



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

October, 2025

**Government of India
Ministry of Power
Central Electricity Authority**

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Disclaimer

This Resource Adequacy study for the state of Uttarakhand has been conducted based on data and inputs provided by Uttarakhand Power Corporation Limited (UPCL). The findings, analysis and conclusions presented in this report are contingent upon the accuracy, completeness and timeliness of the information furnished by UPCL. 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 UPCL 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 UPCL.

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 and 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 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 also recently 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 energy consumption must be met from renewable energy sources.

To support the utility in fulfilling this requirement, CEA, in collaboration with the State, initially conducted a Resource Adequacy (RA) study with a planning horizon up to FY 2034-35, based on the data received from the UPCL and in compliance with the RPO trajectory specified in the Ministry of Power's 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 State and planning assumptions. The RPO requirement for the utility has also been assessed in accordance with the recent gazette notified trajectory.

The electrical energy requirement and peak electricity demand for Uttarakhand is increasing with a CAGR of 4.9 % and 4.6 % respectively from 2025-26 to 2035-36 as forecasted by UPCL. 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 or by procuring power. In view of the reduction in cost of solar panels and newer technology options like 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.

A study has been carried out for Uttarakhand considering the existing contract capacity and planned capacity addition. It was found that the State's likely contracted capacity may not be sufficient to meet the projected demand. Further, the total unserved energy in the year 2035-36 is expected to be about 9.1 BU which is about 30% of the annual projected 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, 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 plan of Uttarakhand along with RPO constraints for solar and wind 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 is 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 9928 MW which consists of 2215 MW from coal, 390 MW from gas, 52 MW from Biomass, 111 MW from nuclear, 3524 MW from hydro, 100 MW from Hybrid, 1644 MW from solar, 476 MW from Distributed Renewable Energy (DRE), 1250 MW of PSP and 166 MW of BESS. 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 the state of Uttarakhand based on inputs furnished by UPCL. The study recommends an optimal resource mix up to FY 2035-36, taking into account technical and financial parameters associated with various capacities. It aims to optimize long-term power procurement while ensuring resource adequacy to meet demand on a 24×7 basis, considering variations in demand, RE generation, and forced outage of thermal capacities. The study 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 inputs from UPCL and in accordance with the prevailing RPO trajectory specified in the Ministry of Power's Gazette notification dated 20th October, 2023.

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

1. In the earlier Resource Adequacy (RA) study, the 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 by UPCL as on June, 2024, is given in Fig 1.

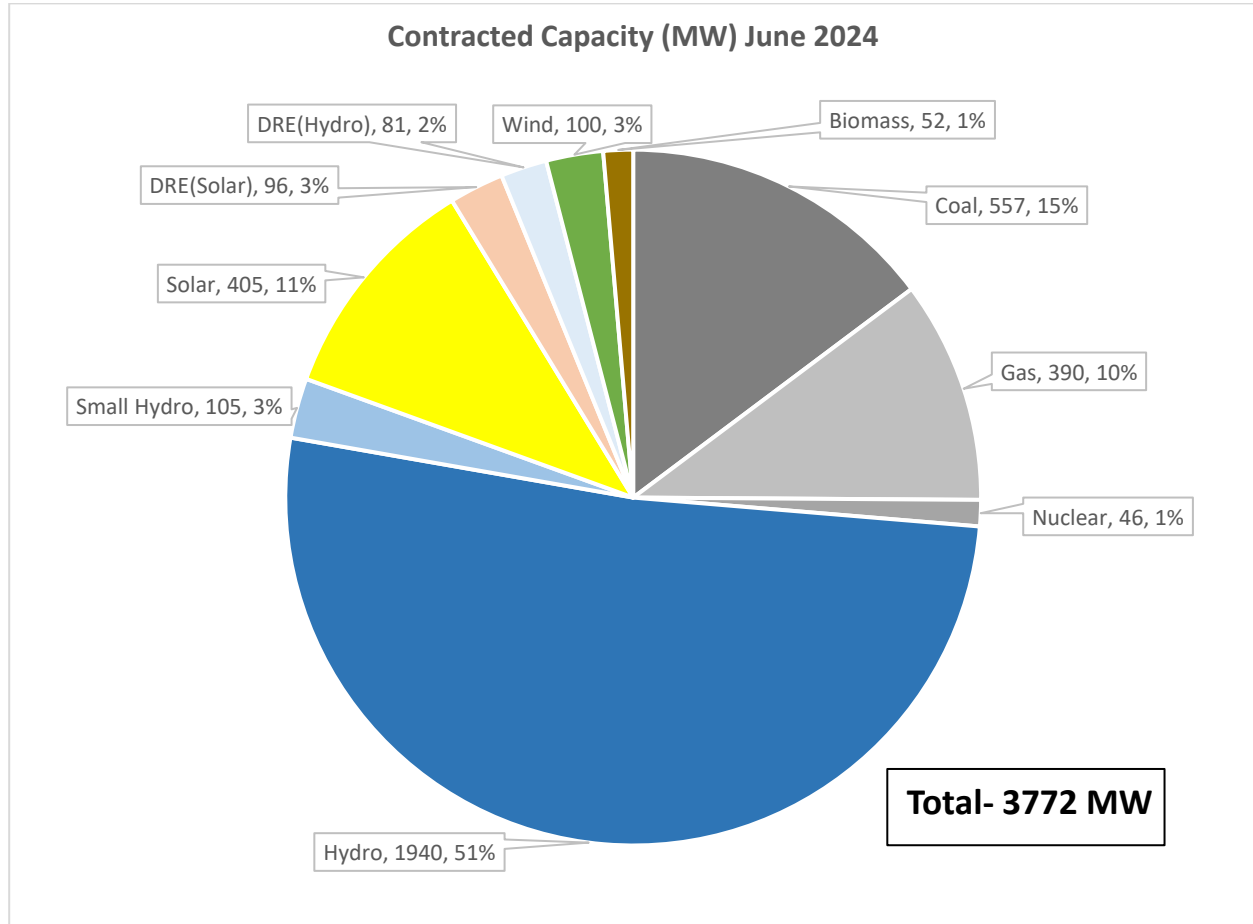


Figure 1: Contract Capacity (June 2024)

2. The hourly demand pattern for 2023-24 was analysed and had been considered as a base profile to interpolate the demand for future years.
3. The peak electricity demand and electrical energy projections as per state had been considered in the study is given in Table 1.

Table 1: Peak electricity demand and Electrical Energy Requirement Projections as per state

	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35
Energy Projections (MU)	18080	19093	20140	21230	22370	23700	24620	25520	26720	28330	30030
Year on Year Growth (%)		5.60%	5.48%	5.41%	5.37%	5.95%	3.88%	3.66%	4.70%	6.03%	6.00%

Peak Demand Projections (MW)	2905	3072	3249	3433	3623	3847	4004	4159	4224	4371	4634
Year on Year Growth (%)		5.75%	5.76%	5.66%	5.53%	6.18%	4.08%	3.87%	1.56%	3.48%	6.02%

4. The actual peak electricity demand and electrical energy requirement of the state during 2023-24 and 2024-25 as per the Power Supply Position (PSP) report of CEA is given in Table 2.

Table 2: Actual Peak Electricity Demand and Electrical Energy requirement

Year	Actual Electrical Energy Requirement (in MU)	Actual Peak Electricity Demand (in MW)
2023-24	15644	2635
2024-25	16770	2863

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 3.

