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

January, 2026

Government of India
Ministry of Power
Central Electricity Authority

Contents

Disclaimer

This Resource Adequacy Study for the state of Sikkim has been conducted based on data and inputs provided by the Sikkim. 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 Sikkim 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 any financial implications etc., 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 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 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 2034-35, based on the data available with CEA 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 2035-36, incorporating the latest data furnished by the state and planning assumptions.

The electrical energy requirement and peak electricity demand for Sikkim, as furnished by the state, are projected to increase with a CAGR of 5.0% and 2.97% 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 Sikkim is projected to increase with a CAGR of 3.3% and 2.1% respectively from 2025-26 to 2035-36. The study has been done considering the demand projections as provided by the state, as these projections are more aligned with the past growth trend of peak electricity demand and electrical energy requirement of the state. 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 capacity or by procuring power. In view of the reduction in cost of solar panels and technology options like 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 Sikkim, based on existing contracted capacity and planned capacity additions, 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 23 MU, accounting for around 2% of the projected 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 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, variation in RE and forced outage of thermal generators (Coal/ Lignite) etc.

Generation capacity expansion pathways have been considered for the long-term study based on the yearly capacity addition plan of Sikkim along with RPO constraints for solar and DRE technologies. The Renewable capacities have been assessed in view of adherence to RPO notified by order of Ministry of Power dated 20th October,2023, 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 629 MW which consists of 116 MW from coal; 469 MW from hydro; 7 MW from solar; 21 MW from Distributed Renewable Energy (DRE) source and 16 MW from MToA/SToA arrangement. This capacity shall be able to meet the projected demand with prescribed reliability criteria.

1.0 Introduction

Ministry of Power has notified the 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 Sikkim based on inputs furnished by Sikkim. 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 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 available with CEA and in accordance with the then 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 2034–35)

1. In the earlier Resource Adequacy (RA) study, financial year 2022-23 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 Sikkim as on 31st March, 2023 is given in Fig. 1.

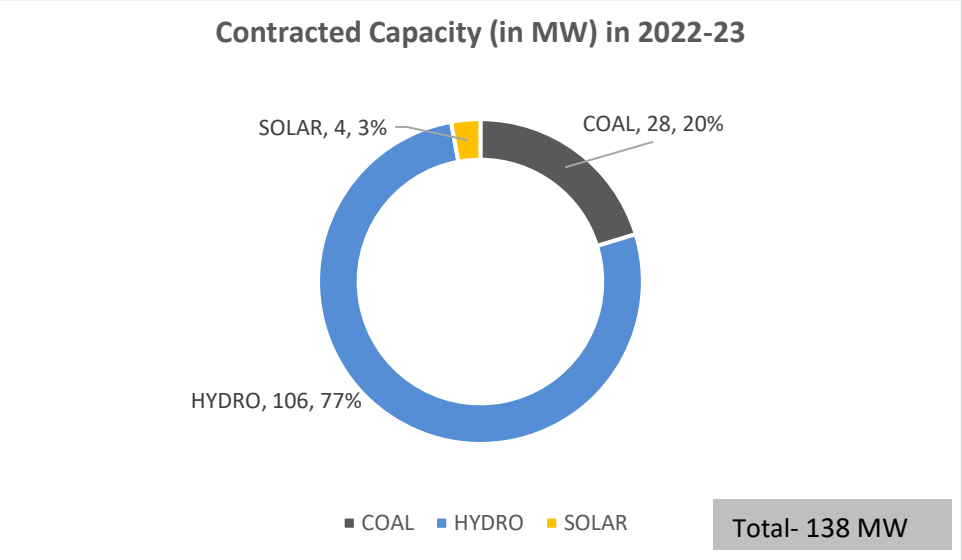


Figure 1: Fuel-wise Contracted Capacity (in MW) as on 31st March, 2023

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

Table 1: Peak electricity demand and electrical energy projections provided by the state

	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35
Electrical Energy Projections (MU)	721	757	794	834	876	920	966	1014	1065	1118	1174
Y-o-Y Growth		5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Peak Electricity Demand Projections (MW)	142	158	165	173	182	191	201	210	222	235	248
Y-o-Y Growth		11.3%	4.4%	4.8%	5.2%	4.9%	5.2%	4.5%	5.7%	5.9%	5.5%

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	Hydro	Solar	DRE	SToA/MToA*	Total
2024-25	29	106	4	4	93	236
2025-26	42	122	4	6	78	252
2026-27	42	122	4	9	87	264
2027-28	42	187	4	11	78	322
2028-29	54	187	4	14	74	333
2029-30	84	187	4	17	48	340
2030-31	110	187	4	20	28	349
2031-32	119	187	4	23	29	362
2032-33	129	187	4	26	30	376
2033-34	139	187	4	30	30	390
2034-35	142	187	4	33	50	416

*****_The SToA/MToA value represents the annual 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 addition (MW)

FY	Thermal		Hydro	DRE	Total		SToA/MToA*
	Planned	Additional	Planned	Additional	Planned	Additional	Additional
2024-25	1	0	0	4	1	4	93
2025-26	13	0	16	2	29	2	78
2026-27	0	0	0	2	0	2	87
2027-28	0	0	65	2	65	2	78
2028-29	12	0	0	3	12	3	74
2029-30	0	30	0	3	0	33	48
2030-31	0	26	0	3	0	29	28
2031-32	0	9	0	3	0	12	29
2032-33	0	10	0	3	0	13	30
2033-34	0	10	0	4	0	14	30
2034-35	0	3	0	4	0	7	50
Total	26	88	81	33	107	121	

*_Requirement is for a particular year_

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

3.1 Present Power Scenario in Sikkim

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

Table 4: Power Supply Position of Sikkim

Power Supply Position						
Year	**Energy required (MU)**	**Energy supplied (MU)**	**Gap (MU)**	**Peak Demand (MW)**	**Peak Met (MW)**	**Demand not met (MW)**
2020-21	546	546	0	120	120	0
2021-22	609	609	0	133	133	0
2022-23	587	587	0	124	124	0
2023-24	543	543	0	133	133	0
2024-25	574	574	0	138	138	0

The data in Table 4 indicates that over the past five years, Sikkim's electrical energy requirement and peak electricity demand have increased at a Compound Annual Growth Rate (CAGR) of 1.3% and 3.6%, respectively.

As of March 2025, the total contracted capacity for Sikkim is 185 MW. Out of the total contracted capacity (CC), the share of non-fossil fuel-based CC is 51.4 %.

