
# Report On
# Resource Adequacy Plan
# For the State of
# Sikkim
## (2024-25 to 2034-35)

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

# Contents

# Executive Summary

India's power sector has seen a huge transition during the last few years, driven primarily by climate change and energy security concerns. In August 2022, India updated its NDC according to which target to reduce emissions intensity of its GDP has been enhanced to 45 percent by 2030 from 2005 level, and the target on cumulative electric power installed capacity from non-fossil fuel-based energy resources has been enhanced to 50% by 2030.Consecutively, there has been substantial addition of renewable energy (RE) and transmission capacities.

Ministry of Power had notified Electricity (Amendment) Rules in December, 2022. As per Rule 16 of the Electricity (Amendment) Rules, Ministry of Power has notified Resource Adequacy guidelines. As per the Resource Adequacy (RA) Guidelines, Central Electricity Authority is entrusted to prepare Long Term-National Resource Adequacy Plan (LT-NRAP). Further Distribution Utility need to carry out LTDRAP (Long term Distribution Licensee Resource Adequacy Plan) to meet the utility peak and energy requirement reliably.

As per the Resource Adequacy Guidelines, each Distribution licensee shall undertake a Resource Adequacy Plan (RAP) for a 10-year horizon (Long-term Distribution Licensee Resource Adequacy Plan (LT-DRAP)) to meet their own peak and electrical energy requirement. The plan shall be vetted/validated by Central Electricity Authority for leveraging the benefit of national level optimization for the Distribution licensees. The LT-DRAP shall be carried out by the distribution licensees on an annual rolling basis considering the contracted capacity as a part of the system and shall optimize for additional capacity required.

The Government of India has recently notified new Renewable Purchase Obligation (RPO) trajectory till 2029-30 which ensure certain amount of energy consumption to be met from renewable energy sources. RPO requirement for Sikkim has been assessed in compliance with new RPO trajectory.

The electrical energy demand for the State of Sikkim is increasing with a CAGR of 5.9 % from 2024-25 to 2034-35 as forecasted by 20$^{th}$ EPS. The projections of Sikkim also indicate that electricity demand may increase with a CAGR of 5 % from 2024-25 to 2034-35. For satisfying resource adequacy i.e., meeting the electricity demand reliably and at affordable cost, the State need 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 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.

A study was carried out for the state considering existing capacity, planned capacity & capacity required to fulfil the Renewable Purchase Obligations (RPO). It was found that the state's likely contracted capacity is not sufficient to meet projected demand. It was observed that the total unserved energy in the year 2034-35 is expected to be about 257 MU which is about 21.9 % annual energy during the year 2034-35.

To find out the least cost option for generation capacity expansion for the period 2024-25 to 2034-35, long-term study for the State of Sikkim was carried with an objective to minimize the total system cost of generation including the cost of anticipated future investments while fulfilling all the technical/financial 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 (Solar, Wind) and forced outage of thermal generators (Coal, gas) etc.

Generation capacity expansion pathways have been considered for the long-term study based on the yearly capacity addition plans of the state 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.

No capacity addition in nuclear capacity has been considered in the studies.

The Resource adequacy studies have projected likely optimal capacity mix for future years till 2034-35 which is able to meet anticipated demand reliably at every instance.

# 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 20$^{th}$ October, 2023 had notified the RPO trajectory for the states. Based on the trajectory specified the 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 have to contract in addition to its existing/planned capacity to meet their RPO targets.

Resource Adequacy study has been carried out for Sikkim based on the inputs received from Sikkim with a view of fulfilling RPO trajectory. The study suggests the optimal resource mix till 2034-35 taking into account all technical and financial parameters associated with capacities. The study optimizes power purchase on a long-term basis while evaluating resource adequacy for meeting the demand on 24 X 7 basis while considering variation in demand, RE generation and forced outages of thermal capacities. The study has also assessed the requirement of Planning Reserve Margin for Sikkim for catering to above highlighted uncertainties so that demand can be met reliably throughout the year.

# 2.0 Sikkim RA Study

## 2.1 Present Power Scenario in Sikkim

The current Power Supply Position for the state is shown in the Table 1 below:

*Table 1 Power Supply Position*

| Power Supply Position | | | | | | |
|---|---|---|---|---|---|---|
| **Year** | **Energy required (MU)** | **Energy Supplied (MU)** | **Gap (MU)** | **Peak Demand (MW)** | **Peak Met (MW)** | **Demand Not Met (MW)** |
| **2021-22** | 610 | 609 | **1** | 133 | 133 | **0** |
| **2022-23** | 587 | 587 | **0** | 124 | 124 | **0** |
| **2023-24** | 544 | 543 | **1** | 133 | 133 | **0** |

As of March 2023, the total contracted capacity for Sikkim is 138 MW. Out of the total contracted capacity (CC), the share of non-fossil fuel-based CC is 79.7%.

The fuel-wise contracted capacity as on 31st March, 2023 is given in Table and Figure below:

*Table 2 Fuel-wise Contracted Capacity as on March 2023*

| Source | Contracted Capacity (MW) | Percentage |
|---|---|---|
| Coal | 28 | 20.3% |
| Hydro | 106 | 76.8% |
| Solar | 4 | 2.9% |
| **Total** | **138** | **100%** |

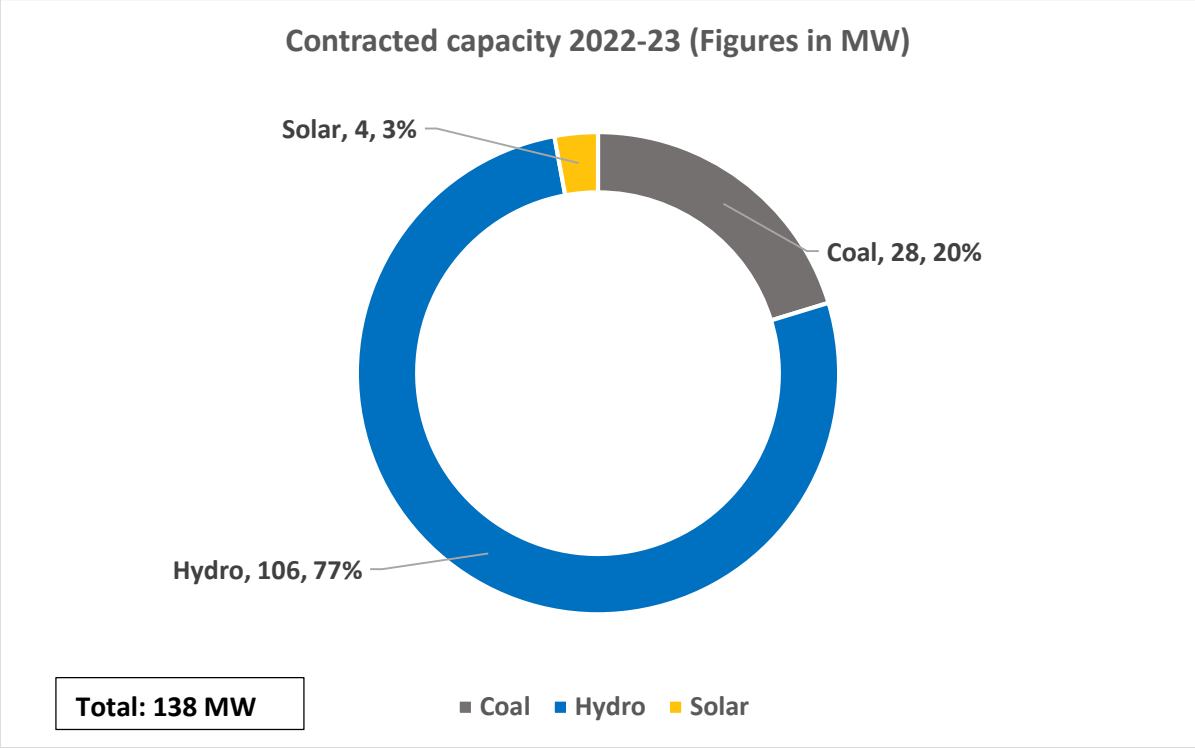



*Figure 1 Fuel-wise Contracted Capacity (in MW) as on 31st March, 2023*

## 2.2 Present Demand Analysis (2022-23)

Hourly demand pattern of 2022-23 was analyzed and it was observed that the peak demand season for Sikkim is during the months of December, January. Sikkim witnesses peak demand during night hours. Optimal utilization of resources through short-term contracts like banking or STOA can be practiced for managing the seasonal variation in demand and is one of the effective ways for ensuring resource adequacy.

