

Report on Resource Adequacy Plan (Generation) for Kerala (2025-26 to 2035-36)

(Version 2.0)

December 2025

Government of India
Ministry of Power
Central Electricity Authority

Contents

Disclaimer i

Executive Summary ii

1.0 Introduction 1

2.0 Highlights of the Previous RA Study (up to FY 2031-32) 2

3.0 RA Study for Kerala (from 2025-26 to 2035-36) 4

3.1 Present Power Scenario in Kerala 4

3.2 Demand Analysis of the FY 2024-25 5

4.0 Principles of Generation Planning 7

4.1 Generation Expansion Planning Tool -ORDENA 7

5.0 Reliability Analysis 8

5.1 Demand variation 9

5.2 Variation in RE 9

5.3 Forced Outage of Thermal Generators 10

6.0 Inputs/Assumptions for the Study 10

7.0 Outcome of the model 14

7.1 Unserved Electrical Energy Projections 14

7.2 Options to meet the unserved electrical energy 15

7.3 Day-wise Surplus Capacity (in MW) 20

8.0 Alternate Demand Scenarios 22

8.1 Scenario-I: 10% Higher Demand 22

8.2 Scenario-II: 10% Lower Demand 24

9.0 Conclusions 26

Disclaimer

This Resource Adequacy study for Kerala has been conducted based on the data and inputs provided by Kerala SLDC/ KSEBL. The findings, analysis and conclusions presented in this report are contingent upon the accuracy, completeness and timeliness of the information furnished by Kerala. 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 Kerala 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 Kerala.

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 the 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 requirements. This plan shall be vetted/validated by CEA to leverage the benefits of national-level optimisation 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 optimising the requirement for additional capacity.

Government of India has 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 electrical energy consumption must be met from renewable energy sources.

To support the utility in fulfilling this requirement, CEA, in collaboration with the utility, initially conducted a Resource Adequacy (RA) study with a planning horizon up to FY 2031-32, based on the data received from the utility and in compliance with the RPO trajectory specified vide gazette notification dated 22nd July, 2022 (applicable at the time of Study). This study has now been updated and extended to cover the period up to FY 2035-36, incorporating the latest data furnished by the utility and planning assumptions. The RPO requirement for the utility has also been re-assessed in accordance with the gazette-notification dated 20th October 2023.

The electrical energy requirement and peak electricity demand for Kerala are increasing with a CAGR of 5.1% and 3.7% respectively, from 2025-26 to 2035-36 as forecasted by Kerala. For satisfying resource adequacy, i.e., meeting the electricity demand reliably and at an affordable cost, the utility needs to methodically plan its capacity expansion either by investing in generation capacity or by procuring power. In view of the reduction in cost of solar, RTC power, wind and technology options like Battery Energy Storage Systems (BESS), planning for a long-term optimal generation capacity mix gains tremendous importance so that the future generation capacity mix is cost-effective as well as environmentally friendly.

A study has been carried out for Kerala, considering the existing contracted capacity and planned capacity addition. It was found that Kerala's likely contracted capacity may not be sufficient to meet the projected electricity demand. Further, the total unserved electrical energy in the year

2035-36 is expected to be about 13,868 MUs, which is about 24.8% of the projected annual 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, a long-term study has been carried out with the objective to minimise 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 plans of the utility, along with RPO constraints. The renewable capacities have been assessed in view of adherence to the RPO trajectory gazette notified by the Ministry of Power, considering the fungibility among different sources.

The Resource adequacy studies have projected a likely optimal capacity mix for future years till 2035-36, which is able to meet the projected electrical demand reliably. Based on the study, the likely total projected contracted capacity for the year 2035-36 is around 18,348 MW which consists of 3,871 MW from Coal, 360 MW from Gas, 371 MW from Nuclear, 3,283 MW from Hydro, 1,159 MW from Wind, 1,947 MW from Solar, 800 MW from RTC, 5,109 MW from Distributed Renewable Energy (DRE) sources, 550 MW/1600 MWh of Energy storage and 897 MW of MTOA/STOA arrangement will be required. This capacity shall be able to meet the projected electricity demand with the prescribed reliability criteria.

1.0 Introduction

The 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 were notified in June 2023 by the Ministry of Power in consultation with the 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 the demand-supply situation in the grid precisely due to high seasonality and intermittency in RE generation. Resource Adequacy exercise may also help in the assessment of capacity requirements to be tied up or contracted on a long-term, medium-term, and short-term basis.

Further, the 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 their 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 Kerala based on inputs furnished by the Utility. 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 optimise long-term power procurement while ensuring resource adequacy to meet demand on a 24x7 basis, considering variations in demand, RE generation, and forced outages of thermal capacities. The study assesses the Planning Reserve Margin (PRM) required by the utility 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 Utility up to FY 2031-32, based on inputs from Kerala SLDC/ KSEBL and in accordance with the RPO trajectory specified in the Ministry of Power's gazette notification dated 22nd July, 2022 (applicable at the time of Study).