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	90	48.6
Hydro	95	51.4
Total	**185**	**100**

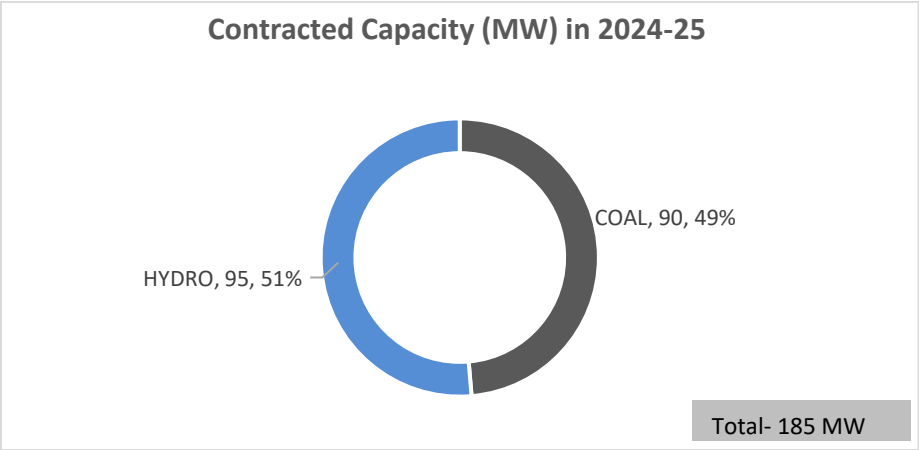


Figure 2: Fuel-wise Contracted Capacity (in MW) as on 31st March, 2025

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 Sikkim is typically during the months from January to February. Sikkim witnesses peak demand during non-solar hours. The month wise average hourly demand observed for the year 2024-25 is shown in Fig. 3.

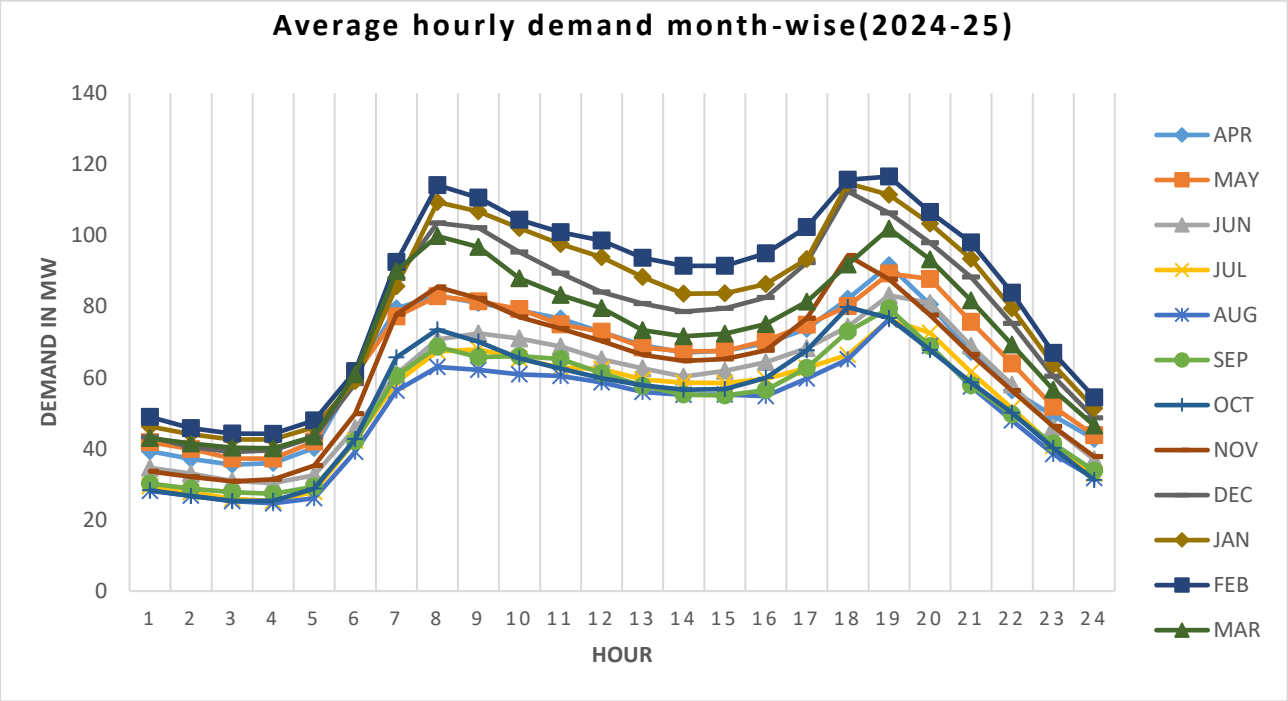


Figure 3: Average Hourly Demand Variation (Month-wise) for 2024-25

From the hourly demand data of 2024-25 the daily peak during solar hours and non-solar hours are plotted in Fig. 4. Daily peak occurs in Sikkim during non-solar hours in almost every month of the year.

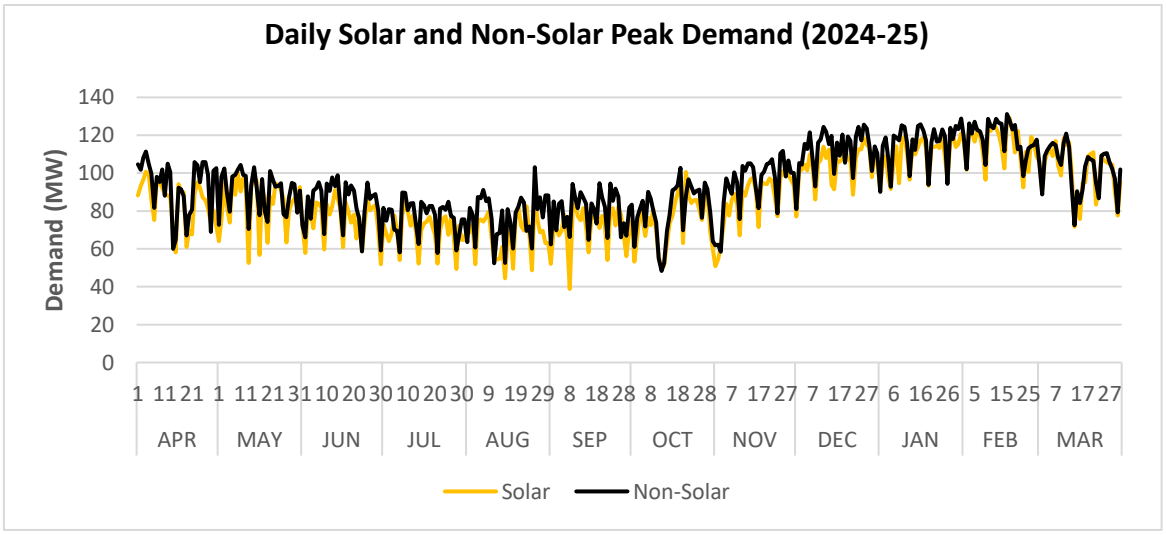


Figure 4: Solar and non-solar peak in MW for the year 2024-25

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.