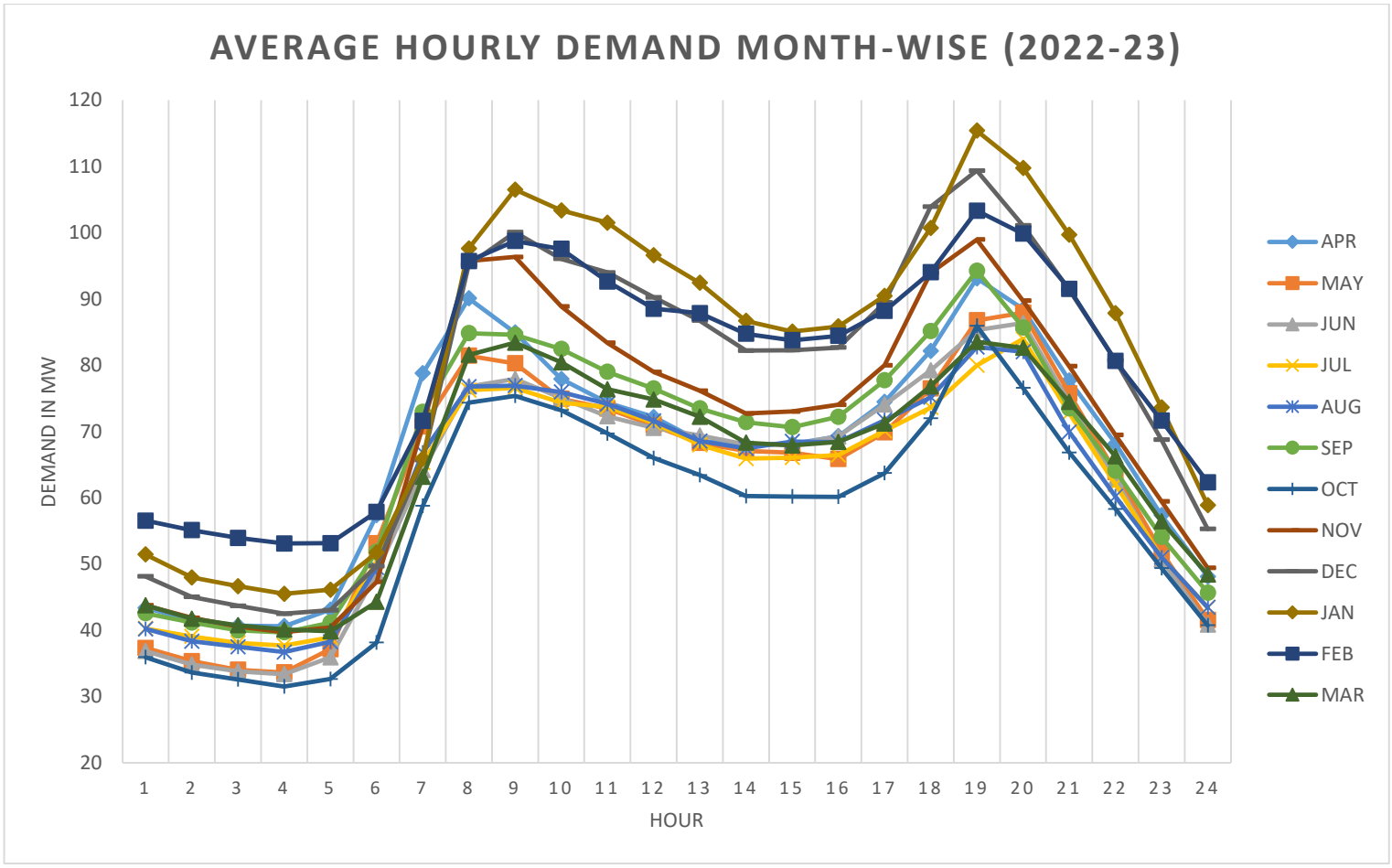



*Figure 2 Average Hourly Demand Variation (Month-wise) of Sikkim for 2022-23*

Sikkim sees daily peak during Non-solar hours in almost every month of the year.

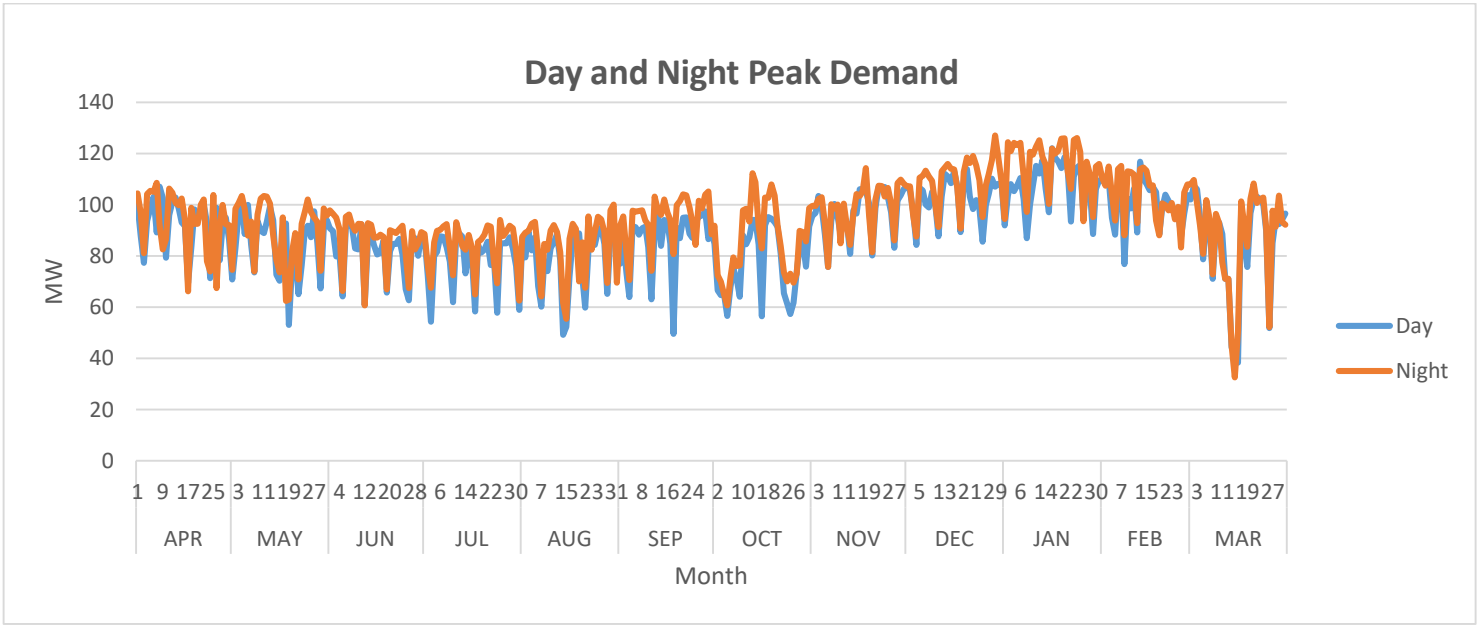



*Figure 3 Day and Night Peak in MW of Sikkim (2022-23)*

The hourly demand pattern of 2022-23 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.

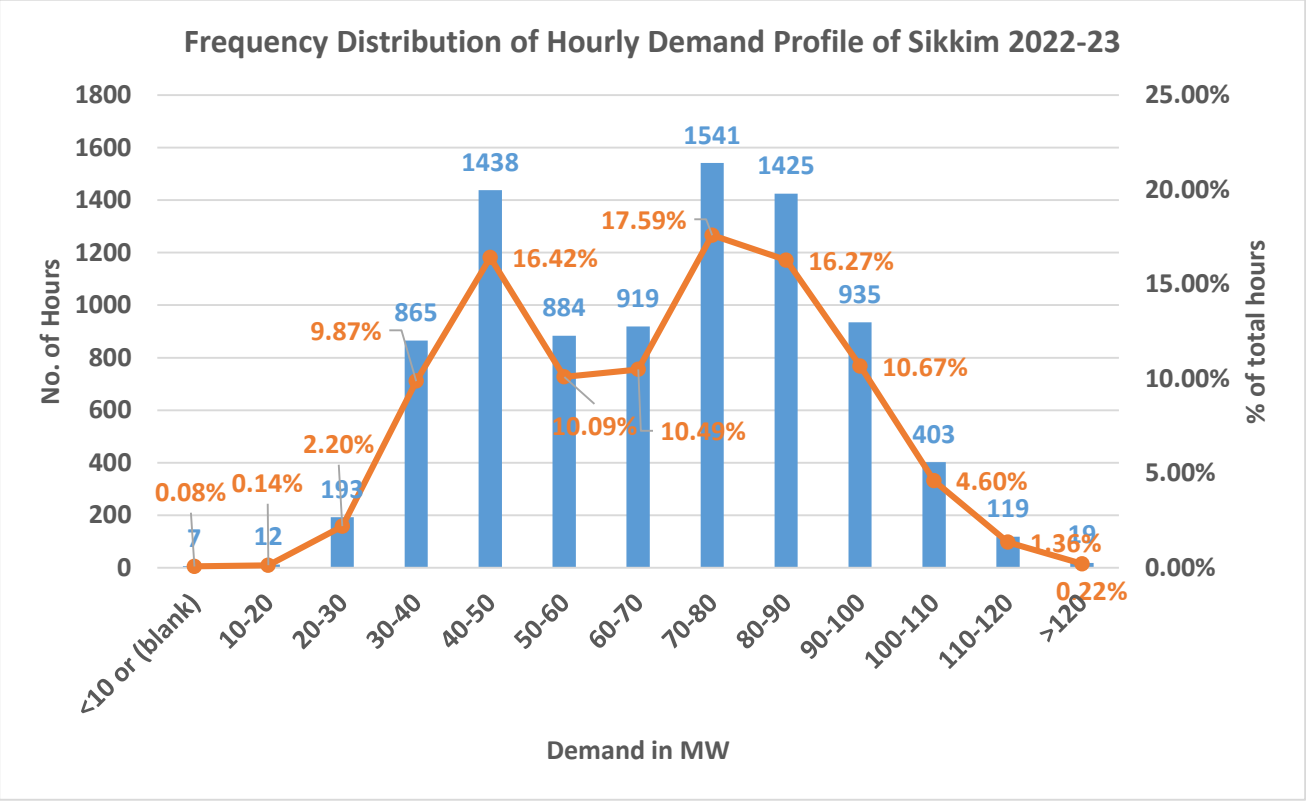



*Figure 4 Frequency Distribution of Hourly Demand Profile of Sikkim 2022-23*

## 3.0 Inputs/Assumptions for the Study

i) The future demand estimation by 20th EPS is higher than that of the state Peak and Energy Demand estimates for Sikkim. The state demand projections have been considered for the studies as these are more close to the past trend. However, 20$^{th}$ EPS demand estimates are considered as a scenario while carrying out studies.