2.0 Highlights of the Previous RA Study (up to FY 2031-32)

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 2023-24 to 2031-32. The fuel-wise contracted capacity as on 31st March, 2023 is given below:

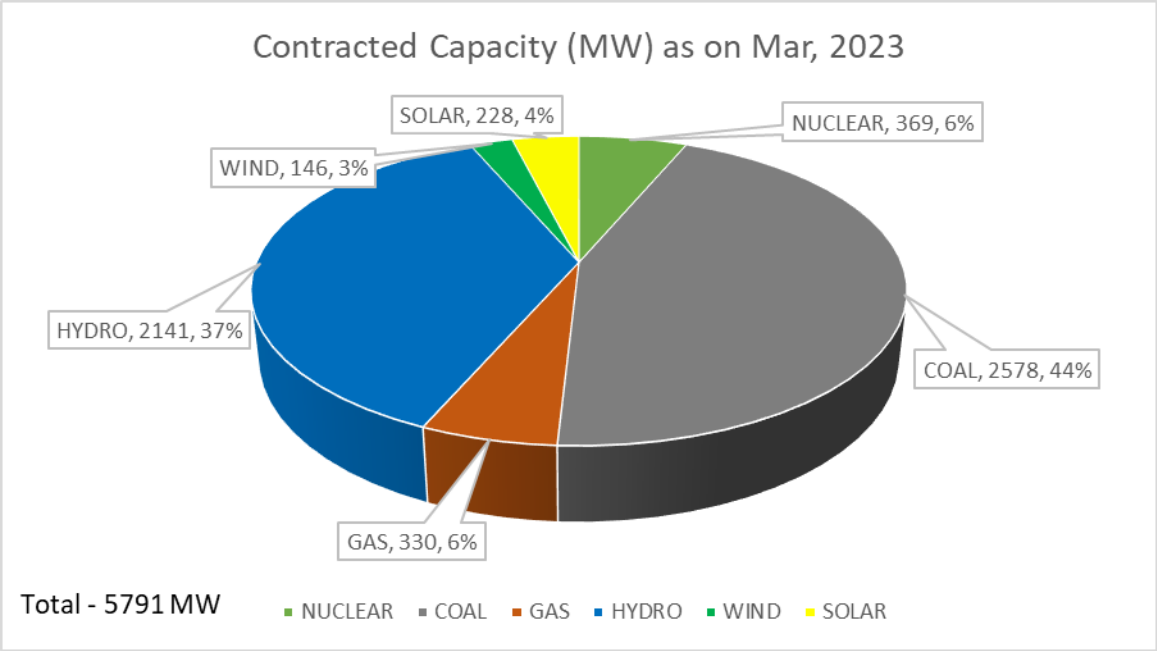


Figure 1: Fuel-wise Contract Capacity (in MW) as on March 2023

2. The hourly demand pattern for 2022-23 had been analysed and considered for the study.

3. The peak electricity demand and electrical energy projections furnished by Kerala were lower than those projected in the 20th EPS. Therefore, the studies had been carried out considering the 20th EPS projections, which are tabulated below:

Table 1: Electrical Energy requirement (MU) and Peak electricity demand (MW) projections

Year	**2022-23**	**2023-24**	**2024-25**	**2025-26**	**2026-27**	**2027-28**	**2028-29**	**2029-30**	**2030-31**	**2031-32**
Electrical Energy Requirement Projections (MU)	27892	29244	30729	32281	33903	35597	37384	39464	41220	42885
Year-on-Year Growth *(Electrical Energy)*		4.85%	5.08%	5.05%	5.02%	5.00%	5.02%	5.56%	4.45%	4.04%
Peak electricity demand Projections (MW)	4592	4808	5044	5291	5549	5818	6101	6431	6707	6967
Year-on-Year Growth (Peak electricity demand)		4.70%	4.91%	4.90%	4.88%	4.85%	4.86%	5.41%	4.29%	3.88%

4. The actual peak electricity demand and electrical energy requirement of the utility observed during 2024-25 is tabulated below:

Table 2: Actual Electrical Energy Requirement and Peak Electricity Demand in 2024-25

Year	Actual electrical energy requirement (in MU)	Actual peak electricity demand (in MW)
2024-25	31,624	5,904

5. 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 tabulated below.

Table 3: Year-wise capacity projections (in MW)

	Coal	Gas	Nuclear	Hydro	Wind	Solar	STOA/MTOA
2023-24	2578	330	369	2251	240	696	719
2024-25	2578	330	369	2283	402	806	889
2025-26	2578	330	369	2291	601	886	1082
2026-27	3507	330	369	2385	720	986	506
2027-28	3531	330	369	2423	937	1504	645
2028-29	3669	330	369	2481	1134	2016	698
2029-30	3849	330	369	2538	1321	2526	768
2030-31	3955	330	369	2538	1821	3026	820
2031-32	4052	330	369	2538	2321	3526	863

*****The STOA/MTOA value represents the peak electricity demand requirement in MW, and it was recommended that this requirement may be met through power procurement from the market or through bilateral agreements.

6. The year-wise planned and additional capacity contract addition (in MW) for the above tabulated cumulative capacity is detailed below.

Table 4: Year wise capacity additions for Kerala (in MW)

	COAL		NUCLEAR		HYDRO		WIND		SOLAR		Battery/PSP	
Year	**Planned Contracts**	**Additional Requirement**	**Planned Contracts**	**Additional Requirement**	**Planned Contracts**	**Additional Requirement**	**Planned Contracts**	**Additional Requirement**	**Planned Contracts**	**Additional Requirement**	**Planned Contracts**	**Additional Requirement**
2023/24	0	0	0	0	111	0	2	92	468	0	0	0
2024/25	0	0	0	0	32	0	14	149	110	0	0	0
2025/26	0	0	0	0	8	0	25	174	80	0	0	0
2026/27	0	929	0	0	94	0	25	94	100	0	0	0
2027/28	0	24	0	0	38	0	22	195	100	417	0	0
2028/29	0	138	0	0	24	34	35	161	125	388	0	0
2029/30	0	179	0	0	15	42	35	152	130	380	0	0
2030/31	0	106	0	0	0	0	0	500	0	500	0	0
2031/32	0	97	0	0	0	0	0	500	0	500	0	0