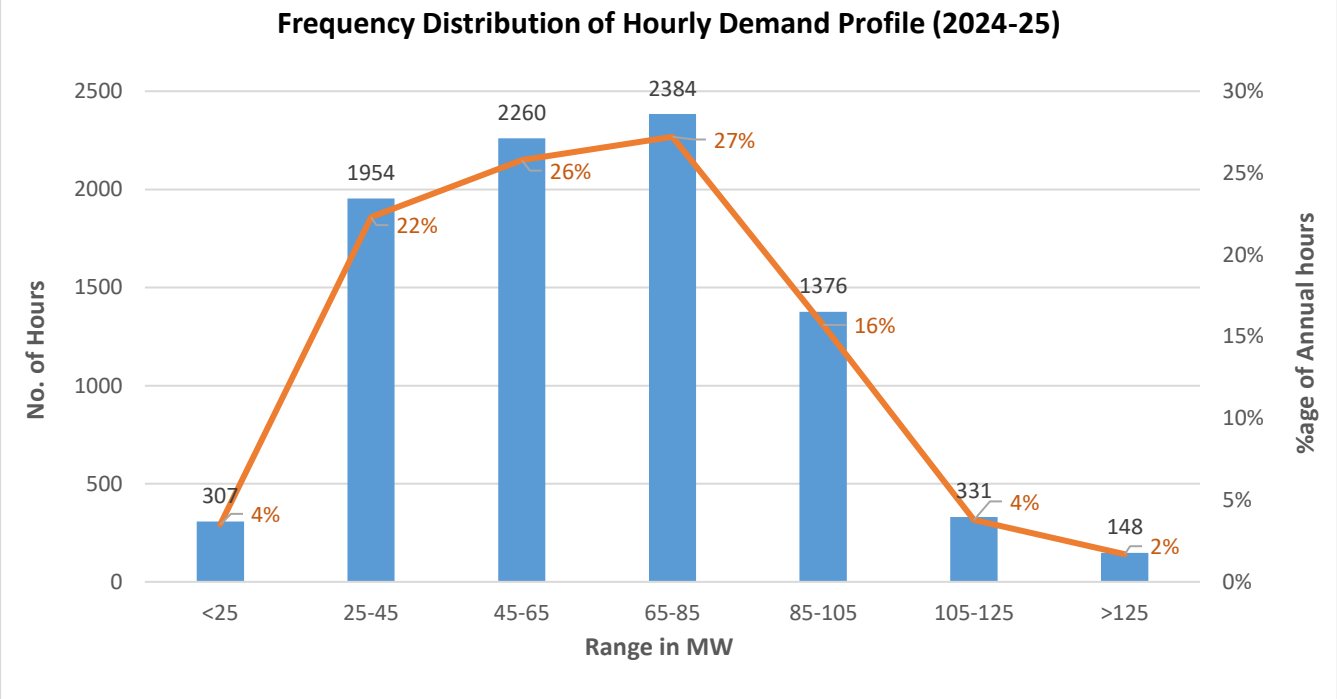


Figure 5: Frequency Distribution of Hourly Demand Profile of 2024-25

4.0 Principles of Generation Planning

The objective of the Generation Planning process is to obtain an optimal generation capacity mix in the least cost manner to meet the projected electricity demand 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
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 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 Fig. 6.

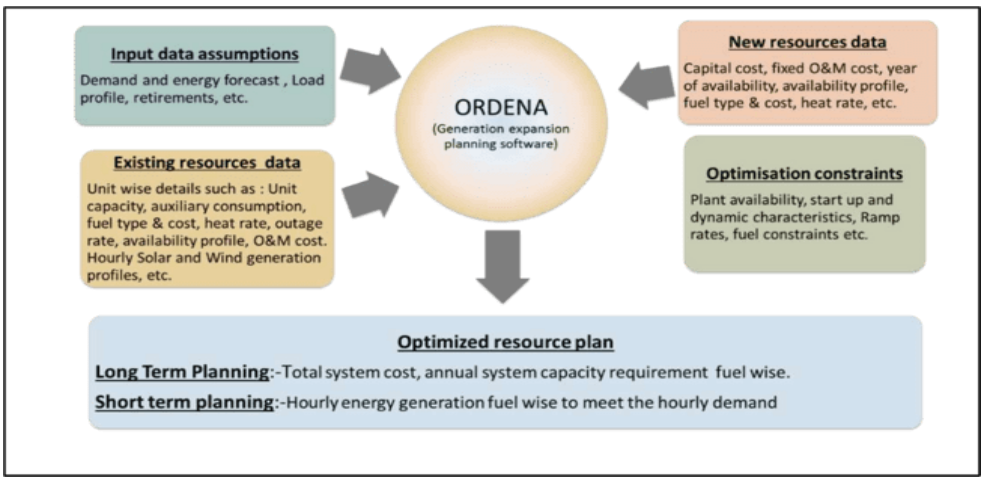


Figure 6: Schematic Diagram

5.0 Reliability Analysis

One of the main criteria of resource adequacy studies is to determine the reliability of the system to meet the electricity 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 and Energy Not Served, ENS) and the system robustness in case of 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 electricity demand pattern for last two years viz. 2023-24 and 2024-25 (with 2023-24 as base year) has been analyzed. The electricity demand variation pattern across 2023-24 and 2024-25 is shown in Fig. 7.