Table 3: Projected contracted capacity (in MW)

	Coal	Gas	Nuclear	Hydro	Wind	Solar	Cogen	DRE (Hydro)	DRE (Solar)	SHP	Total	PSP	STOA
2024-25	610	390	46	1940	100	651	52	86	96	120	4091	200	1480
2025-26	610	390	46	1940	100	751	52	86	96	120	4191	200	1500
2026-27	610	390	46	2020	100	796	52	86	96	120	4316	200	1550
2027-28	610	390	79	2020	100	796	52	131	96	133	4407	200	1580
2028-29	610	390	79	2403	100	804	52	137	137	229	4941	200	1550
2029-30	1791	390	111	2403	100	804	52	141	207	264	6263	200	1600
2030-31	1791	390	111	3027	100	804	52	141	272	281	6969	200	1430
2031-32	1906	390	111	3027	100	804	52	141	340	281	7152	200	1480
2032-33	2062	390	111	3027	100	804	52	141	418	281	7386	200	1600
2033-34	2274	390	111	3027	100	804	52	141	512	281	7692	200	1630
2034-35	2488	390	111	3027	100	804	52	141	615	281	8009	200	1600

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

Table 4: Year wise planned and additional capacity (in MW)

FY	Coal		Nuclear	Hydro	SHP	PSP	Solar	DRE (Hydro)	DRE (Solar)		Total		STOA
	Planned	Additional	Planned	Planned	Planned	Planned	Planned	Planned	Planned	Additional	Planned	Additional	
2024-25	52	0	0	0	15	200	246	5	0	0	518	0	1480
2025-26	0	0	0	0	0	0	100	0	0	0	100	0	1500
2026-27	0	0	0	80	0	0	45	0	0	0	125	0	1550

FY	Coal		Nuclear	Hydro	SHP	PSP	Solar	DRE (Hydro)	DRE (Solar)		Total		STOA
	Planned	Additional	Planned	Planned	Planned	Planned	Planned	Planned	Planned	Additional	Planned	Additional	
2027-28	0	0	33	0	13	0	0	45	0	0	91	0	1580
2028-29	0	0	0	383	96	0	8	6	0	41	493	41	1550
2029-30	0	1181	33	0	35	0	0	4	0	70	72	1251	1600
2030-31	0	0	0	624	17	0	0	0	0	65	641	65	1430
2031-32	0	115	0	0	0	0	0	0	0	68	0	183	1480
2032-33	0	156	0	0	0	0	0	0	0	78	0	234	1600
2033-34	0	212	0	0	0	0	0	0	0	94	0	306	1630
2034-35	0	214	0	0	0	0	0	0	0	103	0	317	1600
Total	52	1878	66	1087	176	200	399	60	0	519	2040	2397	

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

3.1 Present Power Scenario in Uttarakhand

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

Table 5: Power Supply Position of Uttarakhand

Power Supply Position						
Year	Energy required (MU)	Energy supplied (MU)	Gap (MU)	Peak Demand (MW)	Peak Met (MW)	Demand not met (MW)
2021-22	15521	15426	94	2468	2468	0
2022-23	15647	15386	261	2594	2594	0
2023-24	15644	15532	112	2635	2405	230
2024-25	16770	16727	43	2863	2863	0

As of June 2025, the total contracted capacity for Uttarakhand is 4,080 MW. Out of the total contracted capacity (CC), the share of non-fossil fuel-based Contracted Capacity is 76%.

The fuel-wise contracted capacity as on June, 2025 is given in Table 6 and Figure 2.

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

Source	Contracted Capacity (MW)	Percentage (%)
Coal	589	14%
Gas	390	10%
Nuclear	78	2%
Hydro	2069	51%
Solar	525	13%
DRE	177	4%
PSP	100	2%
Hybrid	100	2%
Biomass	52	1%
Total	4080	100%

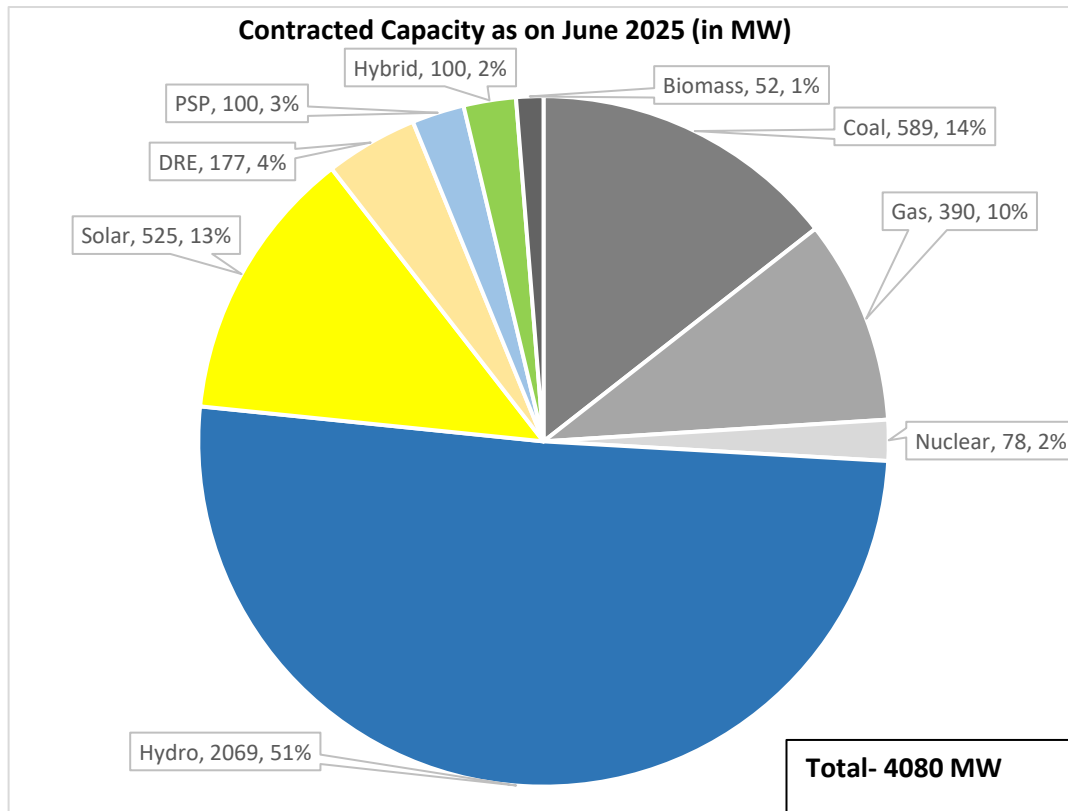


Figure 2 Fuel-wise Contracted Capacity (in MW) as on June, 2025

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 Uttarakhand occurs during non-solar hours of June month. Overall, the demand during the non-solar hours in May and June is significantly higher than in the rest of the year.

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

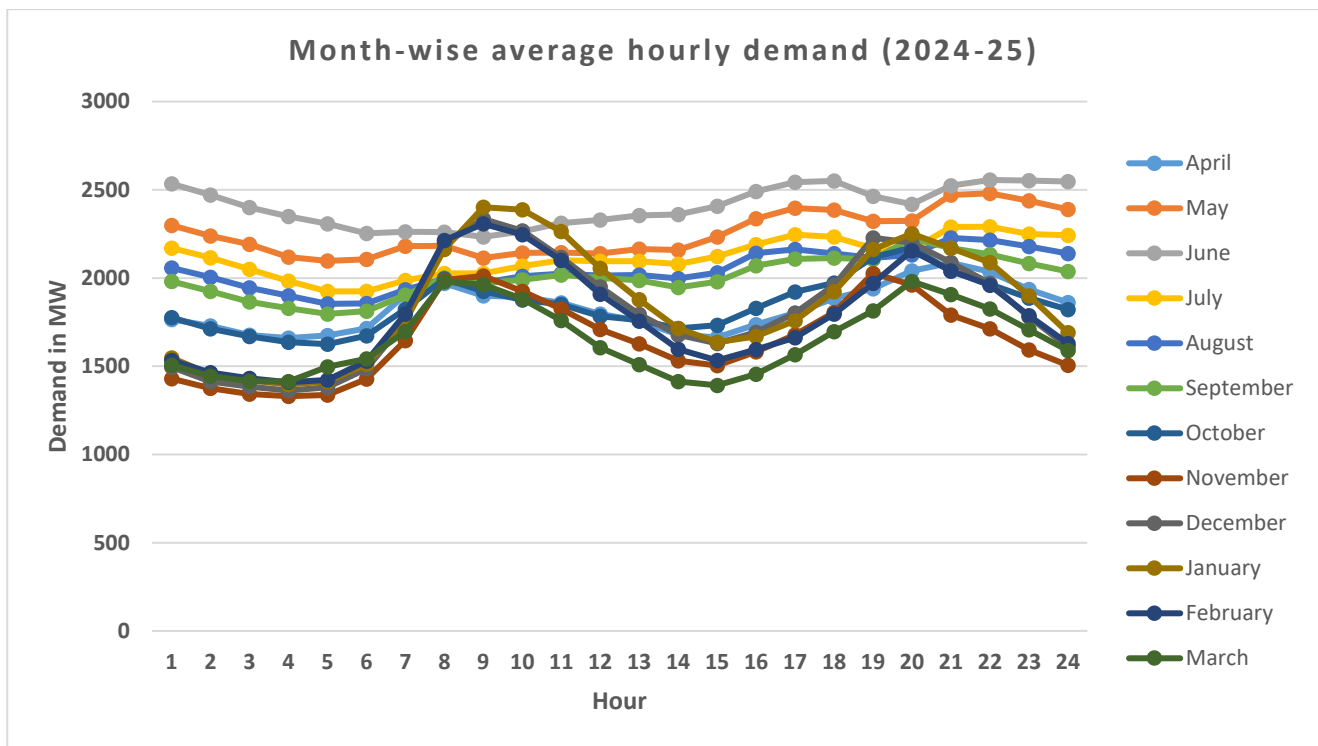


Figure 3: Average Hourly Demand Variation (Month-wise) for 2024-25

From the hourly demand data of 2024-25 the daily peak during solar hours (06:00 to 18:00 hrs) and non-solar hours are plotted in Figure 4.