*Table 3 Future Demand Projection as provided by Sikkim*

| | 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)** | 721 | 757 | 794 | 834 | 876 | 920 | 966 | 1014 | 1065 | 1118 | 1174 |
| **Year on Year Growth** | | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% |
| **Peak Demand Projections (MW)** | 142 | 158 | 165 | 173 | 182 | 191 | 201 | 210 | 222 | 235 | 248 |
| **Year on Year Growth** | | 11.3% | 4.4% | 4.8% | 5.2% | 4.9% | 5.2% | 4.5% | 5.7% | 5.9% | 5.5% |

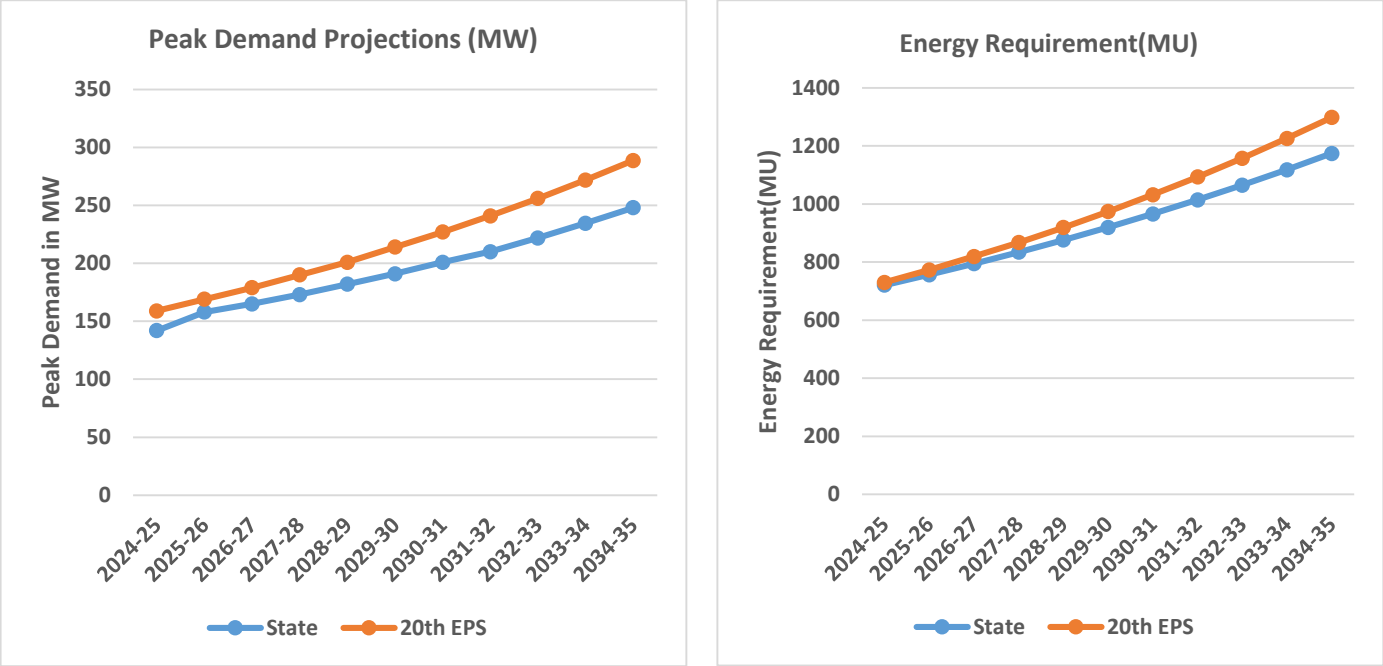



*Figure 5 Comparison of Energy Requirement and peak Demand Projections of 20th EPS vs Sikkim*

ii) Future demand profile for the year 2034-35 has been projected using the demand profile for the year 2022-23 as the base profile.

iii) The actual solar and wind generation profiles and CUFs have been referred from National Electricity Plan 2023 (Vol I Generation).

iv) Capital cost of candidate plants for Coal, Wind, Solar, Battery and PSP have been referred from National Electricity Plan 2023 (Vol I Generation).

v) Planned Capacity: As per the information available with CEA. (List of Planned Thermal and Hydro is attached in **Annexure-I**)

vi) According to the data available with CEA, an additional 26 MW of Coal, 81 MW of Hydro is planned.

vii) Ministry of Power, via 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. In view of the country's energy transition 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 increase beyond 2029-30. Therefore, the RPO trajectory is assumed to rise steadily beyond 2029-30 and hence, RPO trajectory till 2034-35 are given below:

*Table 4 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) | (6) | (5) | (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 | 43.00% | | | 2.50% | 45.50% |
| 8. | 2031-32 | 44.25% | | | 2.75% | 47.00% |
| 9. | 2032-33 | 45.30% | | | 3.00% | 48.30% |
| 10. | 2033-34 | 46.25% | | | 3.25% | 49.50% |
| 11. | 2034-35 | 47.50% | | | 3.50% | 51.00% |

*Trajectory for RPO till 2029-30 as per MoP RPO order notified in October,2023. After 2029-30, RPO targets assumed based on anticipated RE capacity requirement on national level given in National Electricity Plan (Vol-I Generation)

Sikkim 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. 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:

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 5 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) | (6) | (5) | (7) |
| **1** | **2024-25** | 5 | 3 | 202 | 5 | 215 |
| **2** | **2025-26** | 11 | 9 | 222 | 8 | 250 |
| **3** | **2026-27** | 16 | 11 | 249 | 11 | 286 |
| **4** | **2027-28** | 20 | 12 | 278 | 14 | 324 |
| **5** | **2028-29** | 26 | 12 | 307 | 17 | 362 |
| **6** | **2029-30** | 32 | 12 | 334 | 21 | 399 |
| **7** | **2030-31** | 415 | | | 24 | 439 |
| **8** | **2031-32** | 449 | | | 28 | 477 |
| **9** | **2032-33** | 482 | | | 32 | 514 |
| **10** | **2033-34** | 517 | | | 36 | 553 |
| **11** | **2034-35** | 558 | | | 41 | 599 |

*Considering the fungibility aspect of RPO targets among Wind, Hydro and other RE generation

*Table 6 Renewable Energy Deficit/Surplus*

| FY | RE Generation required to meet RPO (Excluding DRE) | RE Generation required to meet RPO | RE Generation available/met (From existing/planned Contracts) | RPO met (%) | RPO Surplus(+)/ Deficit (-) |
|---|---|---|---|---|---|
| | (MU) | (%) | (MU) | (%) | (%) |
| **2024/25** | 210 | 29.15% | 443 | 61.5% | 32.4% |
| **2025/26** | 242 | 31.96% | 492 | 65.0% | 33.0% |
| **2026/27** | 275 | 34.60% | 507 | 63.8% | 29.2% |
| **2027/28** | 310 | 37.16% | 609 | 73.0% | 35.8% |
| **2028/29** | 345 | 39.42% | 630 | 71.9% | 32.5% |
| **2029/30** | 378 | 41.08% | 652 | 70.9% | 29.9% |
| **2030/31** | 415 | 43.00% | 676 | 70.0% | 27.0% |
| **2031/32** | 449 | 44.25% | 701 | 69.1% | 24.9% |
| **2032/33** | 482 | 45.30% | 727 | 68.3% | 23.0% |
| **2033/34** | 517 | 46.25% | 751 | 67.2% | 20.9% |
| **2034/35** | 558 | 47.50% | 769 | 65.5% | 18.0% |

It can be observed that RPO (Excluding DRE) met by state of Sikkim is in Surplus in all years so no additional capacity is required (other than planned) to meet RPO (Excluding DRE).

Accordingly, the source wise MW requirement –planned by the state and additional, considering the fungibility aspects in the RPO, has been estimated and is tabulated below:

*Table 7 Projected RE capacity addition required (MW) as per RPO trajectory.*

| FY | Hydro | | DRE | | TOTAL | |
|---|---|---|---|---|---|---|
| | **Planned** | **Additional** | **Planned** | **Additional** | **Planned** | **Additional** |
| 2024/25 | 0 | 0 | 0 | 4 | **0** | **4** |
| 2025/26 | 16 | 0 | 0 | 2 | **16** | **2** |
| 2026/27 | 0 | 0 | 0 | 2 | **0** | **2** |
| 2027/28 | 65 | 0 | 0 | 2 | **65** | **2** |
| 2028/29 | 0 | 0 | 0 | 3 | **0** | **3** |
| 2029/30 | 0 | 0 | 0 | 3 | **0** | **3** |
| 2030/31 | 0 | 0 | 0 | 3 | **0** | **3** |
| 2031/32 | 0 | 0 | 0 | 3 | **0** | **3** |
| 2032/33 | 0 | 0 | 0 | 3 | **0** | **3** |
| 2033/34 | 0 | 0 | 0 | 4 | **0** | **4** |
| 2034/35 | 0 | 0 | 0 | 4 | **0** | **4** |
| **TOTAL** | **81** | **0** | **0** | **33** | **81** | **33** |

It is observed that with existing and planned capacity as shown in Table-6, RPO energy requirement(excluding DRE) is fulfilled for every year.

## 4.0 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 very 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 load) 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 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 % of peak load forecast of the system.

## 4.1 Demand variation

The variation in demand pattern of Sikkim for last 5 years has been analyzed. The hourly demand variation for consecutive years (i.e., 2021-22 and 2022-23) has been analyzed. The Demand pattern variation of 2021-22 and 2022-23 is shown below.