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

3.1 Present Power Scenario in Kerala

As of March 2025, the total contracted capacity of Kerala is 7,323 MW, including 1347 MW DRE. Out of the total contracted capacity (CC), the share of non-fossil fuel-based CC is 65.4%. Fuel-wise contracted capacity as on 31st March, 2025, is given in Table 5 and Figure 2:

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

Source	Contracted Capacity (MW)	Percentage (%)
COAL	2171	30%
GAS	360	5%
NUCLEAR	371	5%
HYDRO	2131	29%
WIND	145	2%
SOLAR	797	11%
DRE	1347	18%
Total	**7323**	**100%**

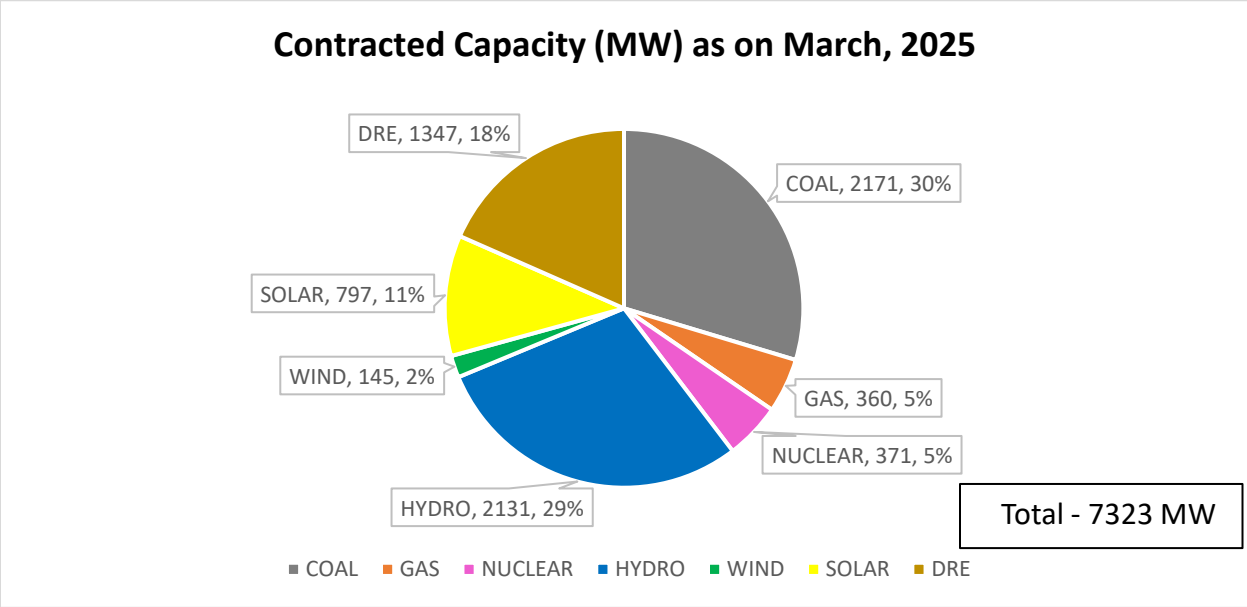


Figure 2: Fuel-wise Contracted Capacity (in MW) as on March, 2025

3.2 Demand Analysis of the FY 2024-25

The hourly demand pattern of 2024-25 has been analysed, and it was observed that peak electricity demand occurs twice, with one peak during daytime at around 15:00 Hours and another during nighttime at around 23:00 hours in the month of April. Further, it can be observed that the demand is comparatively higher during the months from February to May than the rest of the year. The month-wise variation in average hourly demand observed for the year 2024-25 is depicted in Figure 3.