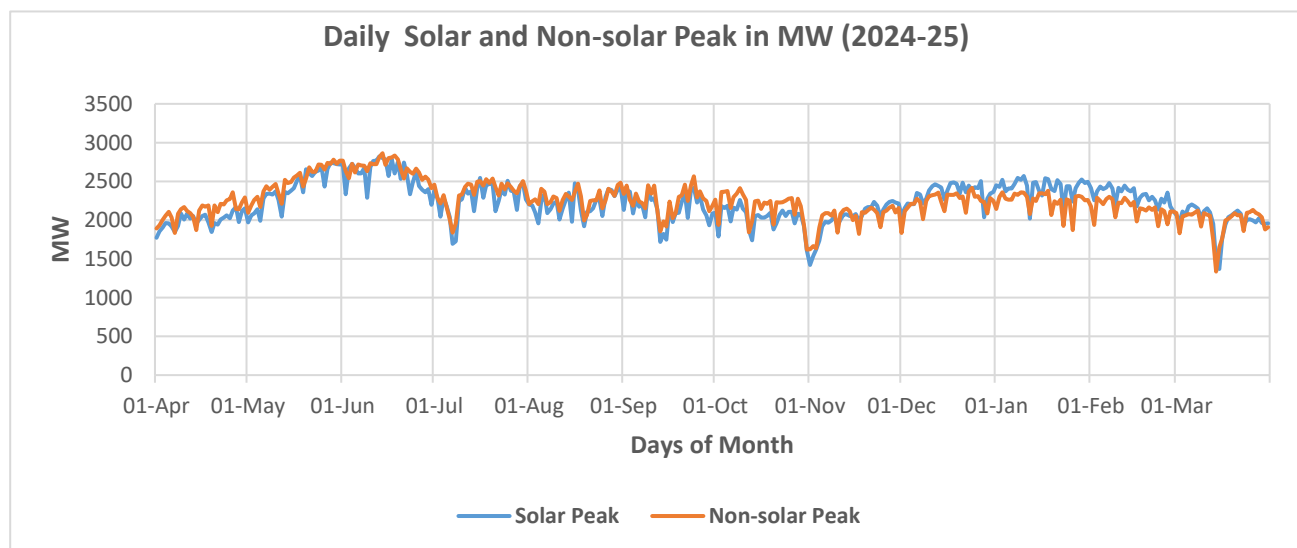


Figure 4: Solar and non-solar Peak in MW for the year 2024-25

As seen in Figure 4, the daily peak demand occurs during non-solar hours during summer months. In winter season, it can be observed that the peak demand occurs during solar hours.

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.

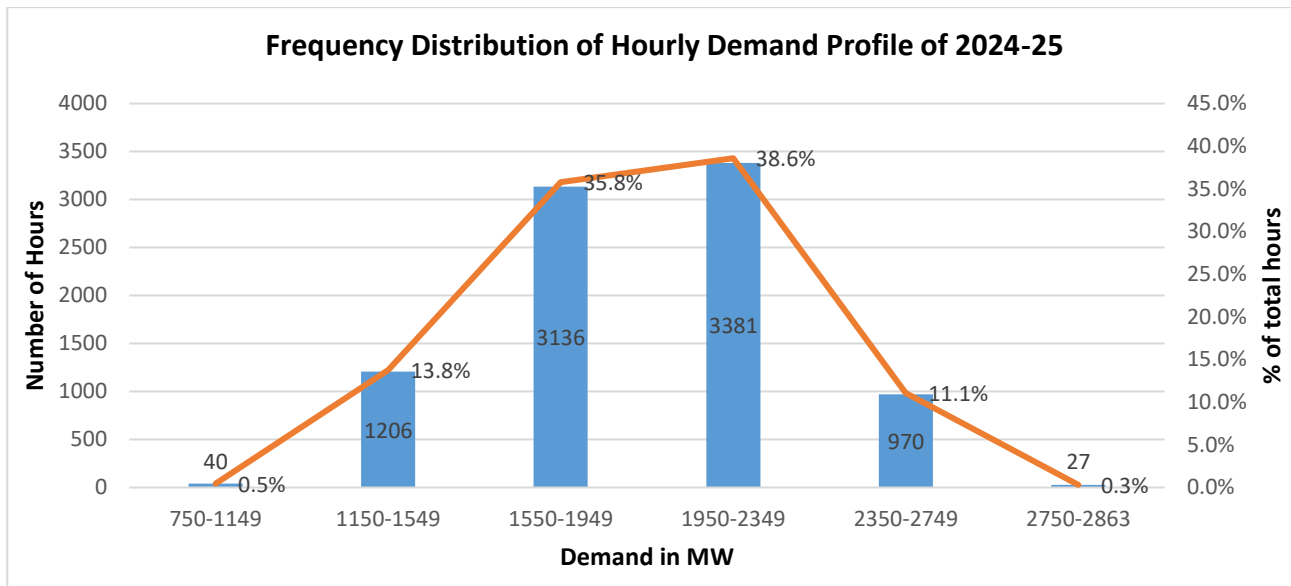


Figure 5 Frequency Distribution of Hourly Demand Profile of 2024-25

4.0 Principles of Generation Planning

The objective of the Generation Planning process is to obtain an optimal generation capacity mix in the least cost manner to meet the demand at every instance of time while ensuring the most efficient use of resources. Planning is therefore an activity encompassing balancing demand and supply at all instances of time and at all locations, which makes it a regular ongoing process.

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 operating 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 Exhibit.

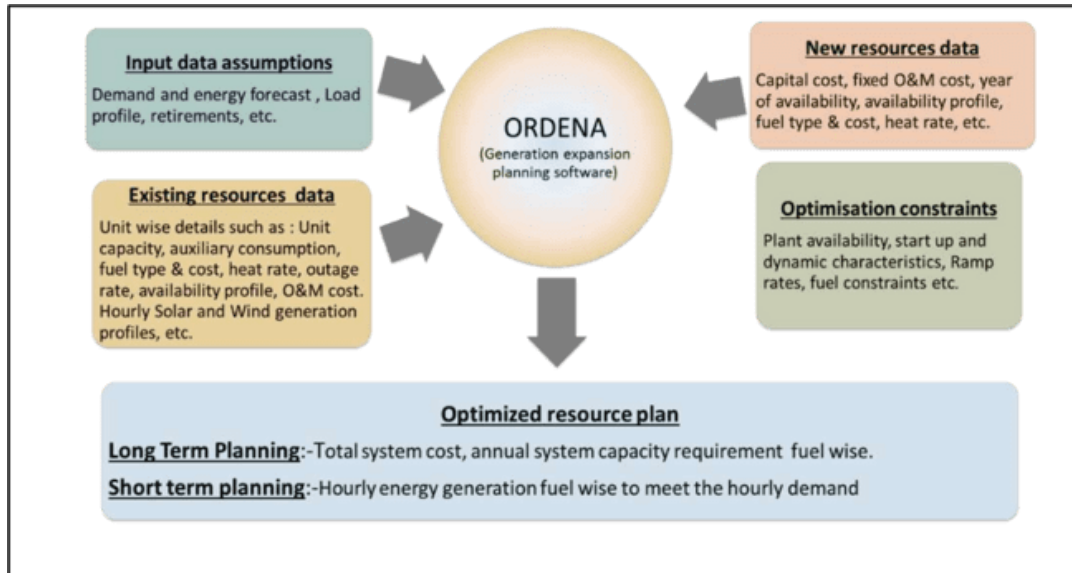


Exhibit: Schematic Diagram-Ordenna

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 instant 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 load in MWh) 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 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 expressed as a certain percent of projected peak load of the system.

5.1 Demand variation

The variation in demand pattern for the past two years has been analyzed. 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.