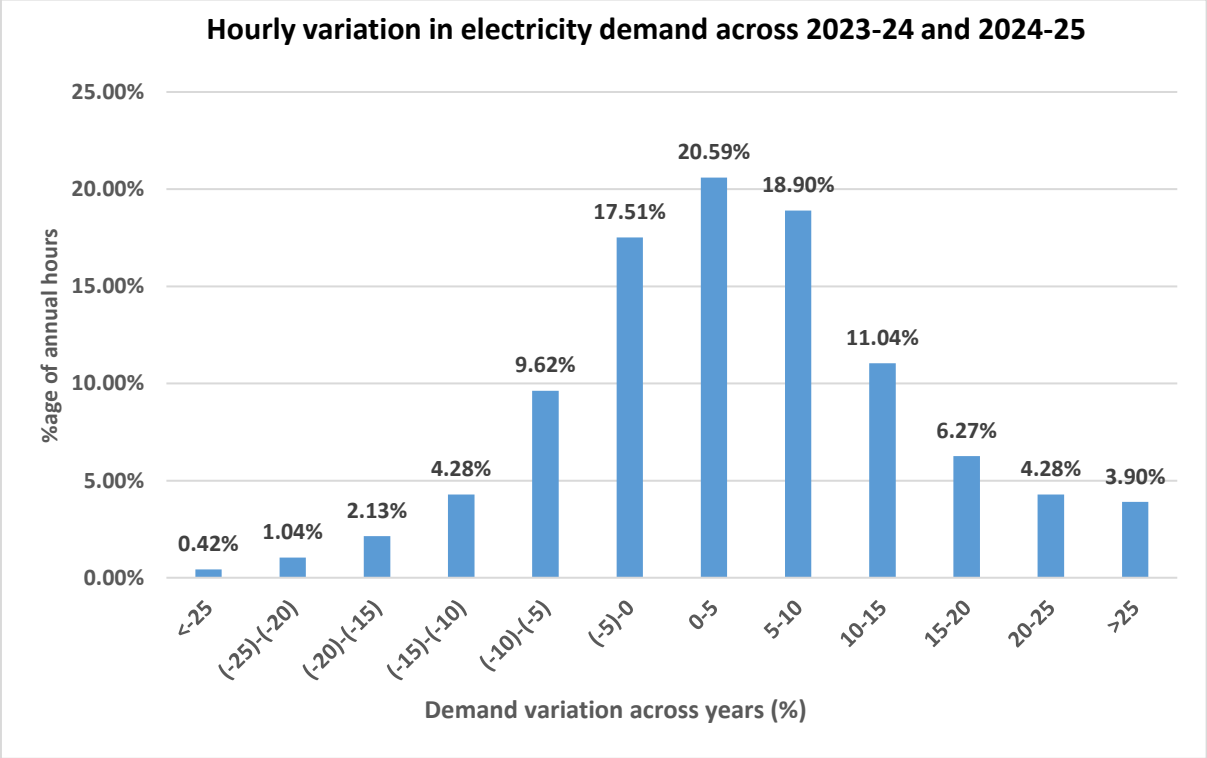


Figure 7: Hourly Variation in Electricity Demand across years

It can be observed that the hourly demand typically varies within ±10% for 66.62% 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 is considered based on the observed solar generation data to determine the optimal capacity mix. However, due to intermittent nature of solar, generation may vary across years. As per the analyses carried out based on historical generation data, solar and hydro based generation has been varied by ± 10% 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 for Sikkim is given in Table 6. Electricity demand projection as per Sikkim has been considered in the Study.

Table 6: Electricity Demand Projections

	Projections as per Sikkim		Projections as per mid-term review of 20th EPS	
FY	Peak Electricity Demand Projections (MW)	Electrical Energy Requirement Projections (MU)	Peak Electricity Demand Projections (MW)	Electrical Energy Requirement Projections (MU)
2025-26	147	716	147	597
2026-27	152	752	155	627
2027-28	156	789	160	658
2028-29	161	829	165	690
2029-30	166	870	168	715
2030-31	171	914	170	733
2031-32	176	960	168	734
2032-33	181	1008	171	761
2033-34	187	1058	174	787
2034-35	192	1111	177	811
2035-36	197	1167	181	826

ii) Future demand profile till the year 2035-36 has been projected based on the demand profile for the year 2024-25 as the base profile.

iii) The actual solar and hydro generation profiles and CUFs have been considered as per the data available in CEA.

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

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

Table 7: Source wise planned capacity addition

FY	Hydro (MW) (Conventional/Small)	Coal (MW)	Solar (MW)
2025-26	-	14	-
2026-27	120	-	7
2027-28	75	-	-
2028-29	61	12	-
2029-30	97	-	-
2030-31	21	-	-
Total	**374**	**26**	**7**

vi) **Renewable Purchase Obligation (RPO) trajectory**: Ministry of Power 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 (%) as per MoP order

Sl. No.	Year	Wind renewable energy	Hydro renewable energy	Other renewable energy	Distributed renewable energy	Total renewable energy
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1.	**2024-25**	0.67	0.38	27.35	1.5	29.91
2.	**2025-26**	1.45	1.22	28.24	2.1	33.01
3.	**2026-27**	1.97	1.34	29.94	2.7	35.95
4.	**2027-28**	2.45	1.42	31.64	3.3	38.81
5.	**2028-29**	2.95	1.42	33.1	3.9	41.36
6.	**2029-30**	3.48	1.33	34.02	4.5	43.33

Further, in view of the country's energy transition goals as well as the long-term net zero target of 2070, it is estimated that the share of RE generation in the generation mix will continue to proportionally increase beyond 2029-30. Therefore, the RPO trajectory is assumed to rise steadily beyond 2029-30. However, the DRE percentage has been assumed to be constant from 2029-30 onwards. Further, being a hilly state, the DRE percentage for Sikkim has been taken as half of the percentage what other states are

obliged to meet. 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 considered for the study (in %)

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	28.10	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	45.5
8.	**2031-32**	44.75			2.25	47
9.	**2032-33**	46.05			2.25	48.3
10.	**2033-34**	47.25			2.25	49.5
11.	**2034-35**	48.75			2.25	51.0
12.	**2035-36**	49.75			2.25	52.0

** For Hilly states, DRE Percentage is half of the percentage what other states are obliged to meet.*

Based on the specified trajectory, 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**	10.38	8.74	209.72	7.52	236.35
2.	**2026-27**	14.81	10.08	235.30	10.15	270.34
3.	**2027-28**	19.33	11.20	262.66	13.02	306.21
4.	**2028-29**	24.46	11.77	290.56	16.17	342.87
5.	**2029-30**	30.28	11.57	315.55	19.58	376.97
6.	**2030-31**	395.31			20.57	415.87
7.	**2031-32**	429.60			21.60	451.20
8.	**2032-33**	464.18			22.68	486.86
9.	**2033-34**	499.91			23.81	523.71
10.	**2034-35**	541.61			25.00	566.61
11.	**2035-36**	580.58			26.26	606.84

As indicated in Table 11, the state with its existing and planned capacity additions will be able to meet its RPO requirements from RE sources. However, as indicated in Table 12, from the year 2025-26 onwards, the state will not be able to fulfill its DRE obligations.

Table 11: Renewable Energy (excl. DRE) deficit/surplus

FY	RE Generation required to meet RPO		RE Generation available/met (From existing/ planned contracts)		RPO Surplus (+) / Deficit (-)
	(MU)	(%)	(MU)	(%)	(%)
2025-26	228.83	31.96%	283.28	40%	7.60%
2026-27	260.19	34.60%	507.66	68%	32.91%
2027-28	293.19	37.16%	572.31	73%	35.38%
2028-29	326.71	39.41%	635.35	77%	37.23%
2029-30	357.40	41.08%	698.46	80%	39.20%
2030-31	395.31	43.25%	735.79	81%	37.25%
2031-32	429.60	44.75%	763.96	80%	34.83%
2032-33	464.18	46.05%	793.36	79%	32.66%
2033-34	499.91	47.25%	821.78	78%	30.42%
2034-35	541.61	48.75%	849.96	77%	27.75%
2035-36	580.58	49.75%	902.27	77%	27.57%

Table 12: DRE Surplus/Deficit

FY	DRE required to meet RPO		DRE available/met (From existing/ planned contracts)		RPO Surplus (+)/ Deficit (-)
	(MU)	(%)	(MU)	(%)	(%)
2025-26	7.52	1.05%	0.00	0.0%	-1.05%
2026-27	10.15	1.35%	0.00	0.0%	-1.35%
2027-28	13.02	1.65%	0.00	0.0%	-1.65%
2028-29	16.17	1.95%	0.00	0.0%	-1.95%
2029-30	19.58	2.25%	0.00	0.0%	-2.25%
2030-31	20.57	2.25%	0.00	0.0%	-2.25%
2031-32	21.60	2.25%	0.00	0.0%	-2.25%
2032-33	22.68	2.25%	0.00	0.0%	-2.25%
2033-34	23.81	2.25%	0.00	0.0%	-2.25%
2034-35	25.00	2.25%	0.00	0.0%	-2.25%
2035-36	26.26	2.25%	0.00	0.0%	-2.25%

7.0 Outcome of the Study

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 23 MUs which is about 2% of the electrical energy requirement in 2035-36. The year-wise likely unserved energy with the planned capacities is given in Fig 8.