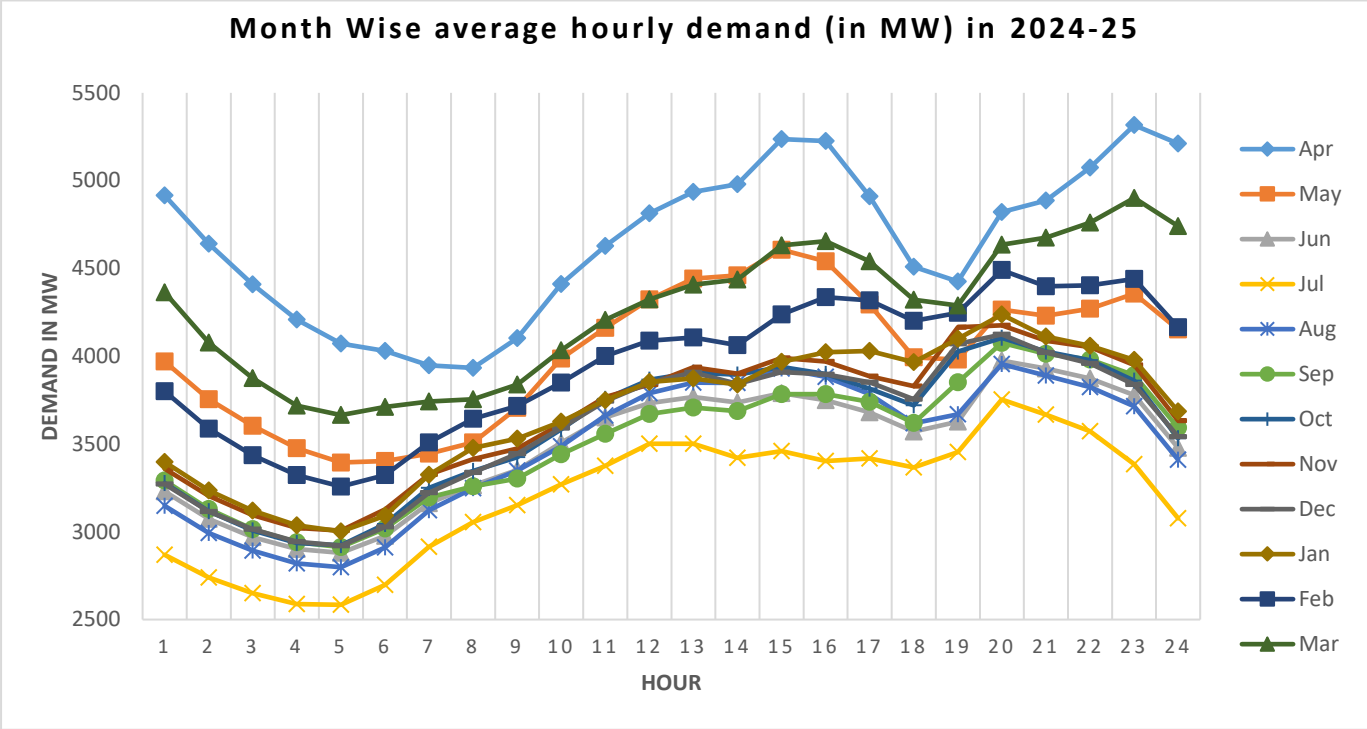


Figure 3: Average Hourly Demand Variation (Month-wise) for 2024-25

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

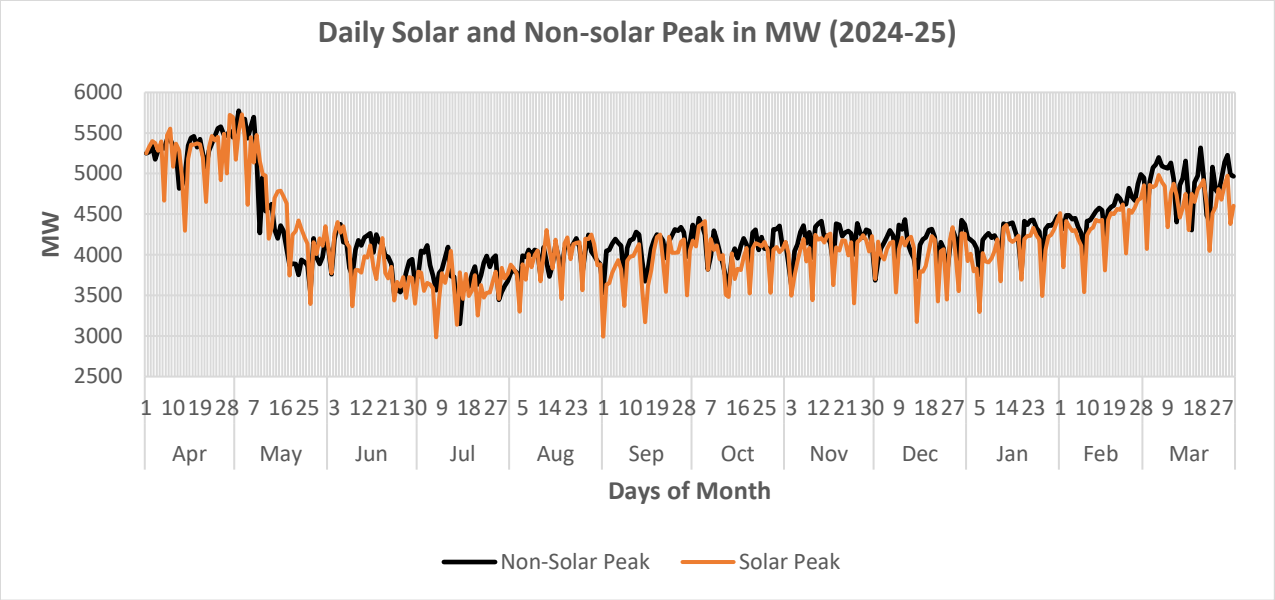


Figure 4: Solar and Non-Solar Peak Electricity Demand in MW for the year 2024-25

As seen from Figure 4 above, the non-solar and solar peak demand in the months of April and May are very close to each other. However, during the rest of the year, the daily peak electricity demand is observed predominantly in non-solar hours.

The hourly demand pattern of 2024-25 was analysed to find out the number of occurrences of the peak electricity demand and near-peak electricity 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.