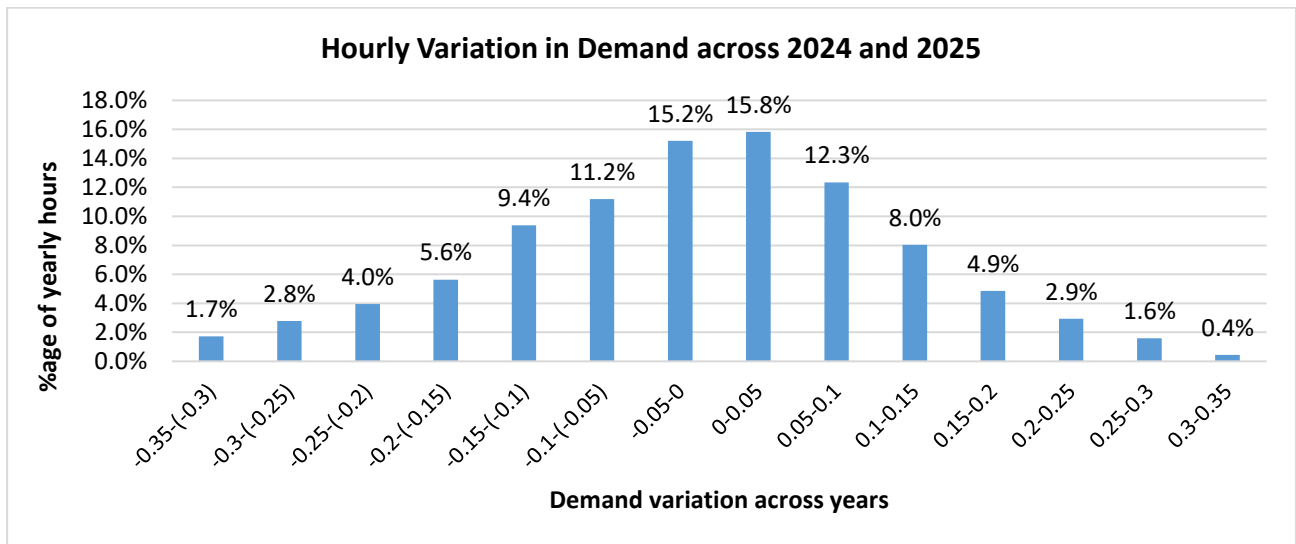


Figure 6 Hourly Variation in Demand across years

It can be observed that the hourly demand typically varies $\pm 15\%$ for 72% 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 varying the projected hourly demand for the future years by varying $\pm 15\%$ 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 $\pm 10\%$ and wind generation has been varied by $\pm 50\%$

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 $\pm 5\%$ 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 electrical energy requirement of Uttarakhand, furnished by UPCL and projections available in the 20th EPS (Electric Power Survey) Mid-term review is tabulated below. The utility's electrical energy requirement and peak electricity demand projections is found to be almost similar to that of 20th EPS (Electric Power Survey) Mid-term review.

Table 7 Future Demand Projection as provided by UPCL and as per mid-term review of 20th EPS Report

Year	Projections by UPCL, Uttarakhand				Projections as per mid-term review of 20 th EPS			
	Peak Electricity Demand		Electrical Energy Requirement		Peak Electricity Demand		Electrical Energy Requirement	
	Projections (MW)	Y-o-Y Growth	Projections (MWh)	Y-o-Y Growth	Projections (MW)	Y-o-Y Growth	Projections (MWh)	Y-o-Y Growth
2025-26	3072		19093		3127		17857	
2026-27	3249	5.76%	20140	5.48%	3347	7.05%	19113	7.04%
2027-28	3433	5.66%	21230	5.41%	3537	5.65%	20426	6.87%
2028-29	3623	5.53%	22370	5.37%	3732	5.52%	21799	6.72%
2029-30	3847	6.18%	23700	5.95%	3917	4.97%	23140	6.15%
2030-31	4004	4.08%	24620	3.88%	4090	4.40%	24427	5.56%
2031-32	4159	3.87%	25520	3.66%	4251	3.95%	25671	5.09%
2032-33	4124	-0.84%	26720	4.70%	4413	3.80%	26935	4.93%
2033-34	4371	5.99%	28330	6.03%	4565	3.45%	28165	4.57%
2034-35	4634	6.02%	30030	6.00%	4707	3.11%	29351	4.21%
2035-36	4822	4.06%	30850	2.73%	4880	3.67%	30428	3.67%

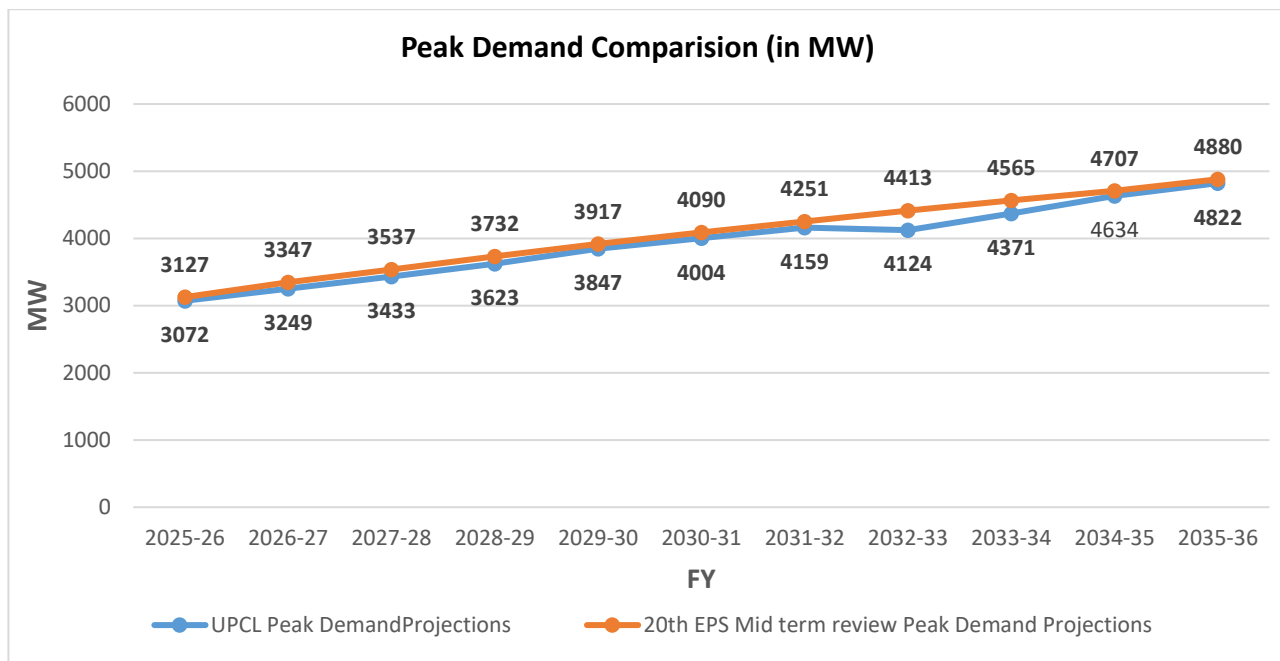


Figure 7 Comparison of Peak Demand Projections of 20th EPS mid-term vs UPCL

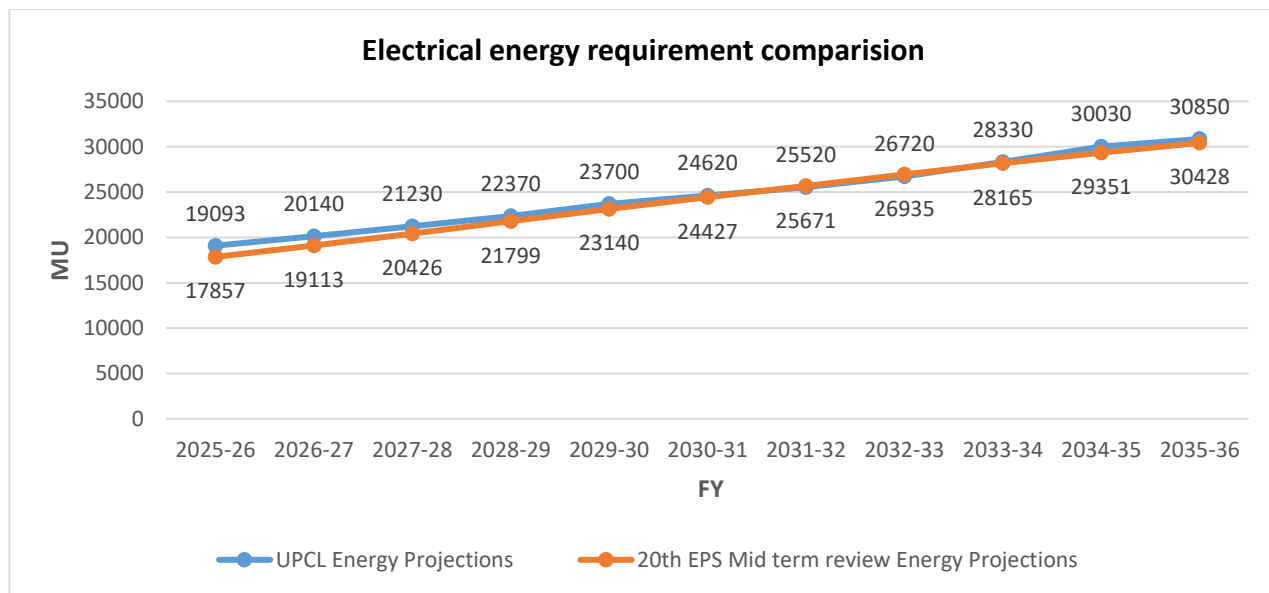


Figure 8 Comparison of Electrical Energy Requirement Projections of 20th EPS mid-term review vs UPCL

The energy requirement and Peak Demand projections of UPCL is almost similar to 20th EPS mid-term review. Therefore, the peak demand and energy requirement projections from UPCL have been considered.