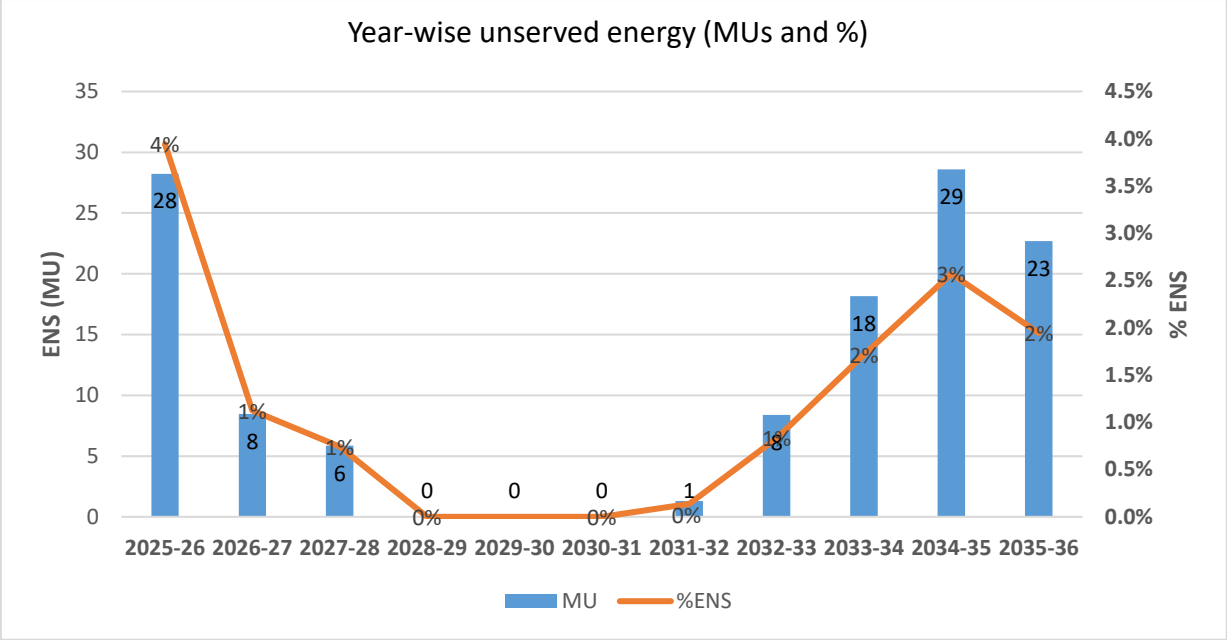


Figure 8: Yearly likely unserved energy (in MU) with the existing and planned capacities

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 projected electricity demand. Details are shown in Fig. 9.

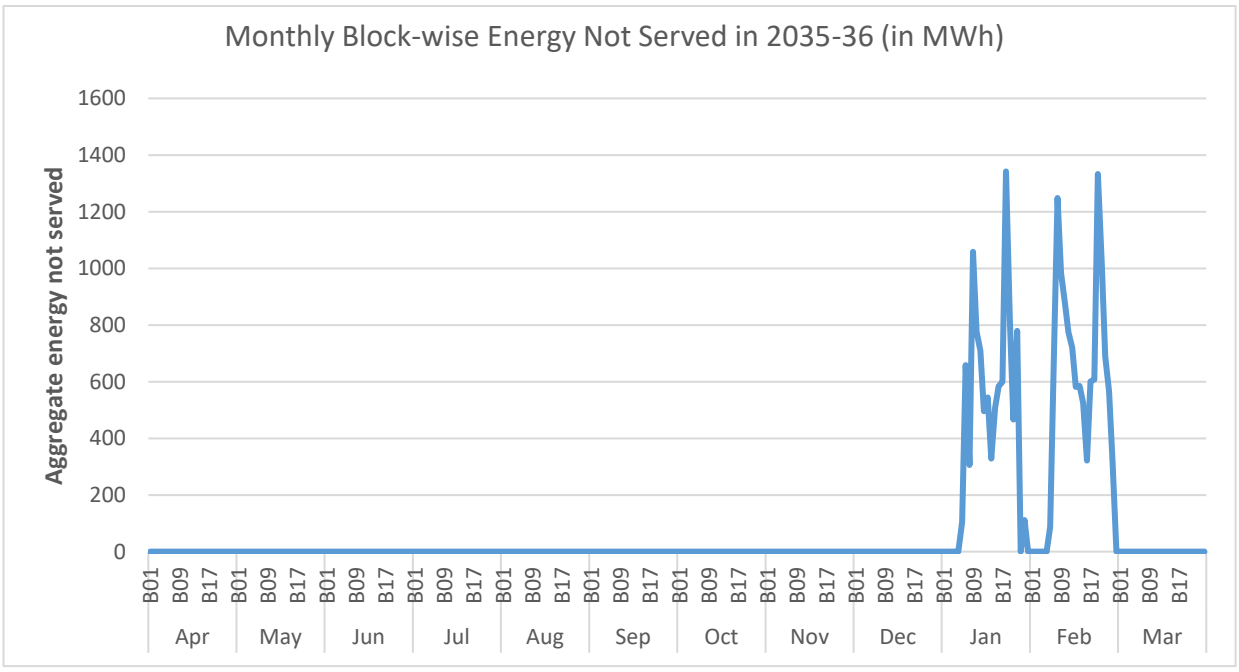


Figure 9: Monthly Block-wise Unserved Energy Pattern MWh (2035-36)

From the above figure, it can be seen that unserved energy is high during high demand and low hydro availability months viz. January to February.

7.2 Investment options to meet the unserved energy

To meet this unserved energy, investment options are given to the model to find the least cost optimal capacity mix required to meet the projected electricity demand with RPO obligations. The capacity projections for Sikkim are given in Table 13.

