projections as per the revised 20th EPS report, which envisages that the annual electrical energy requirement of the state is likely to grow at a CAGR of 4.63% while the peak electricity demand for the state is likely to grow at a CAGR of 3.71% for the period of 2025-26 to 2035-36. It has been observed that the peak demand season is typically from December to February with peak demand occurring during solar hours.
2. Himachal Pradesh, with its existing and planned capacity addition only, is likely to witness energy deficit ranging from 2914 to 6443 MUs in different years from 2026-27 to 2035-36.
3. As per the resource adequacy study, the likely total projected contracted capacity for the year 2035-36 is around 11,524 MW which consists of 410 MW from coal; 4 MW from biomass; 55 MW from nuclear; 2,247 MW from hydro; 4,067 MW from solar; 900 MW from hybrid; 569 MW from hydro based Distributed Renewable Energy (DRE) source; 383 MW from solar based DRE; 448 MW from small hydro plant (SHP); 1,299 MW from Storage

and 1143 MW of MTOA/STOA arrangement 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. The storage requirement can be met from PSP, combination of 2 hr/4 hr BESS or a combination of PSP and BESS.

4. As per the study, the state is expected to have a surplus coal-based capacity available during non-winter months namely June to September of around 125 MW for 2028-29. This surplus capacity may be banked or shared with other states whose demand profile complements that of Himachal Pradesh.
5. The Planning Reserve Margin (PRM) for Himachal Pradesh has been assessed at about 5%. Further, the study indicates year-wise short-term/medium-term/bilateral requirements inclusive of the PRM capacity to optimally meet the demand.
6. The current capacity mix of Himachal Pradesh has 6.1% of contracted capacity from fossil fuel sources. The share of fossil fuel-based capacity is likely to reduce to 4.51 % in 2035-36. In 2035- 36, the RE based generation (that includes hydro, solar, hybrid, biomass and DRE) capacity are likely to constitute around 95% of the total installed capacity.
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.

****

Annexure

Details of upcoming generation projects considered in the study

Sl. No.	Tied capacity name	Type of generation	Expected COD	Himachal Pradesh's share (in MW)
1.	SECI-550 MW	Solar	2025-26	550
2.	SECI-550 MW	Solar	2026-27	550
3.	SECI-900 MW	Hybrid	2026-27	900
4.	Vishnugad Pipalkoti	Hydro	2027-28	19.36
5.	Chanju-III	Hydro	2028-29	41.76
6.	Shongtong Karcham	Hydro	2028-29	391.5
7.	Kashang	Hydro	2028-29	113.1

Assumption for Resource Adequacy Studies

1. Electricity Demand & peak requirement: As per the projections in revised 20th EPS report.
2. Demand Profile: Based on hourly demand profile of 2024-25.
3. Existing and Planned Capacity: As per the information shared by the state.
4. Cost parameters: based on information in National Electricity Plan.

RE CUF considered

Hydro	Hybrid	Solar (existing)	Solar (planned)	DRE
38 %	35%	18%	23.5%	14%

Technical Parameters

Technology	Type	Availability (%)
Coal/ Lignite	Existing/Planned	85
	Candidate	88
Gas	Existing	90
Nuclear	Existing/Planned	68
Biomass	Existing/Planned	60
Hydro	Existing/Planned/ Candidate	As per available hourly generation profile
Solar	Existing/Planned	
	Candidate	
Wind	Existing/Planned	
	Candidate	
Pumped Storage Plant	Existing/Planned	95
	Candidate	
Battery Energy Storage System	Candidate	98

Technology	Type	Heat Rate (MCal/MWh)		Aux. Consum. (%)
		At max loading	At min loading	
Coal	Existing/ Planned	2300 to 2879	2438 to 3052	7.0
	Candidate (SC & USC)	2060 to 2125	2183 to 2253	6.5
Gas	Existing	2000 to 2900	2260 to 3277	2.5
Nuclear	Existing/ Planned	2777	2777	10
	Candidate	2777	2777	10
Biomass	Existing/ Planned	4200	4450	8
	Candidate	4200	4450	8
Hydro	Existing/ Planned	-	-	0.7
	Candidate	-	-	0.7
Pumped Storage	Existing/ Planned	-	-	Round trip efficiency 80 %
	Candidate	-	-	
Battery Energy Storage System	Candidate	-	-	Round trip efficiency 88 %

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	12 Cr	30 Lakh	4	25
Solar	4.5 Cr	1 % of Capex	1	25
Battery Energy Storage System (4-Hour)	4.98 Cr to 3.00 Cr	5.9 Lakh	1	15
PSP	6 Cr	30 Lakh	4	40