- 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 from National Electricity Plan 2023 (Vol I Generation).

- iv) The capital costs of candidate plants for coal, wind, solar, and storage technologies is detailed in the Annexure and are aligned with current market trends and recent price discovery.
- v) The year-wise planned capacity tie-up as per UPCL is given below.

Table 8 Source wise planned capacity addition (MW) as per UPCL

FY	Coal	Hydro	Nuclear	Solar	DRE	Battery	PSP
2025-26	26	71	0	118.75	0	0	100
2026-27	0	22	0	0	289	60	0
2027-28	0	135	0	0	6	106	0
2028-29	0	66	0	0	4	0	0
2029-30	0	0	33	0	0	0	0
2030-31	0	216	0	0	0	0	0
2031-32	0	315	0	0	0	0	0
2032-33	0	81	0	0	0	0	0
2033-34	0	114	0	0	0	0	1050
2034-35	0	31	0	0	0	0	0
2035-36	0	402	0	0	0	0	0
Total	26	1453	33	118.75	299	166	1150

- vi) **Renewable Purchase Obligation (RPO) trajectory:** Ministry of Power vide gazette notification dated 20th October, 2023 had notified the source wise minimum share of consumption of non-fossil sources (renewable energy) by designated consumers till the year 2029-30.

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

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 %

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. Uttarakhand being a hilly state, the share of DRE in the RPO trajectory has been taken as half of the share as stipulated in RPO order dated 20th October, 2023. The other half of the DRE component has been considered to be met from RE generation from other sources. Therefore, the RPO trajectory is assumed to rise steadily beyond 2029-30. Hence, the suggested trajectory of Renewable Purchase Requirement up to FY 2035-36 is presented in Table 10.

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

Sl. No.	Year	Wind renewable energy	Hydro renewable energy	Other renewable energy	Distributed renewable energy	Total renewable energy
1.	2024-25	0.67%	0.38%	28.10%	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%	35.05%	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 tabulated below:

Table 11 Total Electrical 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	276.8	232.9	5592.3	135.6	6302.6
2.	2026-27	396.8	269.9	6301.8	200.5	7240.3
3.	2027-28	493.4	301.5	7067.5	271.9	8239.4
4.	2028-29	659.9	317.7	7840.7	350.3	9252.2
5.	2029-30	824.8	315.2	8596.0	436.2	10269.2
6.	2030-31	10648.2			533.3	11202.1
7.	2031-32	11420.2			554.0	11994.4
8.	2032-33	12304.6			574.2	12905.8
9.	2033-34	13385.9			601.2	14023.4
10.	2034-35	14489.5			637.4	15165.2
11.	2035-36	15193.6			675.7	15887.8

Table 12 Renewable Energy other than DRE

FY	RE Generation required to meet RPO	RE Generation required to meet RPO	RE Generation available/met (From existing/ planned Contracts)	RPO met (%)	RPO Surplus (+) / Deficit (-)
	(MU)	(%)	(MU)	(%)	(%)
2025-26	6102.1	31.96%	9289	48.65%	16.69%
2026-27	6968.4	34.60%	9345	46.40%	11.80%
2027-28	7889.0	37.16%	9719	45.78%	8.62%
2028-29	8818.2	39.42%	9859	44.07%	4.65%
2029-30	9735.9	41.08%	9859	41.60%	0.52%
2030-31	10648.1	43.25%	10730	43.58%	0.33%
2031-32	11420.2	44.75%	11852	46.44%	1.69%
2032-33	12304.5	46.05%	12168	45.54%	-0.51%
2033-34	13385.9	47.25%	12602	44.48%	-2.77%
2034-35	14489.4	48.25%	12648	42.12%	-6.13%
2035-36	15193.6	49.25%	14379	46.61%	-2.64%

Table 13 Renewable Energy from DRE

FY	DRE required to meet RPO	DRE required to meet RPO	DRE available	DRE available	Surplus (+)/ Deficit (-)
	(MU)	(%)	(MU)	(%)	(%)
2025-26	200.5	1.05%	297	1.56%	0.51%
2026-27	271.9	1.35%	797	3.96%	2.61%
2027-28	350.3	1.65%	806	3.79%	2.14%
2028-29	436.2	1.95%	812	3.63%	1.68%
2029-30	533.3	2.25%	812	3.42%	1.17%
2030-31	554.0	2.25%	812	3.30%	1.05%
2031-32	574.2	2.25%	812	3.18%	0.93%
2032-33	601.2	2.25%	812	3.04%	0.79%
2033-34	637.4	2.25%	812	2.86%	0.61%
2034-35	675.7	2.25%	812	2.70%	0.45%
2035-36	694.1	2.25%	812	2.63%	0.38%

As indicated in the tables above, the state will not be able to meet its RPO requirements from 2032-33 till 2035-36 based on the existing and planned contracts.

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 as per UPCL. Considering the existing and planned capacity contracts, the state will not be able to meet its electrical energy requirement and the total unserved energy for the year 2035-36 has been estimated as 9.1 BU. The year-wise likely unserved energy with the existing and planned capacities is given in figure 9.

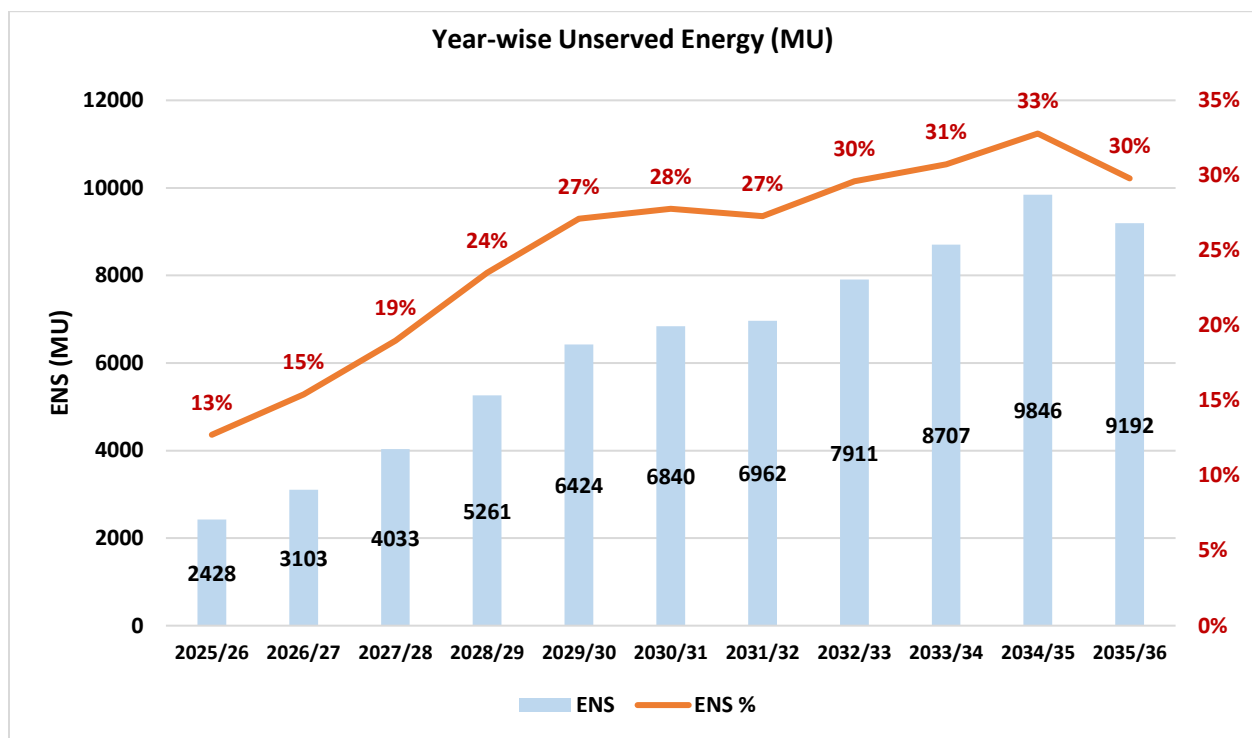


Figure 9 Yearly likely unserved energy (in MU) with the existing and planned capacities

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 (existing and planned) is unable to meet the projected electricity demand.