Table 13: Year-wise contracted capacity projections (existing + planned + additional) (in MW)

Year	Coal	Hydro	Solar	DRE	SToA/MToA
2025-26	104	95	0	6	26
2026-27	104	215	7	8	10
2027-28	104	290	7	11	6
2028-29	116	351	7	13	0
2029-30	116	448	7	16	0
2030-31	116	469	7	17	0
2031-32	116	469	7	18	0
2032-33	116	469	7	18	7
2033-34	116	469	7	19	14
2034-35	116	469	7	20	23
2035-36	116	469	7	21	16

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

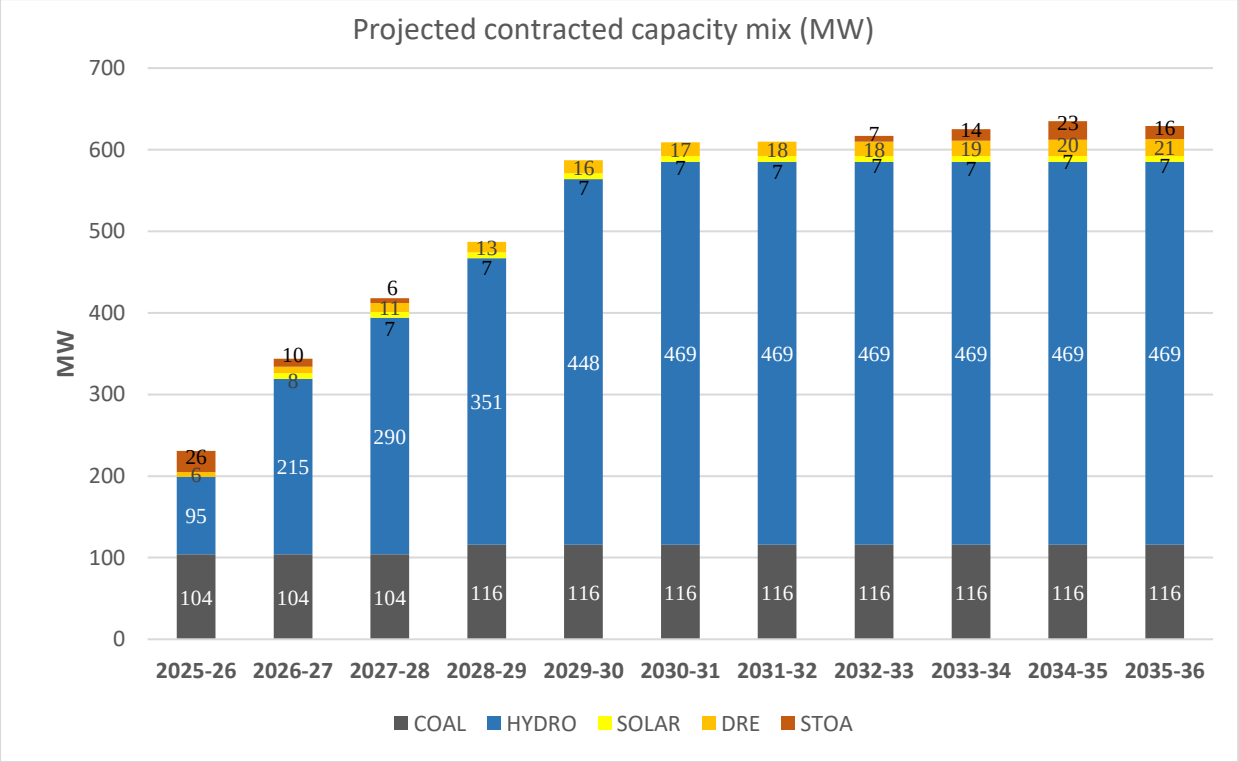


Figure 10: Projected Year-wise Contracted Capacity Mix (MW)

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 per the resource adequacy studies, the likely total projected contracted capacity for the year 2035-36 is around 629 MW which consists of 116 MW from coal; 469 MW from hydro; 7 MW from solar; 21 MW from Distributed Renewable Energy (DRE) source and 16 MW from 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 planning reserve margin for the state has been assessed as 3 %. Capacity mix required by 2035-36 is shown in Figure 11.

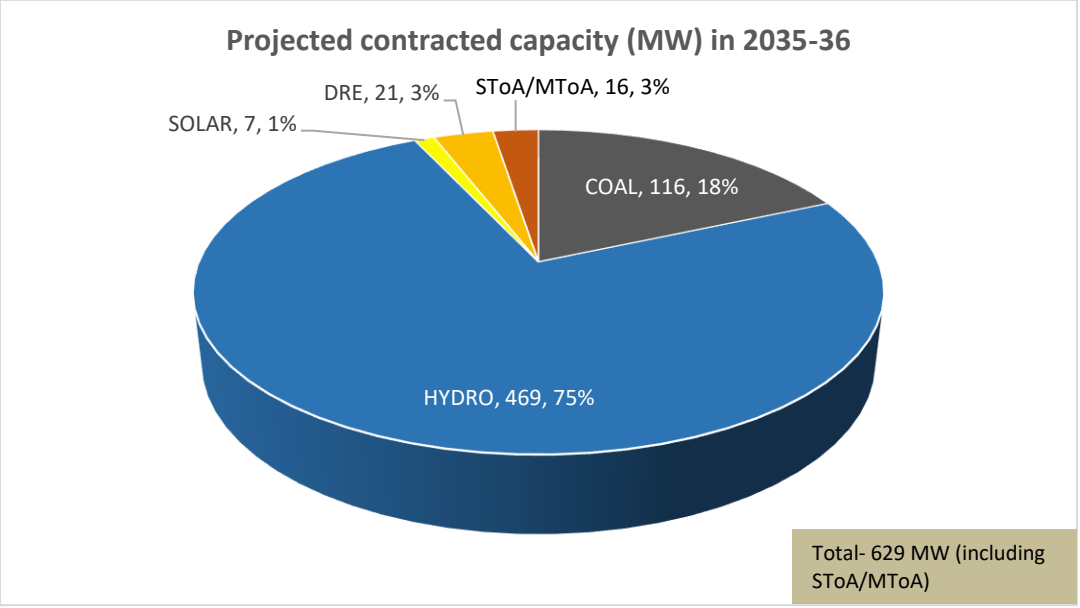


Figure 11: Contracted Capacity Mix in 2035-36

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 14.

Table 14: Year wise Capacity Addition (in MW)

FY	Coal	Hydro	Solar	DRE	TOTAL		STOA/MTOA*
	Planned	Planned	Planned	Additional	Planned	Additional	Additional
2025-26	14	-	-	6	14	6	26
2026-27	-	120	7	2	127	2	10
2027-28	-	75	-	3	75	3	6
2028-29	12	61	-	2	73	2	0
2029-30	-	97	-	3	97	3	0
2030-31	-	21	-	1	21	1	0
2031-32	-	-	-	1	-	1	0
2032-33	-	-	-	0	-	0	7
2033-34	-	-	-	1	-	1	14
2034-35	-	-	-	1	-	1	23
2035-36	-	-	-	1	-	1	16
Total	**26**	**374**	**7**	**21**	**407**	**21**	