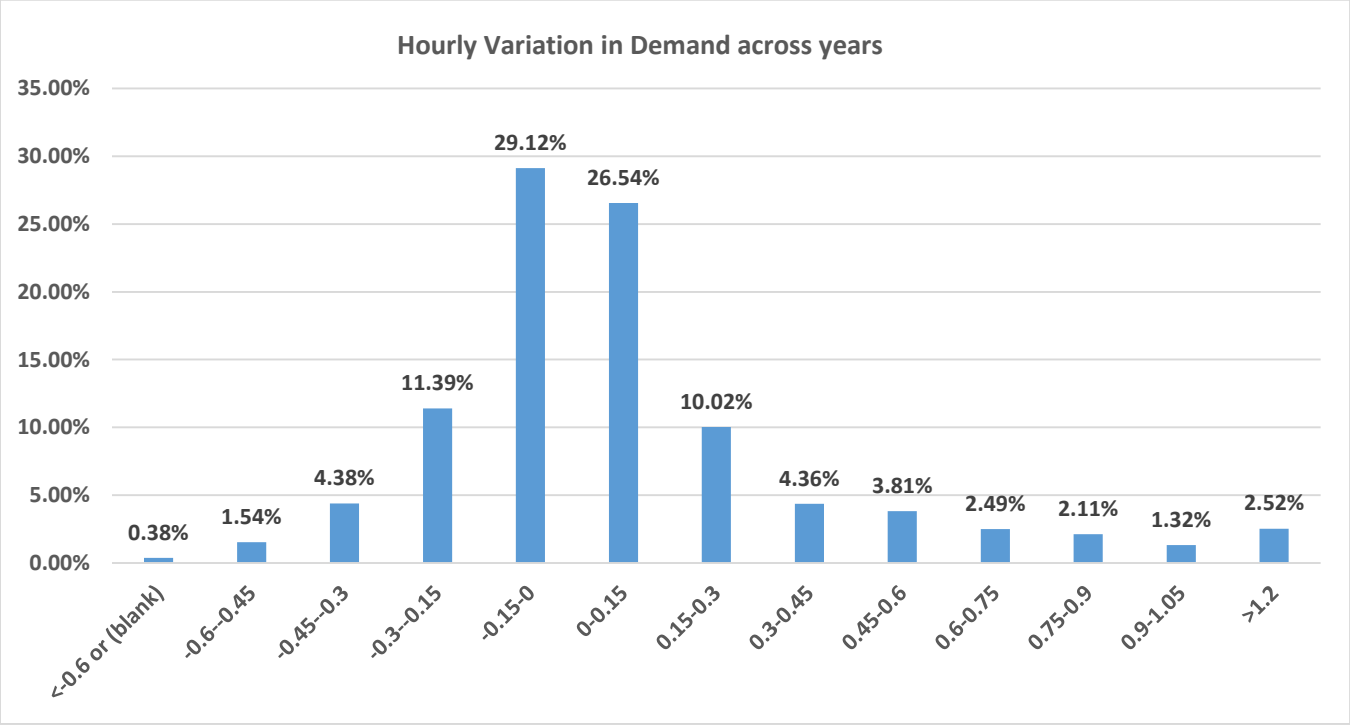



*Figure 6 Hourly Variation in Demand across years*

It can be observed that the hourly demand typically varies ±15% for 56% of instances. This variation is primarily due to temperature, weather parameter or any random outages of transmission line and generation units etc. This variation has been captured in the reliability study

by varying the projected hourly demand for the future years by varying ±15% by introducing a random variable (with normal distribution) for demand as per observed behavior over the years.

### 4.2 RE variation

In the Long-term capacity expansion planning studies, a particular profile for Solar and Wind Plants are considered based on the observed solar and wind 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 generation and wind generation has been varied by 10 % and 60% respectively to incorporate the variation in these generation sources and plan for requisite measures to mitigate such behavior.

### 4.3 Forced Outage of Thermal Generators

The average forced outage rate of thermal generators is typically at 10% with ±5% variation. The same has been incorporated in the model.

Based on the variation reliability studies are carried out to ascertain robustness of the system. The LOLP & EENS of the system is within specified range.

## 5.0 Results of the study

### 5.1 Unserved Energy Projections

The study was carried out considering existing capacity, planned capacity. It was observed that the total unserved energy in the year 2034-35 is about 257 MU. The yearly likely unserved energy with the planned capacities is given below.

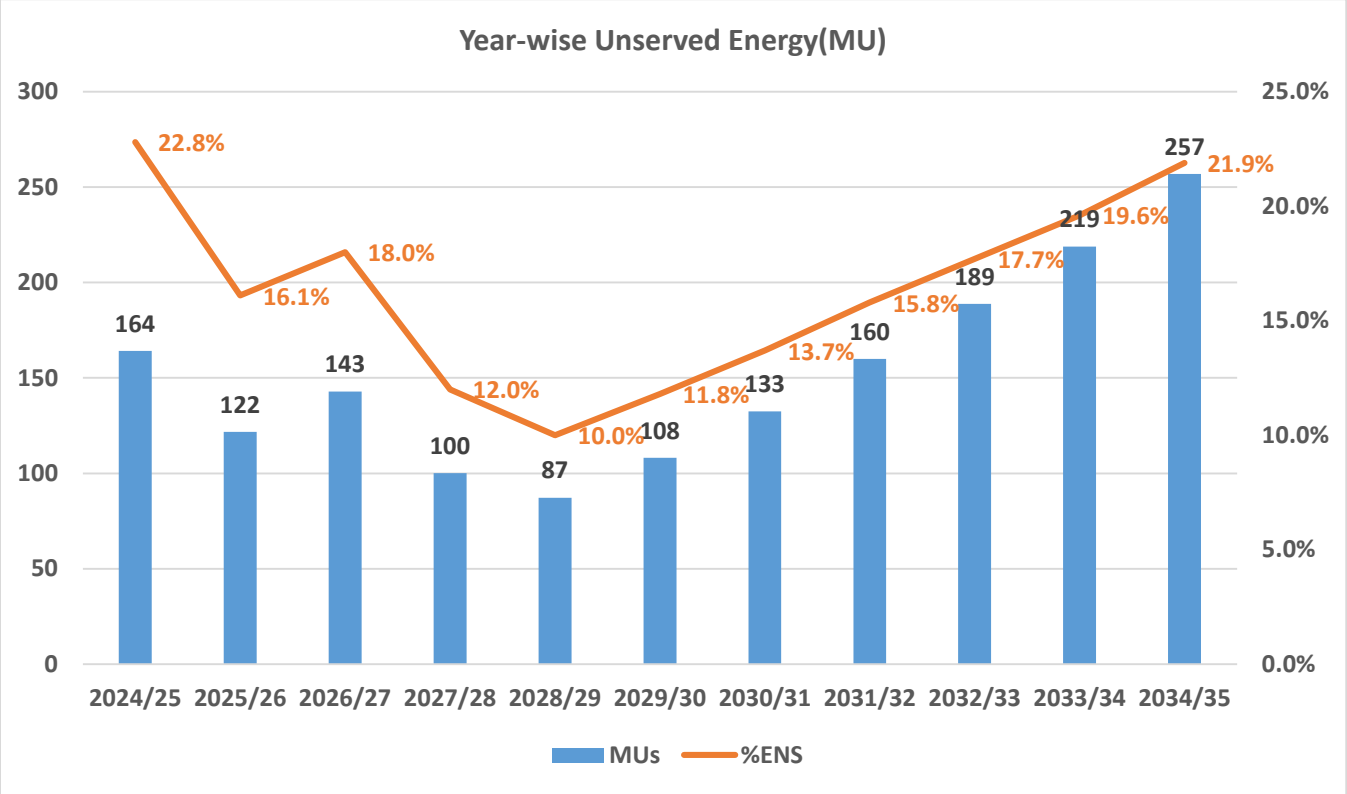



*Figure 7 Yearly likely unserved energy with the planned capacities for Sikkim (in MU)*

The study has also analyzed the Daily and monthly pattern of unserved energy in the year 2034-35, it can be seen that contracted capacity (present and planned) is unable to meet the demand.