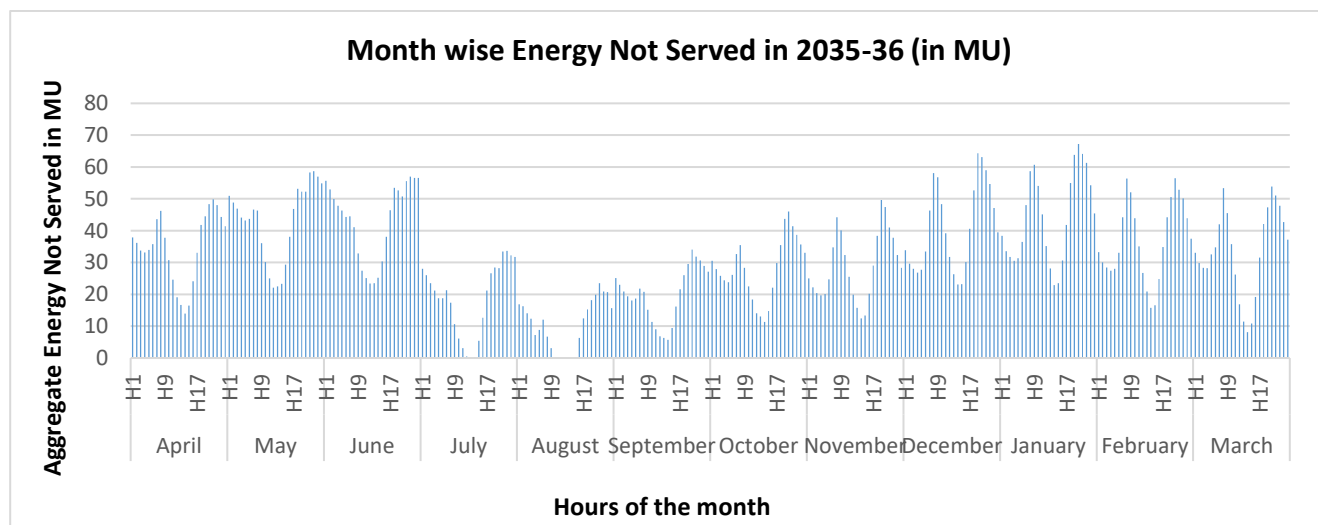


Figure 10 Block-wise Unserved Energy Pattern in MU (2035-36)

The unmet demand occurs during both solar and non-solar hours throughout the year.

7.2 Options to meet the unserved energy

To meet this unserved energy, options (i.e., candidate capacities) are given to the model to find the least cost optimal capacity mix required to meet the demand with RPO obligations. The capacity projections for Uttarakhand are given below:

Table 14: Year-wise contracted capacity projections (existing + planned + additional) (in MW)

Year	Coal	Gas	Nuclear	Biomass	Hydro	Solar	Hybrid	PSP	Battery	DRE	STOA
2025-26	579	390	78	52	2142	644	100	200	0	177	509
2026-27	579	390	78	52	2164	644	100	200	60	466	606
2027-28	579	390	78	52	2299	644	100	200	166	472	722
2028-29	579	390	78	52	2365	644	100	200	166	476	876
2029-30	1079	390	111	52	2365	844	100	200	166	476	598
2030-31	1579	390	111	52	2581	1044	100	200	166	476	238
2031-32	1889	390	111	52	2896	1244	100	200	166	476	9
2032-33	2000	390	111	52	2977	1444	100	200	166	476	43
2033-34	2083	390	111	52	3091	1644	100	1250	166	476	0
2034-35	2215	390	111	52	3122	1644	100	1250	166	476	73
2035-36	2215	390	111	52	3524	1644	100	1250	166	476	0

The projected year-wise contracted capacity mix is given in the figure below:

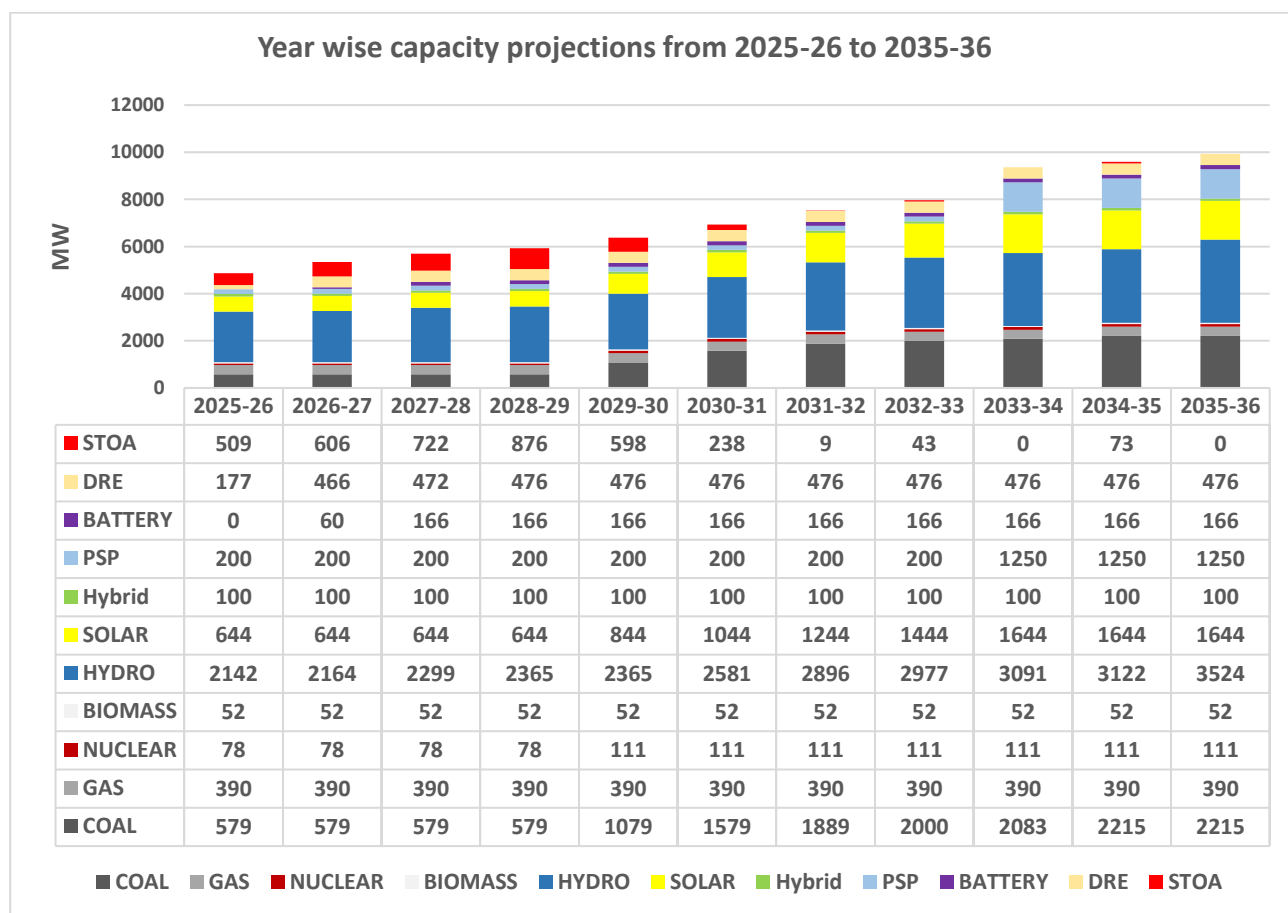


Figure 11 Projected Contracted Capacity Mix Year-wise (MW)

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 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 9928 MW which consists of 2215 MW from coal, 390 MW from gas, 111 MW from nuclear, 3524 MW from hydro, 52 MW from Biomass, 100 MW from Hybrid, 1644 MW from solar, 476 MW from Distributed Renewable Energy (DRE) sources, 166 MW of Battery and 1250 MW of PSP. 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 state is unable to meet the projected peak demand and 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 state's power demand.