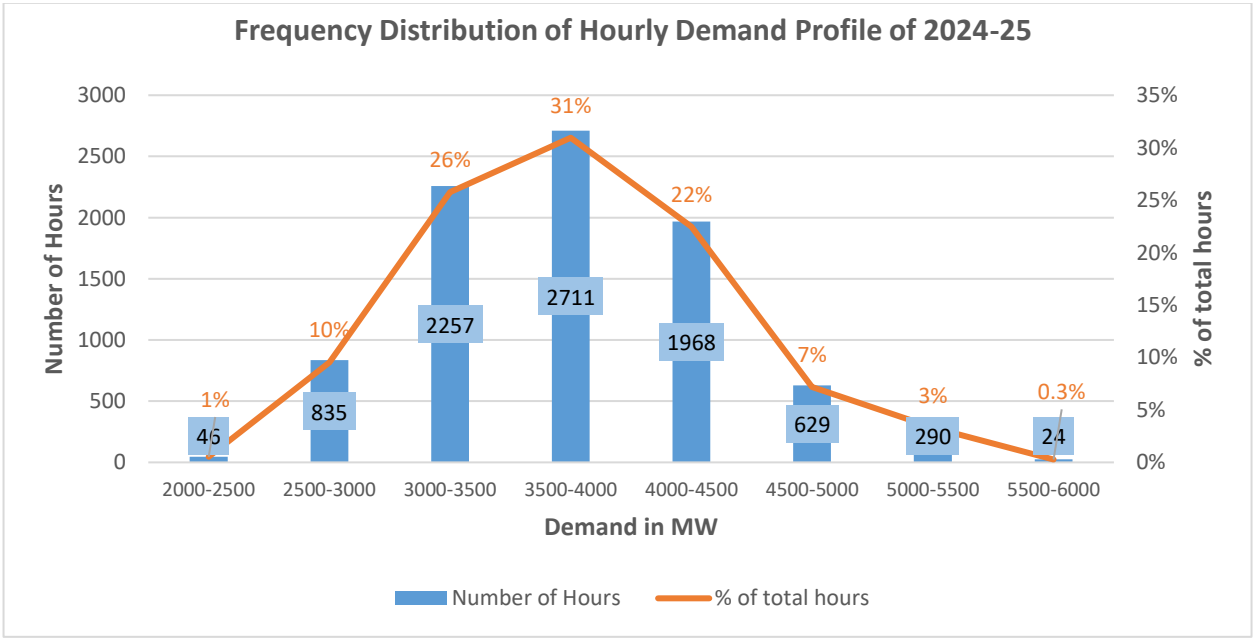


Figure 5: Frequency Distribution of Hourly Demand Profile of 2024-25

4.0 Principles of Generation Planning

The objective of Generation Planning is to determine the optimal cost-effective mix of generation capacities that can reliably meet electricity demand at all times while making the best use of available resources. Rather than attempting to predict the future, generation planning studies aim to collaboratively examine and understand the important factors and interrelationships that will influence the power sector moving forward. As such, planning is a continuous process focused on balancing demand and supply across all times and locations.

The major aspects considered in the planning process are:

i) To supply 24x7 reliable power to consumers
ii) To achieve the 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 generation expansion planning model, namely ORDENA. ORDENA is a mixed integer linear optimisation program that minimises the Net Present Value (NPV) of investment and operation costs subject to several constraints. The major constraints include balancing electricity demand and supply, 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 the Exhibit.

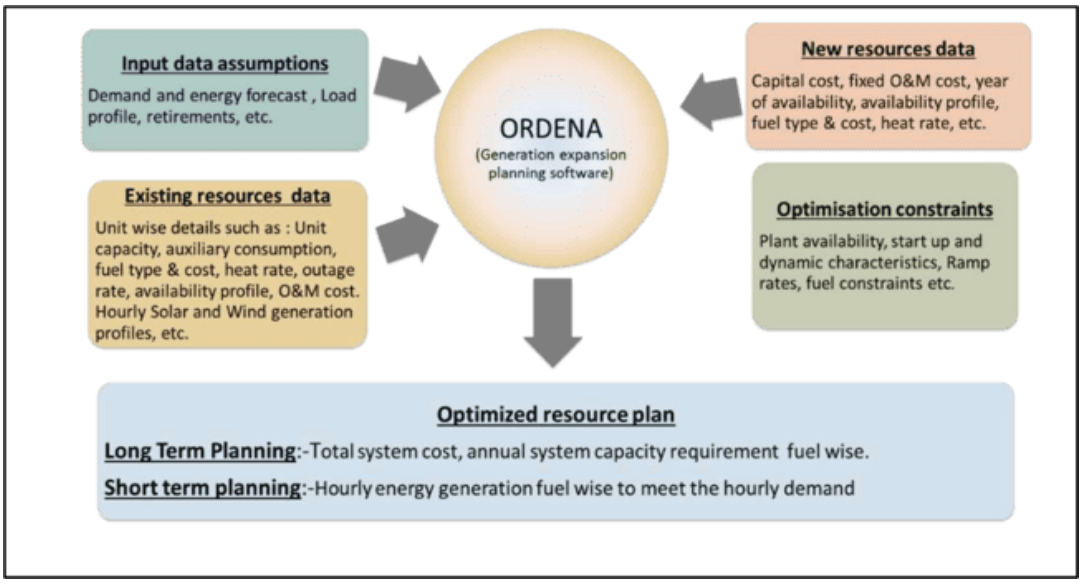


Exhibit: Schematic Diagram -Ordena

5.0 Reliability Analysis

One of the main criteria of resource adequacy studies is to determine the reliability of the system to meet the demand adequately at every instance in 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 not served, calculated in megawatt-hours (MWh). The metric can be normalised (i.e., divided by the projected electrical energy requirement) to create a Normalised 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 that 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 the economic dispatch model. Monte Carlo simulation helps in analysing the randomness associated with RE energy resource, demand pattern changes and forced outages of the 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 the above variation of system parameters.

Planning Reserve Margin (PRM): To meet the prescribed standard of LOLP / NENS conditions, a sufficient reserve margin needs to be maintained in the system to adequately address 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 percentage of the projected peak electricity demand of the system.