*Yearly requirement

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

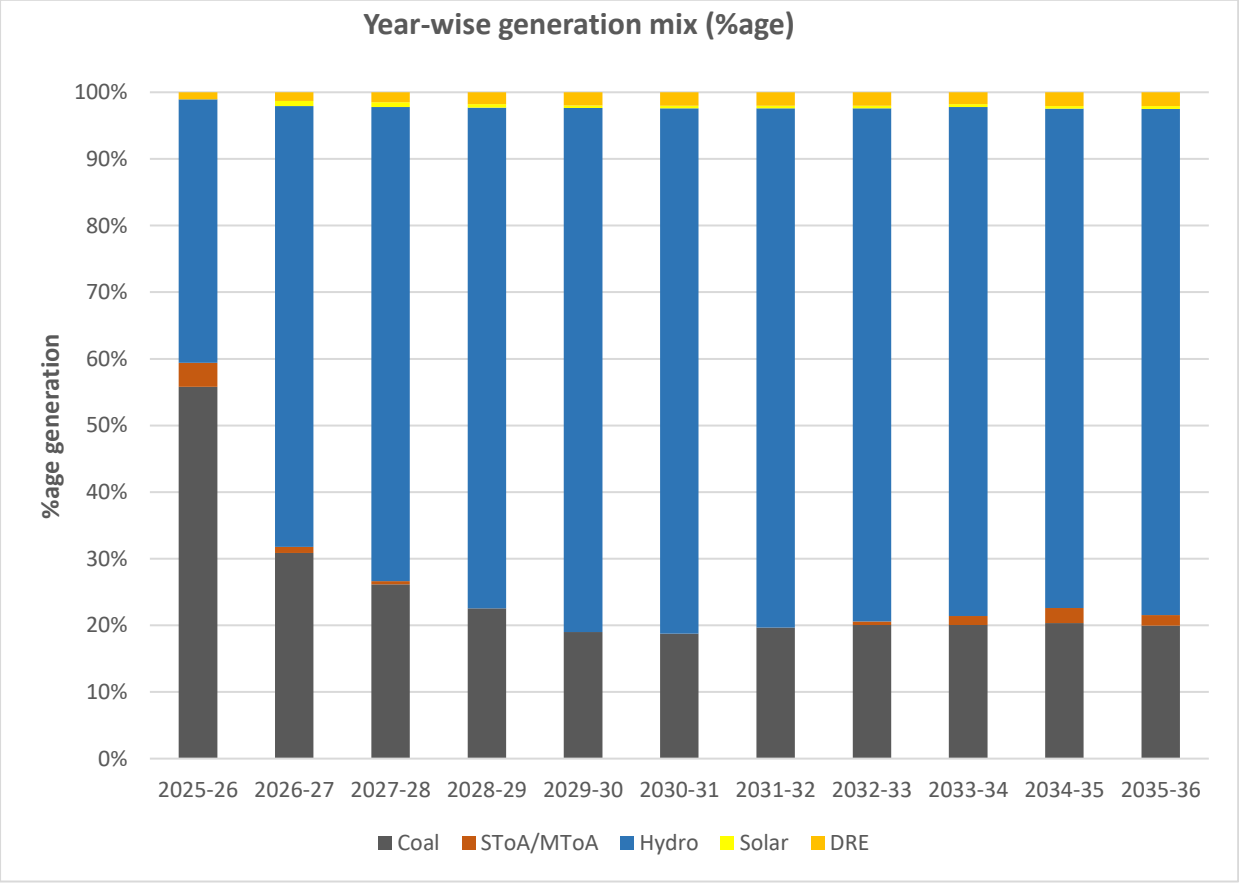
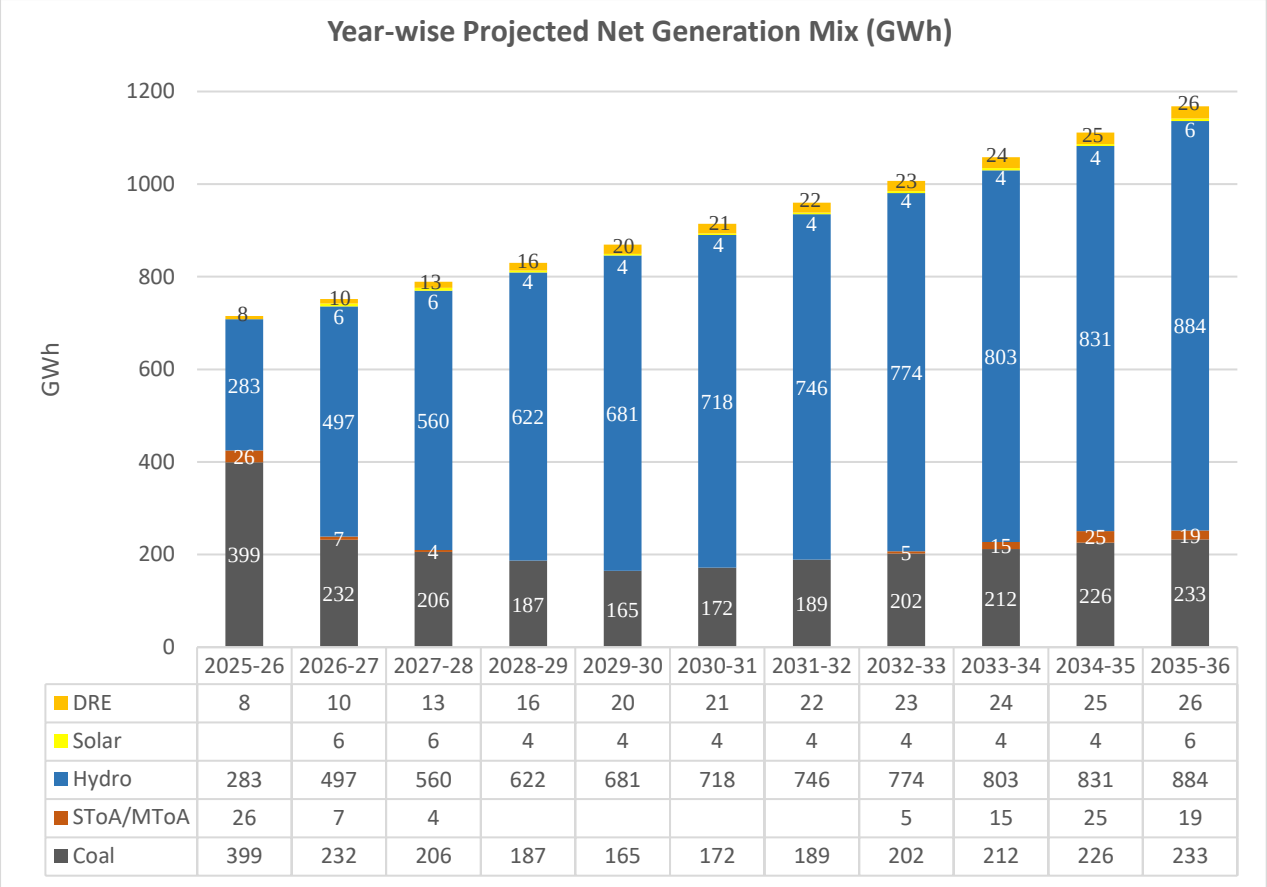


Figure 12: Year-wise projected net generation mix (in %)



	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35	2035-36
DRE	8	10	13	16	20	21	22	23	24	25	26
Solar		6	6	4	4	4	4	4	4	4	6
Hydro	283	497	560	622	681	718	746	774	803	831	884
SToA/MToA	26	7	4					5	15	25	19
Coal	399	232	206	187	165	172	189	202	212	226	233

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

7.3 Day-wise Surplus Coal Capacity

Generally, surplus capacity is available with the state due to RE availability, Demand variation etc. The pattern of surplus capacities has been observed as shown in Figure 15. As can be seen from the figure below, Sikkim is expected to have a minimum surplus coal-based capacity of 75 MW from May-October which can be shared/banked with other states/utilities.