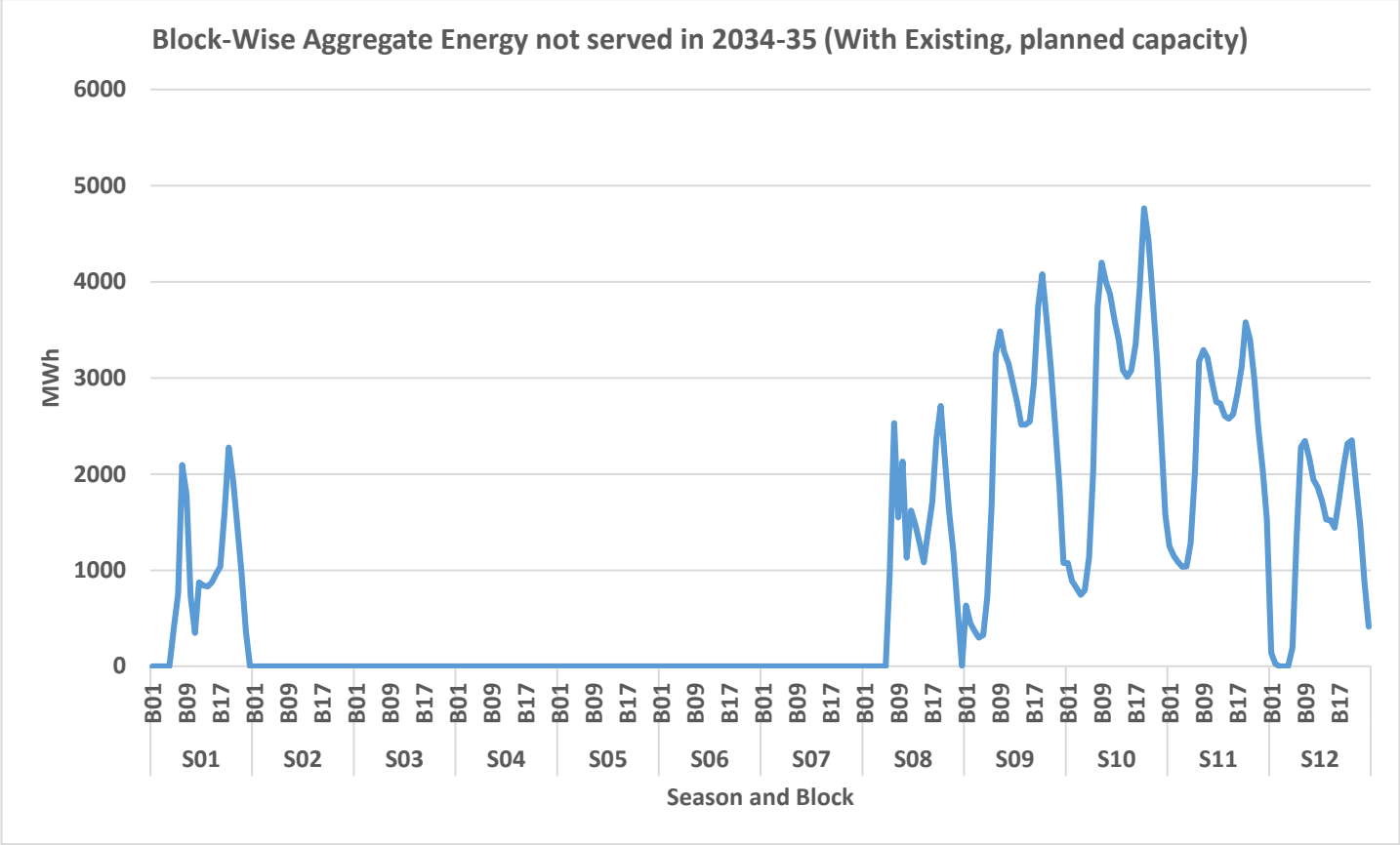



*Figure 8 Block-wise Unserved Energy Pattern MWh (2034-35)*

## 5.2 Capacity Mix Projection

The study was carried out considering existing capacity, planned capacity and capacity required to fulfil the RPO obligations. It was observed unserved energy in the year 2034-35.

To meet the unserved energy, energy investment options (candidate capacities) is given to the model to find the least cost optimal capacity mix required to meet the demand. The following is observed:

i) The STOA/MTOA requirement can be fulfilled through power procurement from markets or bilateral agreements.
ii) The STOA/MTOA value reflects the peak value requirement in terms of MW.

The capacity projections for Sikkim are given below:

*Table 8 Year-wise contracted capacity projections (in MW)*

| Year | Coal | Hydro | Solar | DRE | Total | STOA |
|---|---|---|---|---|---|---|
| **2024/25** | 29 | 106 | 4 | 4 | **143** | 93 |
| **2025/26** | 42 | 122 | 4 | 6 | **174** | 78 |
| **2026/27** | 42 | 122 | 4 | 9 | **177** | 87 |
| **2027/28** | 42 | 187 | 4 | 11 | **244** | 78 |
| **2028/29** | 54 | 187 | 4 | 14 | **259** | 74 |
| **2029/30** | 84 | 187 | 4 | 17 | **292** | 48 |
| **2030/31** | 110 | 187 | 4 | 20 | **321** | 28 |
| **2031/32** | 119 | 187 | 4 | 23 | **333** | 29 |
| **2032/33** | 129 | 187 | 4 | 26 | **346** | 30 |
| **2033/34** | 139 | 187 | 4 | 30 | **360** | 30 |
| **2034/35** | 142 | 187 | 4 | 33 | **366** | 50 |

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

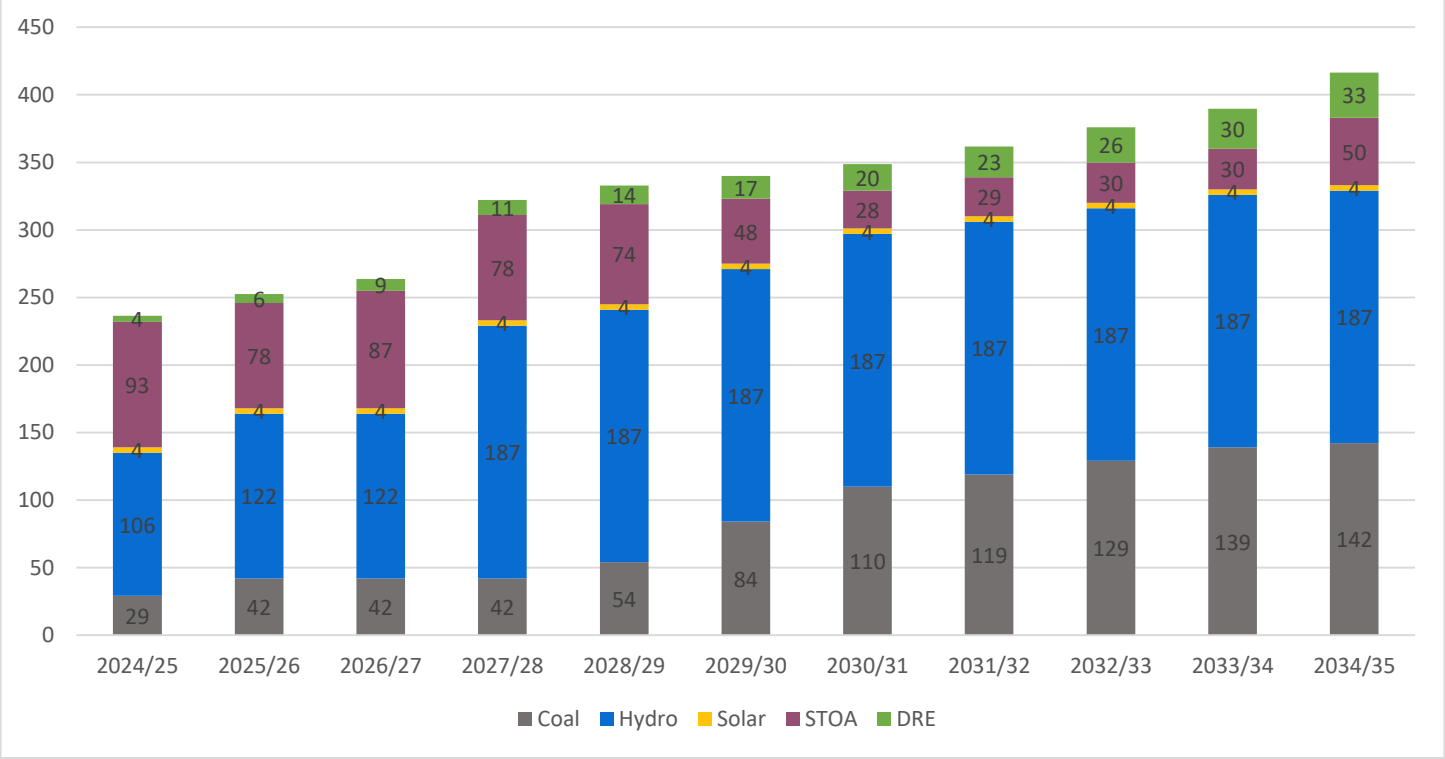



*Figure 9 Projected Contracted Capacity Mix Year-wise (MW) for Sikkim*

As per the Resource Adequacy studies, the total projected contracted Capacity for the year 2034-35 is 366 MW (excluding STOA) which consists of 142 MW from Coal, 187 MW from Hydro, 4 MW from Solar,33 MW from DRE. This IC shall be able to meet the projected demand with prescribed reliability criteria.

The Reliability studies have been carried out to adhere to the reliability criteria of LoLP and NENS as provided in NEP (0.2% and 0.05% respectively). The PRM for the state of Sikkim has been assessed as 24 %. In addition, the projected/contracted capacity fulfils the stipulated Renewable Purchase Obligation.