The Planning Reserve Margin (PRM) for Uttarakhand has been assessed at 13%. Furthermore, the projected/contracted capacity is in compliance with the stipulated Renewable Purchase Obligation (RPO) targets.

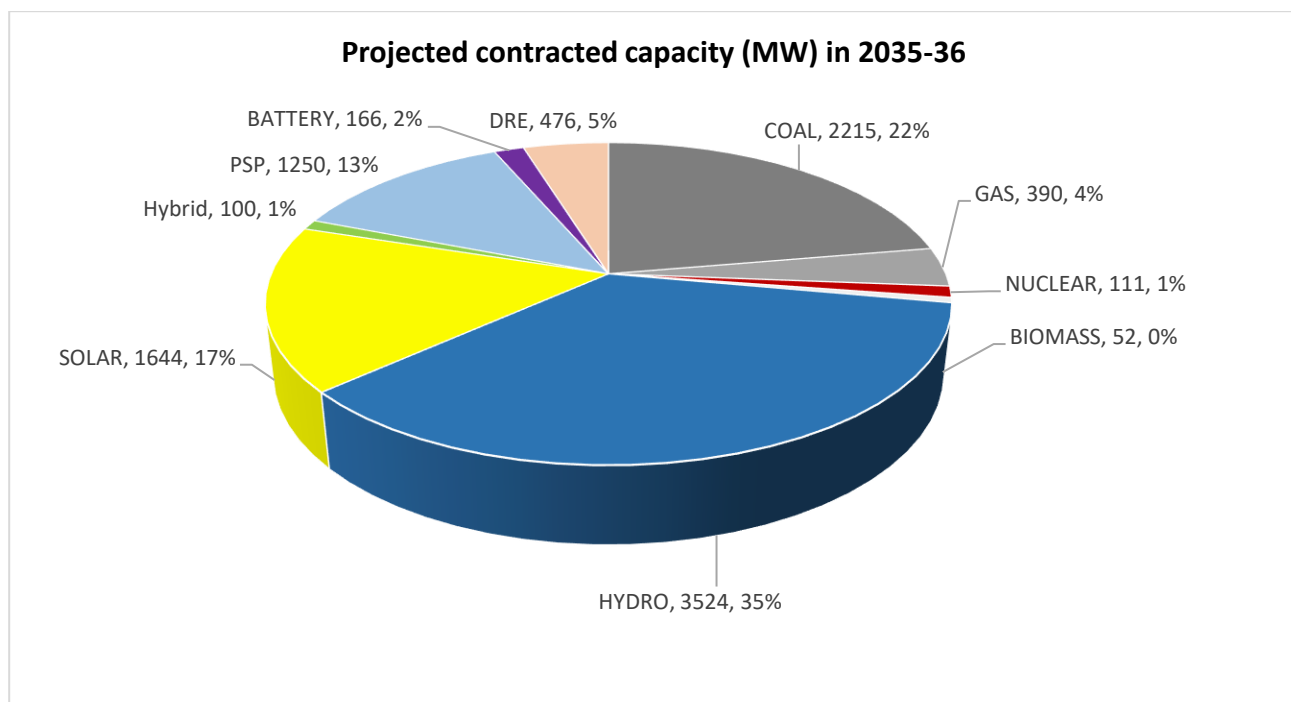


Figure 12 Projected Contracted Capacity Mix in 2035-36

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

Table 15 Year wise Capacity Addition (in MW)

	Coal		Nuclear	Hydro	Solar		DRE	Battery	PSP
Year	Planned Contracts	Additional Requirement	Planned Contracts	Planned Contracts	Planned Contracts	Additional Requirement	Planned Contracts	Planned Contracts	Planned Contracts
2025/26	26	0	0	71	118.75	0	0	0	100
2026/27	0	0	0	22	0	0	289	60	0
2027/28	0	0	0	124	0	0	6	106	0
2028/29	0	0	0	66	0	0	4	0	0
2029/30	0	500	33	0	0	200	0	0	0
2030/31	0	500	0	216	0	200	0	0	0
2031/32	0	309	0	315	0	200	0	0	0
2032/33	0	111	0	81	0	200	0	0	0
2033/34	0	83	0	114	0	200	0	0	1050
2034/35	0	132	0	31	0	0	0	0	0
2035/36	0	0	0	402	0	0	0	0	0
TOTAL	26	1635	33	1453	118.75	1000	299	166	1150

The share of non-fossil fuel-based capacity in the generation mix is projected to remain between 50%-59% from 2025-26 to 2035-36. The projected gross generation mix for the state is shown in Figure 13.

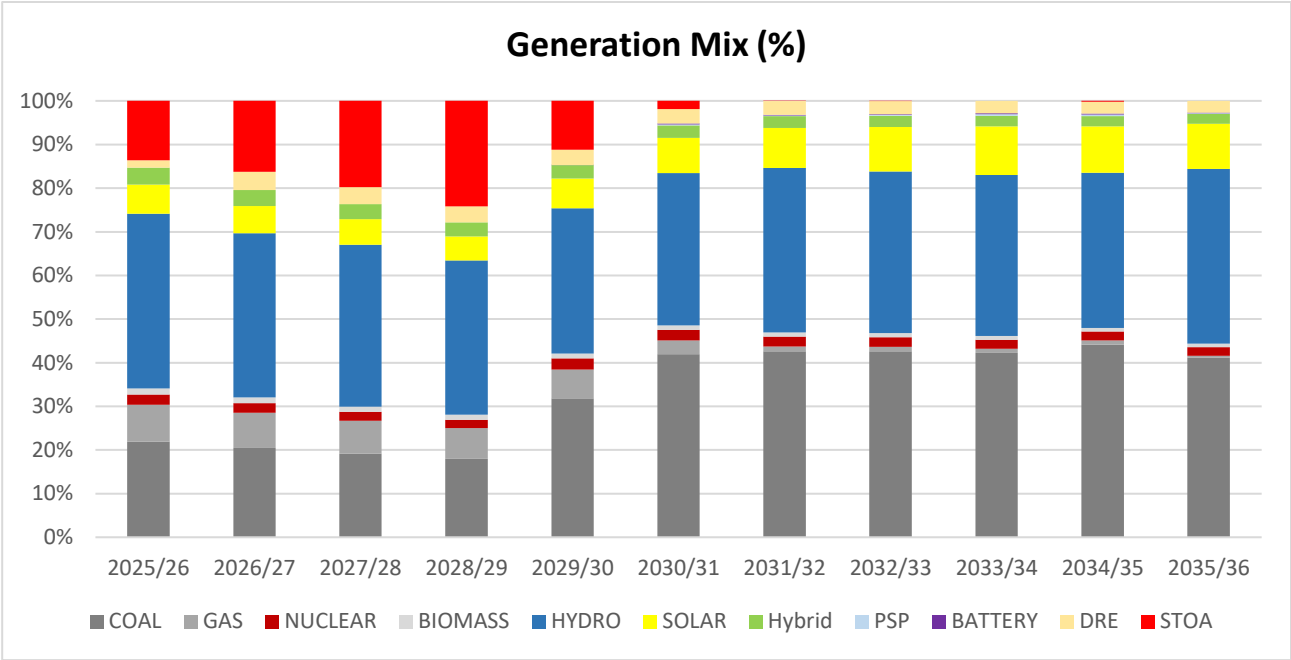


Figure 13 Year-wise projected gross generation mix (in %)