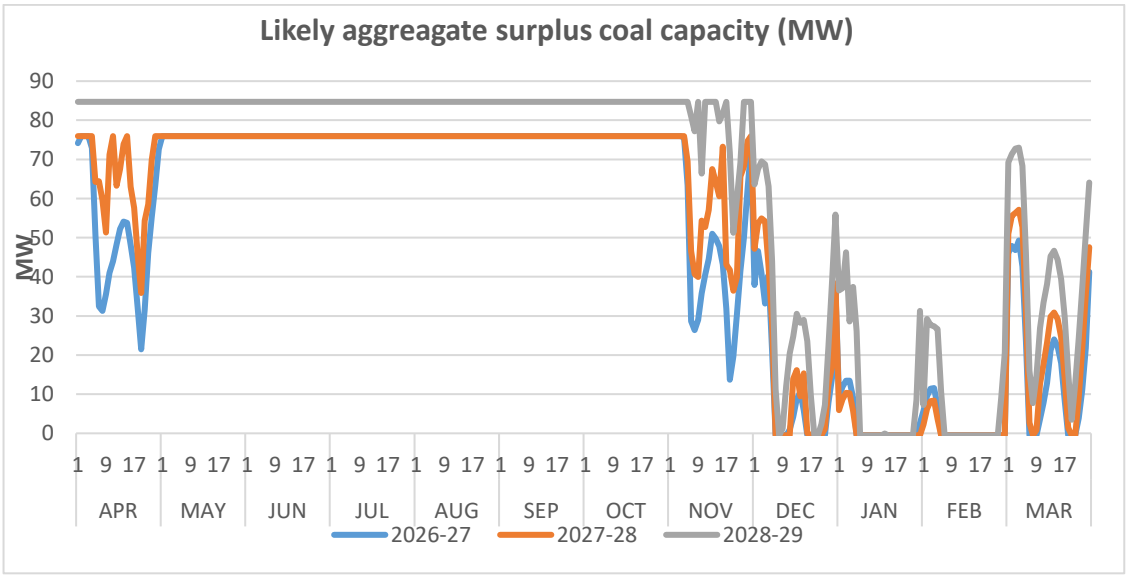


Figure 14: Surplus Coal Capacity Year-wise (MW)

8.0 Conclusions

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

1. The study has been carried out considering peak electricity demand and electrical energy requirement projections as per the projections provided by the states, which envisages that the annual electrical energy requirement of the state is likely to grow at a CAGR of 5.0% while the peak electricity demand for the state is likely to grow at a CAGR of 2.97% for the period of 2025-26 to 2035-36. The projected peak electricity demand and electrical energy requirement in 2035-36 is 197 MW and 1167 MU respectively. It has been observed that the peak electricity demand season is typically from January to February with peak demand occurring during non-solar hours.
2. Sikkim, with its existing and planned capacity addition only, is likely to witness energy deficit ranging from 6 MUs to 28 MUs in different years from 2025-26 to 2027-28 and from 2031-32 to 2035-36. The deficit may reduce depending upon the capacity tie up, banking arrangement etc.
3. Based on the study, the likely total projected contracted capacity for the year 2035-36 is around 629 MW which consists of 116 MW from coal; 469 MW from hydro; 7 MW from solar; 21 MW from DRE and 16 MW from MToA/SToA arrangement. This capacity shall be able to meet the projected demand with prescribed reliability criteria while complying with the stipulated Renewable Purchase Obligation (RPO) targets.
4. In order for Sikkim to fulfill its Distributed Renewable Energy (DRE) Purchase Obligation, the utility, in addition to the existing and already planned contracts, needs to tie up approximately 21 MW of Distributed Renewable Energy (DRE)-based capacity by 2035-36 (refer Table 14).
5. As per studies, the state is expected to have a minimum surplus coal-based capacity of about 75 MW from May to October. This surplus capacity may be banked or shared with other states whose demand profile complements that of Sikkim.
6. The Planning Reserve Margin (PRM) for Sikkim has been assessed at about 3%. Further, the study indicates year-wise short-term/medium-term/bilateral requirements inclusive of the PRM capacity to meet the demand optimally.
7. Timely commissioning of planned capacities is critical to 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

Planned Future Contracted (MW) considered in the study

Sl. No.	Generating Station	Type of generation	Expected COD	Share of Sikkim (in MW)
1.	Buxar	Coal	2025-26	1
2.	Barh-III	Coal	2025-26	13
3.	Rangit-IV	Hydro	2026-27	14.4
4.	Panan HEP	Hydro	2026-27	36
5.	Rellichu-I	Hydro	2026-27	1.44
6.	Teesta-V	Hydro	2026-27	67.42
7.	Rellichu-II	Hydro	2027-28	2.88
8.	Teesta-III	Hydro	2027-28	72
9.	Teesta-VI	Hydro	2028-29	60
10.	Darlipalli-II	Coal	2028-29	12
11.	New Meyongchu	Hydro	2028-29	1.2
12.	Rampakchu Small Hydro	Hydro	2029-30	3
13.	Teesta-III	Hydro	2029-30	72
14.	Rolep	Hydro	2029-30	4.32
15.	Ralong	Hydro	2029-30	4.8
16.	Chakunhchu	Hydro	2029-30	6
17.	Bhasmey	Hydro	2029-30	7.32
18.	Rangit-II	Hydro	2030-31	7.92
19.	Sada Mangdar	Hydro	2030-31	8.52
20.	Suntaleytar	Hydro	2030-31	4.8

Assumption for Resource Adequacy Studies

1. Electricity Demand & peak requirement: As per projections furnished by Sikkim.
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	Solar	DRE
32 %	18%	14 %

Technical Parameters

Technology	Type	Availability (%)	Ramping (%/min)	Min. Technical. (%)
Coal/ Lignite	Existing/Planned	85	1	55
	Candidate	88	1	55
Gas	Existing	90	3	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	-
BESS	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
Hydro	Existing/ Planned	-	-	0.7	-	-
	Candidate	-	-	0.7	-	-
Pumped Storage Plant	Existing/ Planned	-	-	Round trip efficiency 80 %	-	-
	Candidate	-	-		-	-
BESS	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 Cr	5.9 Lakh	1	15
Pumped Storage Plant	6 Cr	30 Lakh	4	40