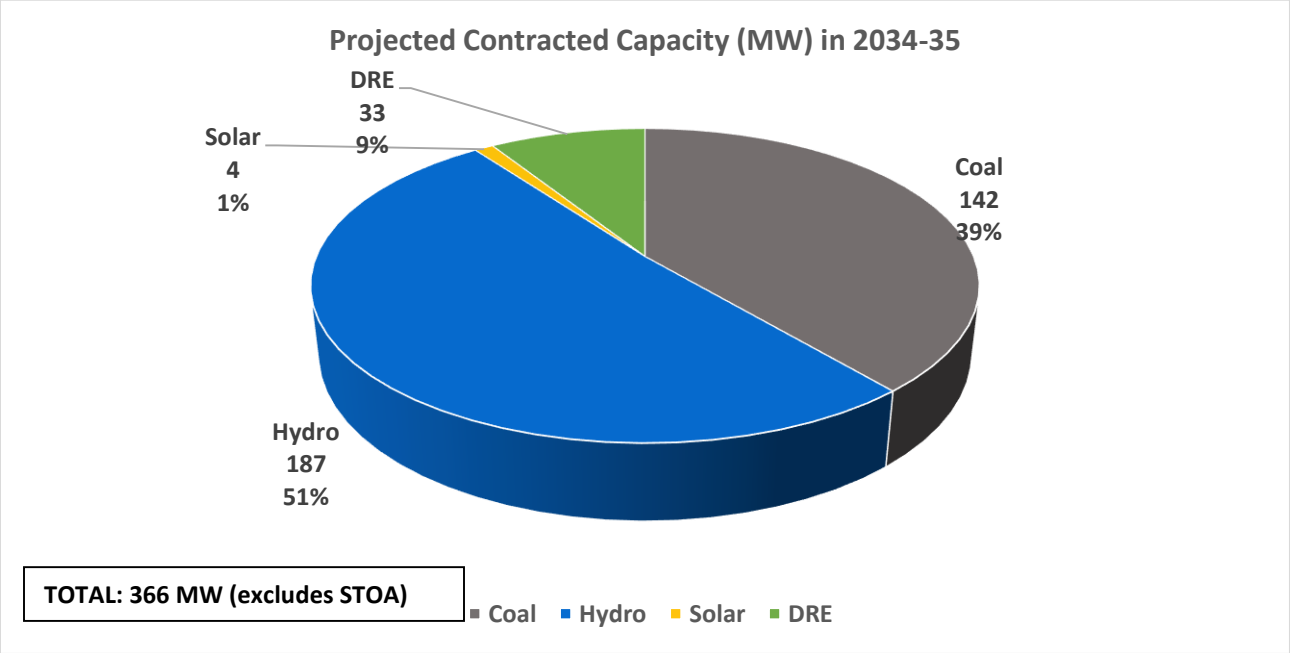
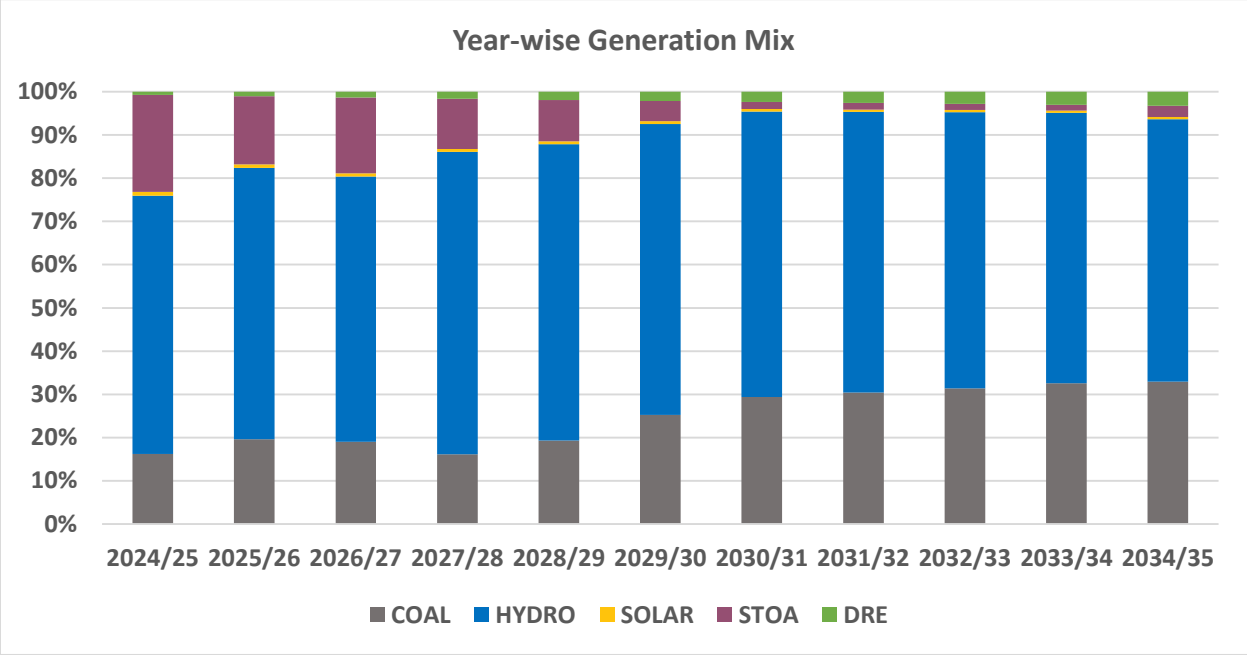
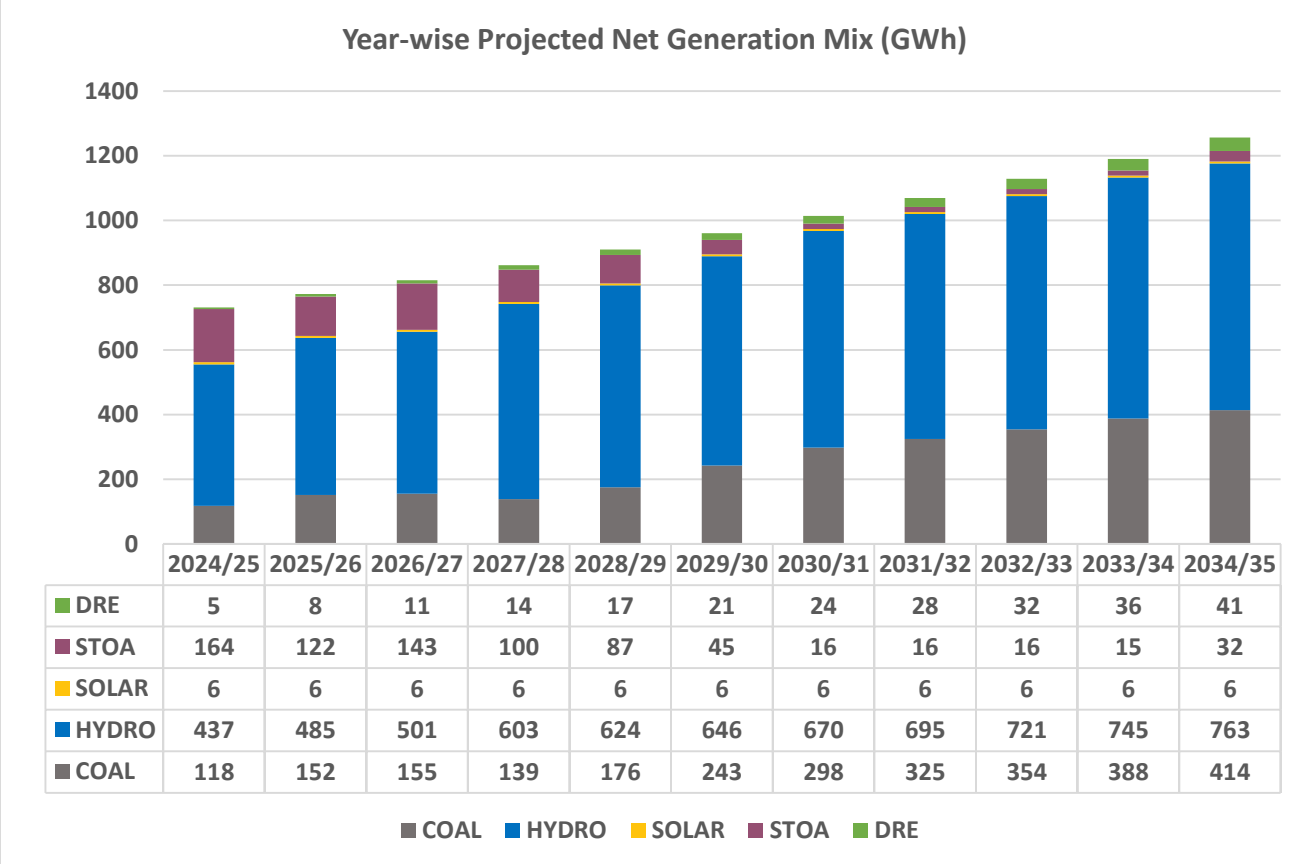



*Figure 10 Contracted Capacity Mix in 2034-35 with 24% PRM*




| | 2024/25 | 2025/26 | 2026/27 | 2027/28 | 2028/29 | 2029/30 | 2030/31 | 2031/32 | 2032/33 | 2033/34 | 2034/35 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DRE | 5 | 8 | 11 | 14 | 17 | 21 | 24 | 28 | 32 | 36 | 41 |
| STOA | 164 | 122 | 143 | 100 | 87 | 45 | 16 | 16 | 16 | 15 | 32 |
| SOLAR | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| HYDRO | 437 | 485 | 501 | 603 | 624 | 646 | 670 | 695 | 721 | 745 | 763 |
| COAL | 118 | 152 | 155 | 139 | 176 | 243 | 298 | 325 | 354 | 388 | 414 |

*Figure 11 Year-wise projected net generation mix (in GWh)*

## 5.3 Capacity contract requirement for future

It has been found out in the studies that Sikkim needs to contract following capacities (planned and additional) per year till to meet its demand reliably along with fulfilment of its RPO as notified by MoP.

*Table 9 Year wise Capacity Addition for Sikkim (in MW)*

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

## 5.4 Coal Capacity Performance

The coal capacity PLF is expected to remain in the range of 48%- 33% for the years till 2035 (reducing from 48% in 2024-25 to 33 % in 2031-32 and then increasing to 35% by 2034-35) due to availability of more Hydro capacity in Sikkim.