5.1 Demand variation

The hourly demand variation for consecutive years (i.e. 2023-24 and 2024-25, considering 2023-24 as the base) has been analysed. The demand pattern variation of 2023-24 and 2024-25 is shown below:

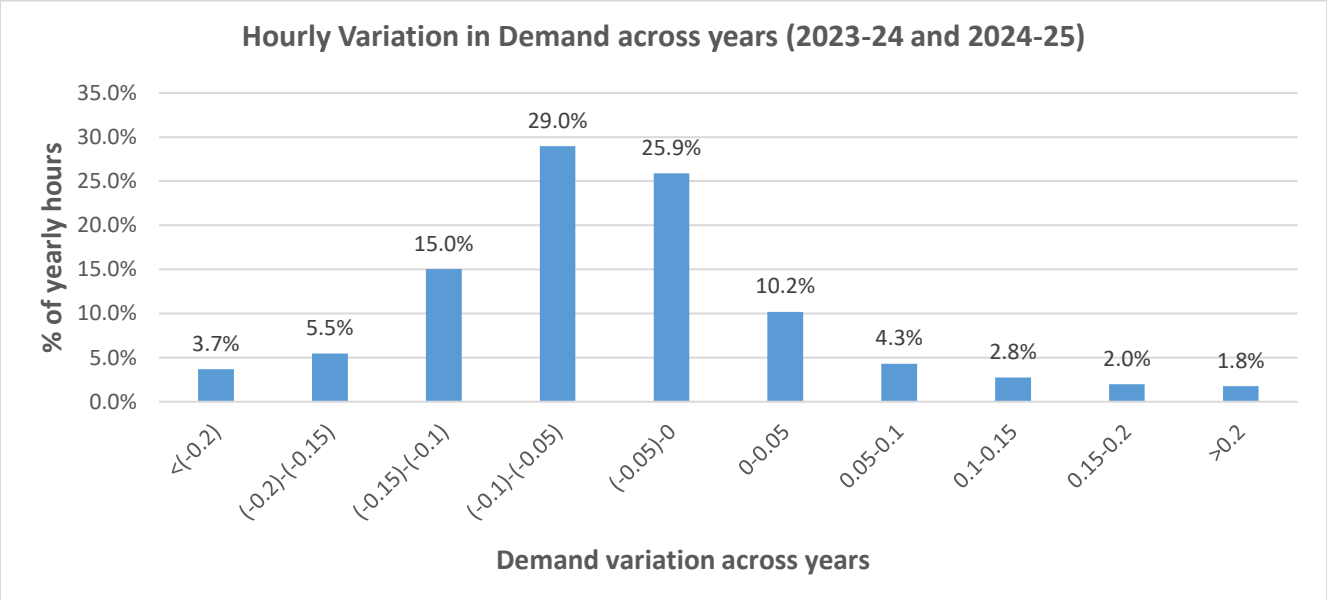


Figure 6: Hourly Variation in Demand across years

It can be observed that the hourly demand typically varies ±15% for around 85% of instances. This variation is primarily due to temperature, weather parameters or any random outages of transmission lines and generation units, etc. This variation has been captured in the reliability study by varying the projected hourly demand for the future years by ±15% by introducing a random variable (with normal distribution) for demand as per observed behaviour over the years.

5.2 Variation in RE

In the Long-term capacity expansion planning studies, a particular profile for solar and wind generation is considered based on the observed solar and wind generation data to determine the

optimal capacity mix. However, due to the 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 have been varied by ± 10 % and wind generation has been varied by ± 50% to incorporate the variation in these generation sources and plan for the requisite measures to mitigate such behaviour.

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.

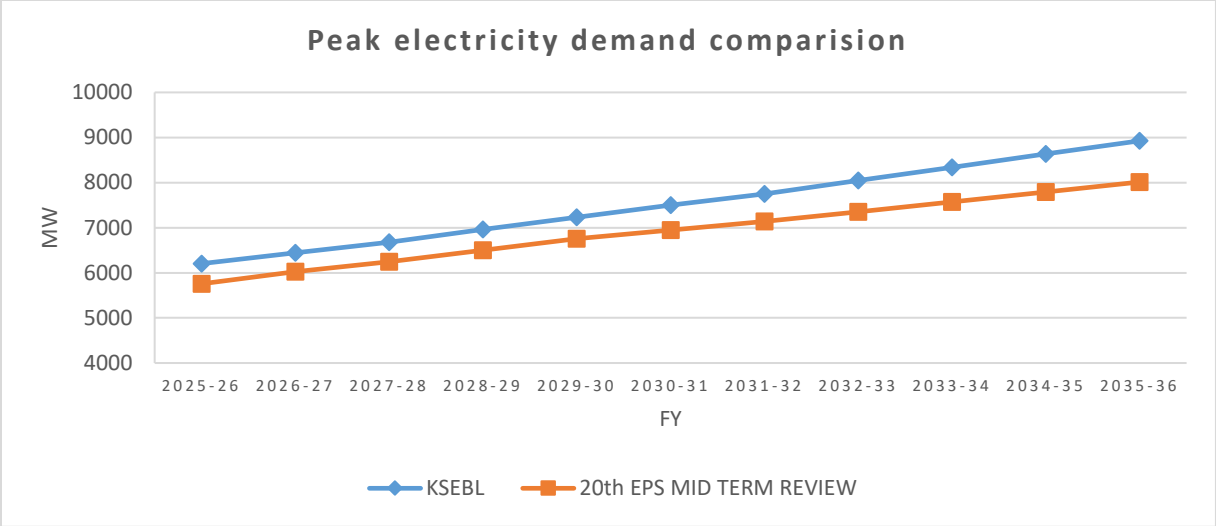
Based on these variations, reliability studies are carried out to ascertain the robustness of the system.