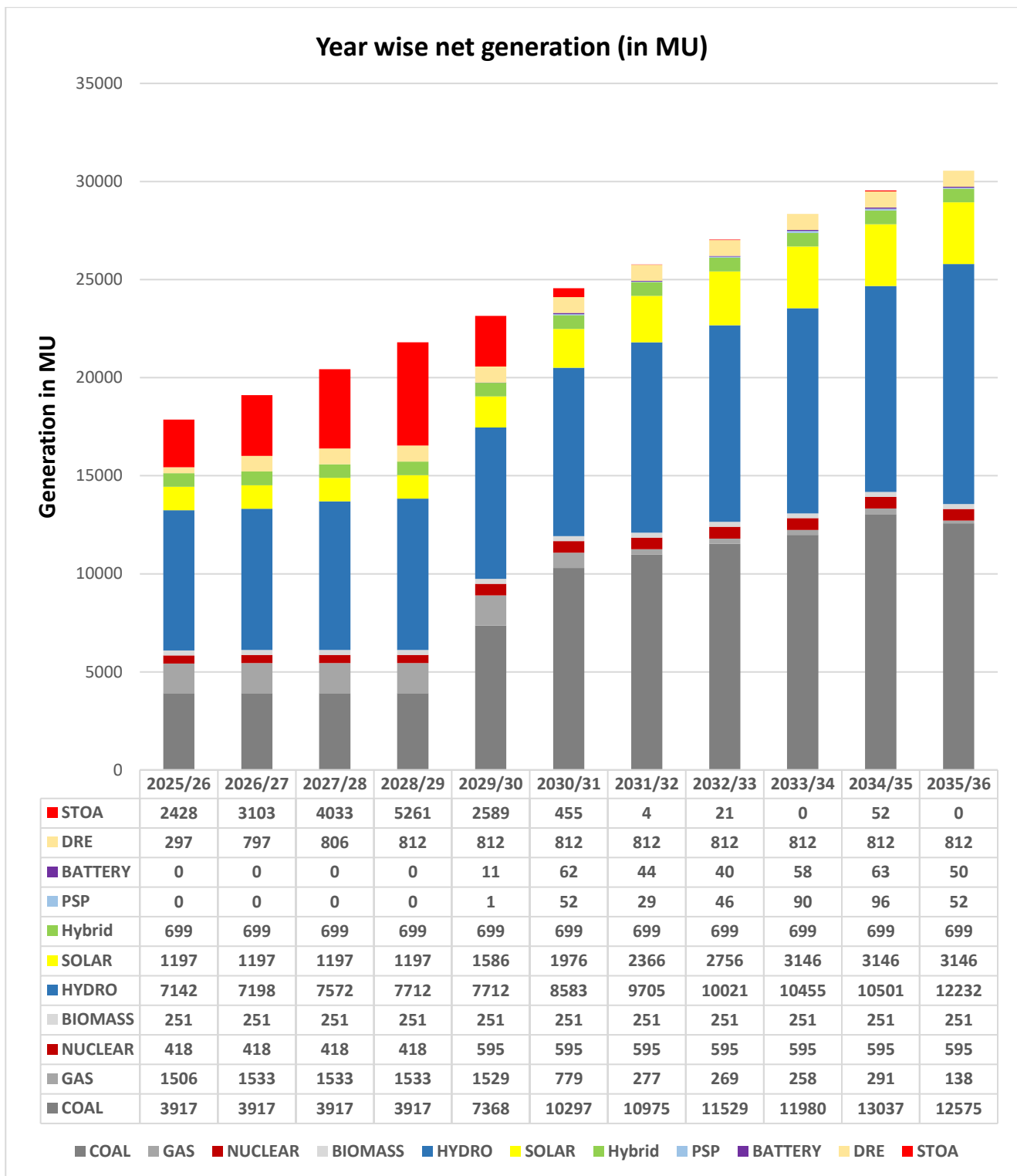


Figure 14 Year-wise projected gross generation (in GWh)

8.0 Conclusions

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

1. The study has been done based on the hourly demand pattern of the year 2024-25. Based on the demand pattern, it is seen that the peak demand season is typically in May and June with peak demand occurring during solar hours.
2. The study has considered electrical energy requirement projections as per UPCL, which envisages that the annual electrical energy requirement of the state is likely to grow at a CAGR of 4.92% while the peak electricity demand for the utility is likely to grow at a CAGR of 4.61% for the period of 2025-26 to 2035-36.
3. Considering only the existing and planned capacity addition by UPCL, Uttarakhand is likely to witness energy deficit ranging from 2.4 to 9.8 BUs in different years from 2025-26 to 2035-36.
4. The Resource adequacy studies have projected likely optimal capacity mix for future years till 2035-36 which is 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 9,928 MW which consists of 2215 MW from coal, 390 MW from gas, 52 MW from Biomass, 111 MW from nuclear, 3524 MW from hydro, 100 MW from Hybrid, 1644 MW from solar, 476 MW from Distributed Renewable Energy (DRE), 1250 MW of PSP and 166 MW of BESS.
5. The contracted capacity in June, 2025 comprises of 76% from non-fossil sources. In 2035-36, the non-fossil based (that includes nuclear, hydro, solar, wind, biomass, DRE, hybrid and Storage) capacity are likely to constitute around 74 % of the total contracted capacity.
6. The state needs to contract STOA/MTOA of around 12 MW to 876 MW in different years as outlined in the report. 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.
7. The projected capacity and generation mix outlined in the report meet the utility's RPO requirements for the years 2025-26 to 2035-36.
8. The Planning Reserve Margin (PRM) for Uttarakhand has been assessed at 13%. Further, the study indicates year-wise short-term/medium-term/bilateral requirements to meet the demand optimally.
9. Accurate demand assessment is fundamental to capacity expansion modelling and directly impacts the Resource Adequacy (RA) study outcomes. To achieve realistic and data-driven results, States 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 state can meet the projected peak demand and 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 state's power demand.

Planned Future Contracted (MW) considered in the study

Sr. No.	Tied capacity name	Type of generation	Expected COD	Tentative UPCL share (in MW)
1.	THDC-Khurja TPS	Thermal	2025-26	26
2.	Vishnugad Pipalkoti	Hydro	2025-26	71
3.	UJVNL solar	Solar	2025-26	38.75
4.	SJVN Solar	Solar	2025-26	80
5.	Tehri	PSP	2025-26	100
6.	Devali	Hydro	2026-27	13
7.	Phata Bhyng	Hydro	2026-27	9.12
8.	Khatima	BESS	2026-27	15
9.	Dhakrani	BESS	2026-27	30
10.	Tiloth	BESS	2026-27	15
11.	MSSY	Solar DRE	2026-27	250
12.	Chilla	BESS	2027-28	90
13.	Pathri	BESS	2027-28	16
14.	Hanol Tuini	Hydro	2027-28	7.2
15.	Tapovan Vishnugad	Hydro	2027-28	83
16.	Melkhet Power	Hydro	2027-28	24
17.	Khutani Syama Power	Hydro	2027-28	21
18.	Bokang Bailang	Hydro	2028-29	19.8
19.	Jakol Sankri (SJVN)	Hydro	2028-29	5.28
20.	Goriganga	Hydro	2028-29	18
21.	Barnigad K Ramchandra Rao	Hydro	2028-29	22.8
22.	Tankul	Hydro	2030-31	12
23.	Tiuni Plasu UJVN	Hydro	2030-31	72
24.	Sarkari Bhyol Rupsibagar UJVN	Hydro	2030-31	120
25.	Jimbagad (UJVN)	Hydro	2030-31	12
26.	Painagad (UJVN)	Hydro	2031-32	15
27.	Lakhwar (UJVN)	Hydro	2031-32	300
28.	Arakot Tiuni UJVN Hydro	Hydro	2032-33	81
29.	Sela Urthing	Hydro	2033-34	114
30.	Lakhwar-Vyasi	PSP	2033-34	300
31.	Vyasi-Katapathar	PSP	2033-34	150
32.	Ichari	PSP	2033-34	600
33.	Urgam - II	Hydro	2034-35	10
34.	Silingad	Hydro	2034-35	5
35.	Supin	Hydro	2034-35	16
36.	Mori Tuni	Hydro	2035-36	102

37.	Bowla Nandprayag UJVN	Hydro	2035-36	300
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Assumption for Resource Adequacy Studies

1. Electricity Demand & peak requirement: As per projections made by UPCL.
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.

RE CUF considered

Hydro	Wind	Solar	DRE
40 %	24%	20-22%	19%

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	-
Storage Energy Storage	Candidate	98	NA	-

Technology	Type	Heat Rate (MCal/MWh)		Aux. Consum. (%)
		At max loading	At min loading	
Coal	Existing/Planned	2300 to 2879	2438 to 3052	7.0
	Candidate (SC & USC)	2060 to 2125	2183 to 2253	6.5

Gas	Existing	2000 to 2900	2260 to 3277	2.5
Nuclear	Existing/Planned	2777	2777	10
	Candidate	2777	2777	10
Biomass	Existing/Planned	4200	4450	8
	Candidate	4200	4450	8
Hydro	Existing/Planned	-	-	0.7
	Candidate	-	-	0.7
Pumped Storage	Existing/Planned	-	-	pump efficiency 80 %
	Candidate	-	-	
Storage 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
Wind (Onshore)	8 Cr	1% of Capex	1.5	25
Storage (2-Hour)	5.13 Cr to 3.13 Cr	1 % of Capex	0.5	14
Storage (4-Hour)	8.22 Cr to 4.72 Cr	1 % of Capex	0.5	14
Storage (5-Hour)	9.77Cr to 5.51 Cr	1 % of Capex	0.5	14
Storage (6-Hour)	11.31 Cr to 6.30 Cr	1 % of Capex	0.5	14