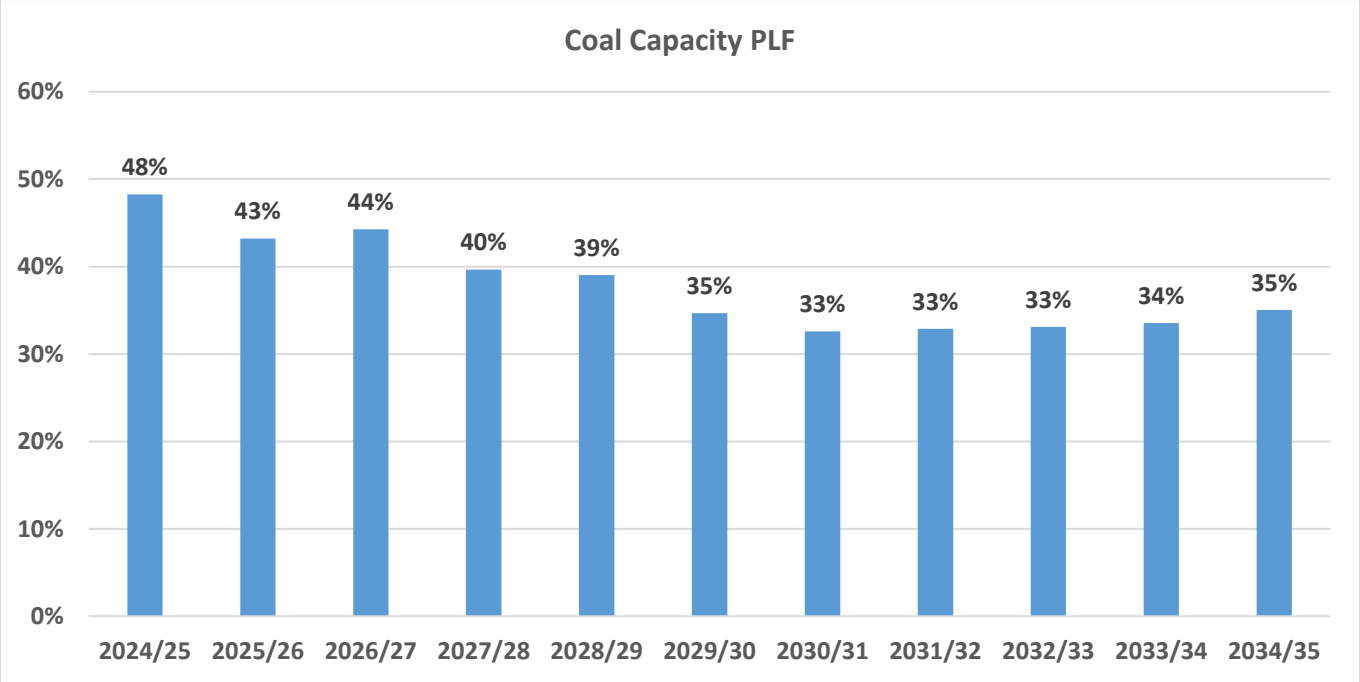



*Figure 12 Year-wise coal capacity PLF for Sikkim (in %)*

## 5.5 Day-wise Surplus Capacity Sikkim (MW)

Surplus capacity is available with states due to RE availability, Demand variation etc. The pattern of surplus capacities for Sikkim has been observed as below. This capacity can be shared with other states and reduce the fixed cost burden on the utilities resulting in reduction in the cost for consumer. Sikkim has likely surplus capacity available during monsoon months (June, July, August, September, October) in the range of 42 MW for 2027-28 as shown below which can be shared with other states.

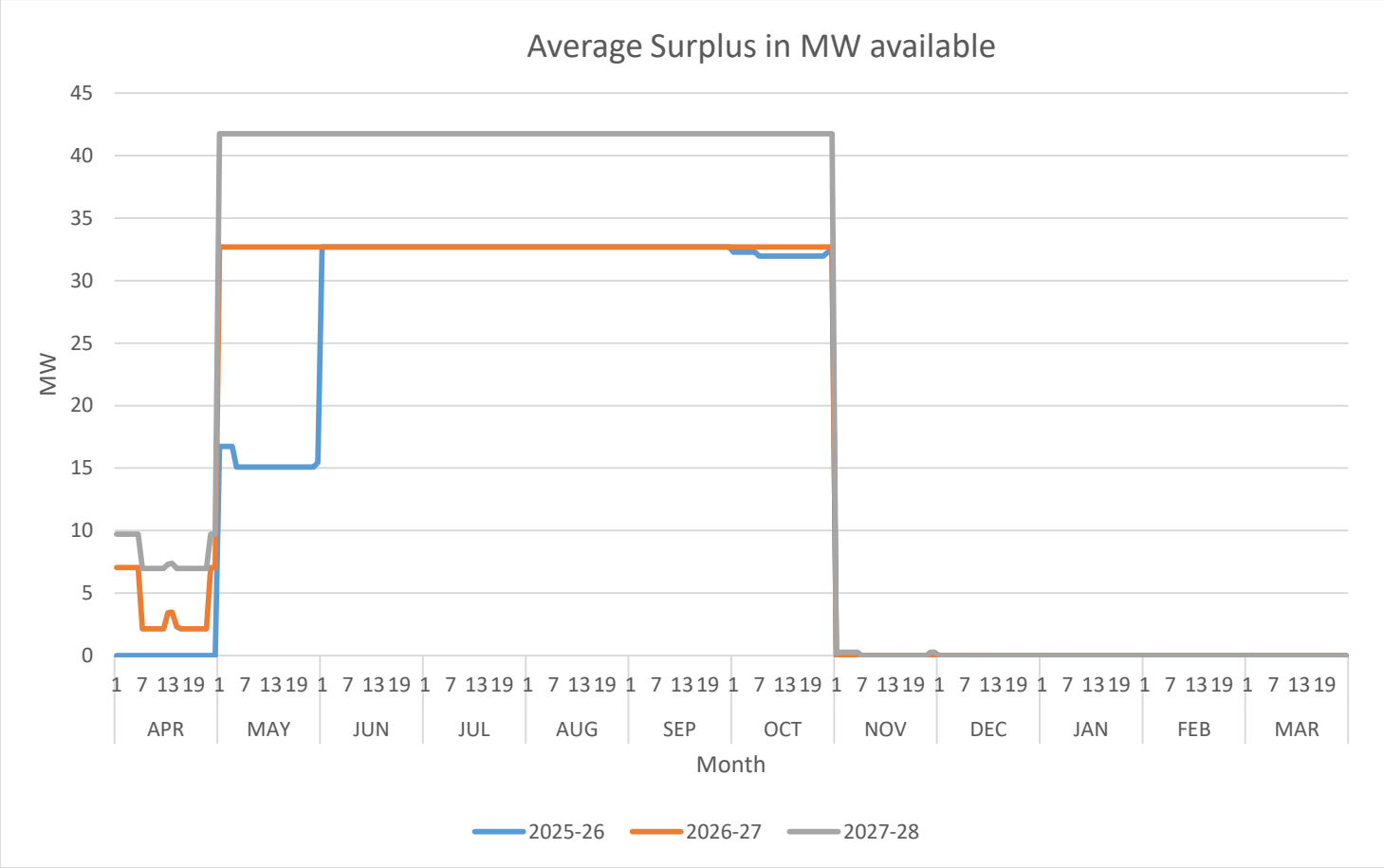



*Figure 13 Surplus Coal Capacity Year-wise (MW)*

## 6.0 Alternate Resilient Scenario Analysis

In view of the recent surge in Power demand during the year 2023-24 and capacity addition being delayed compared to the envisaged timelines, it was realized that a stress scenario may be assessed to comprehend such situations arising in the future and prepare the utilities for navigating such challenging situations optimally so as to fulfil their consumer end demand reliably.

The following cases were considered to occur simultaneously in the Alternate Resilient scenario:

- Peak and Energy Demand: Demand Projection as per 20$^{th}$ EPS (As it is more than projections submitted by Sikkim).
- Capacity Addition being delayed from their anticipated year as follows:

*Table 8 Time Delay in commissioning of contracted capacity*

| Contracted Capacity Type | Years Delayed |
|---|---|
| Hydro | 2 |
| Nuclear | 2 |
| Renewable Energy Capacity | 1 |
| Coal | 1 |