6.0 Inputs/Assumptions for the Study

i) The peak electricity demand and electrical energy requirement for the state of Kerala has been taken as per the projection by Kerala SLDC/ KSEBL. The actual peak electricity demand and electrical energy requirement of Kerala during 2024-25 was higher than the projections as per the 20th EPS mid- term review. Therefore, the studies have been carried out considering demand projections by Kerala SLDC/ KSEBL.

Table 6: Electricity Demand Projection as provided by Kerala SLDC/ KSEBL

Electrical Energy Requirement (MU) and Electrical Peak Demand (MW) Projections				
	Electrical Energy Requirement (MU)	Year-on-Year Growth	Peak Electricity Demand (MW)	Year-on-Year Growth
2025-26	34008		6204	
2026-27	36055	6.02%	6445	3.89%
2027-28	38179	5.89%	6678	3.62%
2028-29	40384	5.77%	6959	4.20%
2029-30	42673	5.67%	7233	3.93%
2030-31	44726	4.81%	7500	3.69%
2031-32	46804	4.65%	7746	3.28%
2032-33	48966	4.62%	8045	3.87%
2033-34	51215	4.59%	8335	3.60%
2034-35	53557	4.57%	8637	3.62%
2035-36	55996	4.55%	8926	3.35%



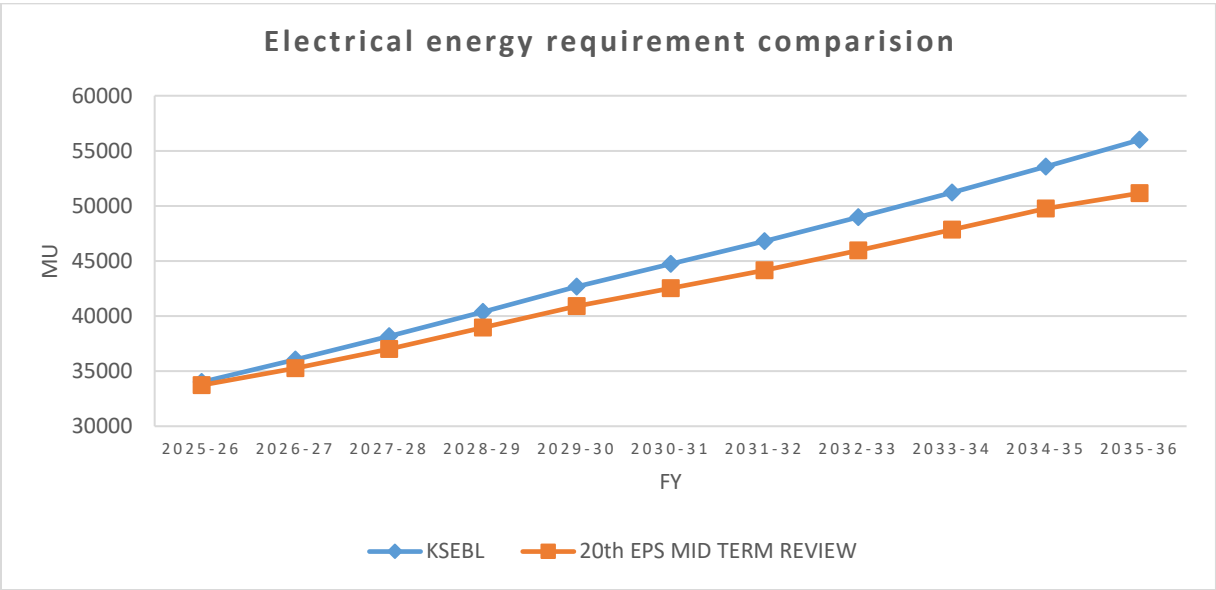


Figure 7: Comparison of Electrical Energy Requirement and peak Demand Projections of 20th EPS Mid Term Review vs Kerala SLDC/ KSEBL

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 and wind generation profiles and CUFs have been referred from the previous year's generation data provided by Kerala SLDC/ KSEBL, while the hydro generation profiles and PLFs have been taken from the National Electricity Plan 2023 (Vol. I - Generation).

iv) The capital costs of candidate plants for coal, wind, solar, and battery 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 furnished by Kerala SLDC/ KSEBL. Source-wise planned capacity is given below:

Table 7: Source-wise planned capacity addition

FY	Coal	Hydro	Solar	Wind	BESS 2hr	BESS 4hr	Solar Rooftop DRE	Hydro DRE
2025-26	**300**	24	-	14	-	-	448	0
2026-27	**-**	24	550	200	-	125	450	0
2027-28	**-**	-	100	300	50	125	450	0
2028-29	**-**	-	-	-	250	-	450	0
2029-30	**400**	-	-	-	-	-	450	8
2030-31	**-**	64	-	-	-	-	250	57
2031-32	**-**	-	-	-	-	-	250	0
2032-33	**-**	-	-	-	-	-	250	0
2033-34	**-**	-	-	-	-	-	250	0
2034-35	**-**	-	-	-	-	-	250	0
2035-36	**-**	-	-	-	-	-	200	0
Total	**700**	**112**	**650**	**514**	**300**	**250**	**3698**	**64**

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 8: Renewable Purchase Obligation (RPO) trajectory as per the 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 has been assumed to rise steadily beyond 2029-30. Hence, the suggested trajectory of Renewable Purchase Requirement up to FY 2035-36 is given in Table 9.