## 6.1 Capacity Mix Projections

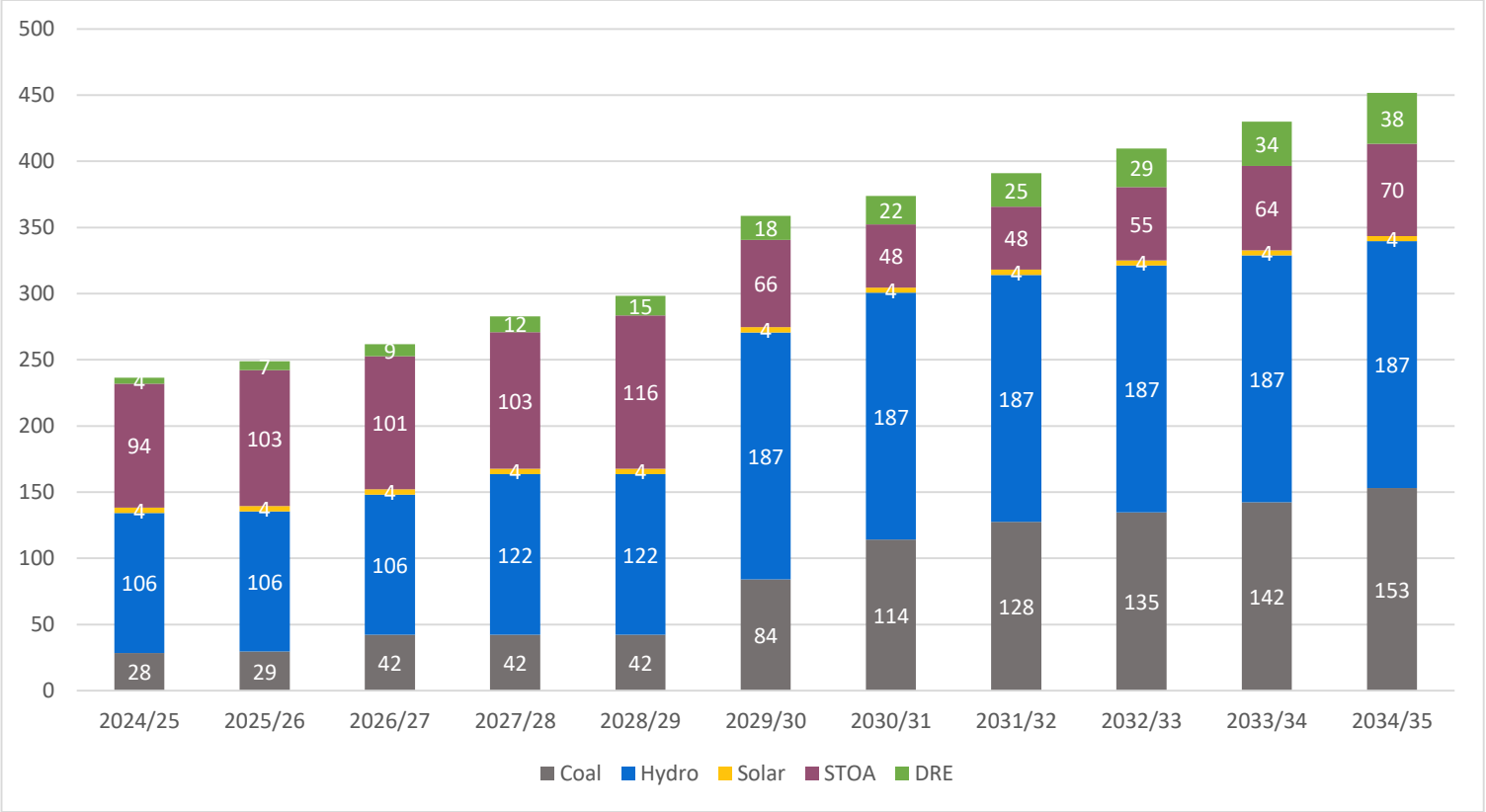



*Figure 14: Year-wise capacity projections (in MW) for Alternate Resilient Scenario*

In this scenario, coal requirement increases by around 11 MW compared to the base case in terminal year 2034-35 while the STOA requirement increases by around 15-35 MW from 2025/26 compared to the base case.

## 7.0 Conclusion

The study was carried for assessing the resource adequacy of Sikkim based on the demand projections provided by State of Sikkim. The following conclusions can be drawn based on the studies: -

- As seen historically, the electricity demand is more in winter months and is maximum during the months of January, December. The RA study is based on the hourly load pattern of the year 2022-23.

- The demand projections by 20$^{th}$ EPS are higher compared to the demand projections by Sikkim but past demand of Sikkim is much closer to actual demand.

- The current capacity mix in Sikkim has 79.7% of IC from non-fossil fuel sources.

- Sikkim is likely to witness energy deficit ranging from 164 MUs to 257MUs in different years from 2024-25 to 2034-35 with the existing and planned capacity addition.

- Sikkim is likely to have unserved energy in coming years and may need to contract capacities for meeting energy requirements other than the planned capacities. The additional quantum of capacities required (other than already planned) to be contracted is about 88 MW from Coal, 33 MW of DRE till 2034-35.

- Sikkim is surplus in fulfilment of its Renewable Purchase Obligations (RPO) and need not contract renewable capacities for fulfilling them except DRE addition and needs to contract renewable capacities for fulfilling them. The projected capacity and generation mix fulfils the RPO by 2030 as per the Ministry of Power notification dated 20$^{th}$ October, 2023.

- The coal capacity PLF is expected to remain in the range of 48%- 33% for the years till 2035 due to availability of more Hydro capacity in Sikkim.

- In Alternate Resilient scenario, coal requirement increases by around 11 MW compared to the base case in terminal year 2034-35. The STOA requirement increases by around 15-35 MW in case of Alternate Resilient scenario from 2025/26 compared to the base case.

- Sikkim may have surplus capacity available during monsoon months (June, July, August, September, and October) in the range of 42 MW for 2027-28 which can be shared with other states.

Annexure-I

## Future Contracted/Approved Capacity (MW) of Central Sector (Thermal/Hydro)

| SR. NO | POWER PLANT | SIKKIM'S SHARE (MW) | TYPE OF GENERATION | EXPECTED COD/ REMARK |
|---|---|---|---|---|
| 1 | Buxar | 1 | THERMAL | FY 2024-25 |
| 2 | Barh STPS Unit-III | 13 | THERMAL | FY 2025-26 |
| 3 | Darlipalli Stage-II | 12 | THERMAL | FY 2028-29 |
| 4 | Rangit-IV | 16 | HYDRO | FY 2025-26 |
| 5 | Teesta-VI | 65 | HYDRO | FY 2027-28 |
| | **TOTAL** | **107** | | |

# Assumption for Resource Adequacy Studies for the State of Sikkim

1. Electricity Demand & peak requirement: As per projections given by Sikkim
2. Demand Profile: Based on hourly demand profile of 2022-23
3. Existing & Planned Capacity: As per the information shared with CEA
4. Future Capacity addition: As per the information shared with CEA; based on RPO trajectory
5. Cost parameters: based on information in National Electricity Plan

## Technical Parameters

| Technology | Type | Availability (%) | Ramping (%/min) | Min. Technical. (%) | Start -up time (hr) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Hot | Warm | Cold |
| **Coal/ Lignite** | Existing/Planned | 85 | 1 | 55 | 2 | 5 | 10 |
| | Candidate | 88 | 1 | 55 | 2 | 5 | 10 |
| **Gas** | Existing | 90 | 5 | 40 | 1.5 | 2 | 3 |
| **Nuclear** | Existing/Planned | 68 | Const. Load | - | - | - | - |
| **Biomass** | Existing/Planned | 60 | 2 | 50 | 2 | 4 | 8 |
| **Hydro** | Existing/Planned/ Candidate | As per available hourly generation profile | 100 | - | - | - | - |
| **Solar** | Existing/Planned | | - | - | - | - | - |
| | Candidate | | - | - | - | - | - |
| **Wind** | Existing/Planned | | - | - | - | - | - |
| | Candidate | | - | - | - | - | - |
| **Pumped storage** | Existing/Planned | 95 | 50 | - | - | - | - |
| | Candidate | | 50 | - | - | - | - |
| **Battery Energy Storage** | Candidate | 98 | NA | - | - | - | - |

| Technology | Type | Heat Rate (MCal/MWh) | | Aux. Consum. (%) | Min. online time (hr) | Min. offline time (hr) | Start-up fuel consumption (MCal/MW) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | At max loading | At min loading | | | | Hot | Warm | Cold |
| Coal | Existing/ Planned | 2300 to 2879 | 2438 to 3052 | 7.0 | 6 | 4 | 600 | 1000 | 1800 |
| | Candidate (SC & USC) | 2060 to 2125 | 2183 to 2253 | 6.5 | 6 | 4 | 600 | 1000 | 1800 |
| Gas | Existing | 2000 to 2900 | 2260 to 3277 | 2.5 | 4 | 3 | 30 | 50 | 90 |
| Nuclear | Existing/ Planned | 2777 | 2777 | 10 | 6 | 4 | - | - | - |
| | Candidate | 2777 | 2777 | 10 | - | - | - | - | - |
| Biomass | Existing/ Planned | 4200 | 4450 | 8 | 6 | 4 | 600 | 1000 | 1800 |
| | Candidate | 4200 | 4450 | 8 | 6 | 4 | 600 | 1000 | 1800 |
| Hydro | Existing/ Planned | - | - | 0.7 | - | - | - | - | - |
| | Candidate | - | - | 0.7 | - | - | - | - | - |
| Pumped Storage | Existing/ Planned | - | - | pump efficiency 80 % | - | - | - | - | - |
| | Candidate | - | - | | - | - | - | - | - |
| Battery Energy Storage | Candidate | - | - | Round trip losses 12% | - | - | - | - | - |

## Transmission Parameters

A single node has been considered for the purpose of study with all generating units and demand connected to the node. No transmission bottleneck has been considered for the study. Interstate ATC limit has not been considered in the study.

## Financial Parameters

Following cost parameters have been assumed in the year 2021-2022:

| Resource | Capex* (in ₹/MW) | O&M Fixed Cost (in ₹/MW) | Construction Time (in years) | Amortization /Life time (in years) |
|---|---|---|---|---|
| Coal | 8.34 Cr | 19.54 Lakh | 4 | 25 |
| Hydro~ | 6 Cr to 20 Cr | 2.5% of Capex | 5 to 8 | 40 |
| Solar** | 4.5 Cr to 4.1 Cr | 1 % of Capex | 0.5 | 25 |
| Wind(Onshore) | 6 Cr | 1% of Capex | 1.5 | 25 |
| Wind(Offshore) | 13.7 Cr | 1% of Capex | 1.5 | 25 |
| Biomass | 9 Cr | 2% of Capex | 3 | 20 |
| Pumped Storage | 3 Cr to 8 Cr | 5 % of Capex | 7 | 40 |
| Battery Energy Storage (2-Hour) | 5.13 Cr to 3.13 Cr | 1 % of Capex | 0.5 | 14 |
| Battery Energy Storage (4-Hour) | 8.22 Cr to 4.72 Cr | 1 % of Capex | 0.5 | 14 |
| Battery Energy Storage (5-Hour) | 9.77Cr to 5.51 Cr | 1 % of Capex | 0.5 | 14 |
| Battery Energy Storage (6-Hour) | 11.31 Cr to 6.30 Cr | 1 % of Capex | 0.5 | 14 |

* All the Capex figures are on actual basis at the cost level of 2021-22 i.e., inflation is not considered while calculating capex.

~ The Capex values of Hydro and PSS candidates are considered as per the project cost details furnished by the respective developers for state and private sector plants and as per RCEs done periodically by CEA for central sector plants.

**Solar Cost is assumed to reduce from Rs 4.5 Cr/MW in 2021-22 to Rs 4.1 Cr/MW in 2029-30.