Table 9: Renewable Purchase Obligation (RPO) trajectory 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%	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%
7.	2030-31	40.50%			5.0%	45.5%
8.	2031-32	41.50%			5.5%	47.0%
9.	2032-33	42.30%			6.0%	48.3%
10.	2033-34	43.00%			6.5%	49.5%
11.	2034-35	43.50%			7.0%	50.5%
12.	2035-36	44.00%			7.5%	51.5%

Based on the trajectory specified, RPO quantum in million units (MUs) from hydro, wind, other (Solar, biomass, etc.) and Distributed Renewable Energy (DRE) has been calculated and is tabulated below.

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.	2025-26	493.12	414.90	9603.88	714.17	11226.06
2.	2026-27	710.29	483.14	10794.98	973.50	12961.91
3.	2027-28	935.39	542.15	12079.91	1259.92	14817.37
4.	2028-29	1191.32	573.45	13366.96	1574.96	16702.65
5.	2029-30	1485.00	567.54	14517.19	1920.26	18490.00
6.	2030-31	18113.96			2236.29	20350.25
7.	2031-32	19423.57			2574.21	21997.77
8.	2032-33	20712.44			2937.94	23650.38
9.	2033-34	22022.61			3329.00	25351.61
10.	2034-35	23297.49			3749.02	27046.51
11.	2035-36	24638.27			4199.70	28837.97

The year-wise total renewable energy, including DRE, met from the existing and planned capacity, along with the deficit, is shown in Table 11.

Table 11: Renewable Energy Deficit/Surplus

FY	RE Generation required to meet RPO (including DRE)		RE Generation (including DRE) available or to be met from existing and planned contracts		RE Generation Surplus (+)/ Deficit (-) (including DRE)
	(MU)	(%)	(MU)	(%)	(%)
2025-26	11226	33.01%	12257	36.04%	3.03%
2026-27	12962	35.95%	14729	40.85%	4.90%
2027-28	14817	38.81%	16171	42.36%	3.55%
2028-29	16703	41.36%	16842	41.71%	0.35%
2029-30	18490	43.33%	17525	41.07%	-2.26%
2030-31	20350	45.50%	18077	40.42%	-5.08%
2031-32	21998	47.00%	18450	39.42%	-7.58%
2032-33	23650	48.30%	18822	38.44%	-9.86%
2033-34	25352	49.50%	19195	37.48%	-12.02%
2034-35	27047	50.50%	19568	36.54%	-13.96%
2035-36	28838	51.50%	19866	35.48%	-16.02%

It may be noted that from the above table, the utility will not be able to meet its RPO requirements from 2029-30 onwards, based on the existing and planned contracts.

7.0 Outcome of the Study

7.1 Unserved Electrical Energy Projections

Initially, the study was carried out considering only the existing and planned capacity contracts by Kerala and does not include any banking arrangements or short-term contracts. The total unserved electrical energy for the year 2035-36 would be 13,868 MU. Year-wise likely unserved electrical energy with the existing and planned capacities is given in Figure 7.

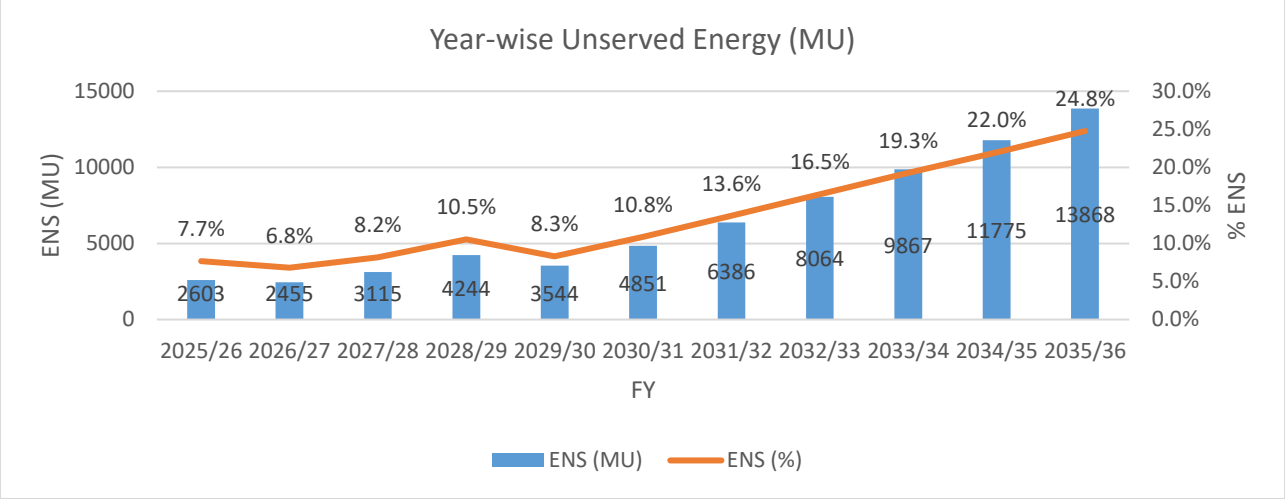


Figure 8: Yearly likely unserved electrical energy (in MU) with the existing and planned capacities

The study has also analysed the daily and monthly pattern of unserved electrical energy in the year 2035-36.

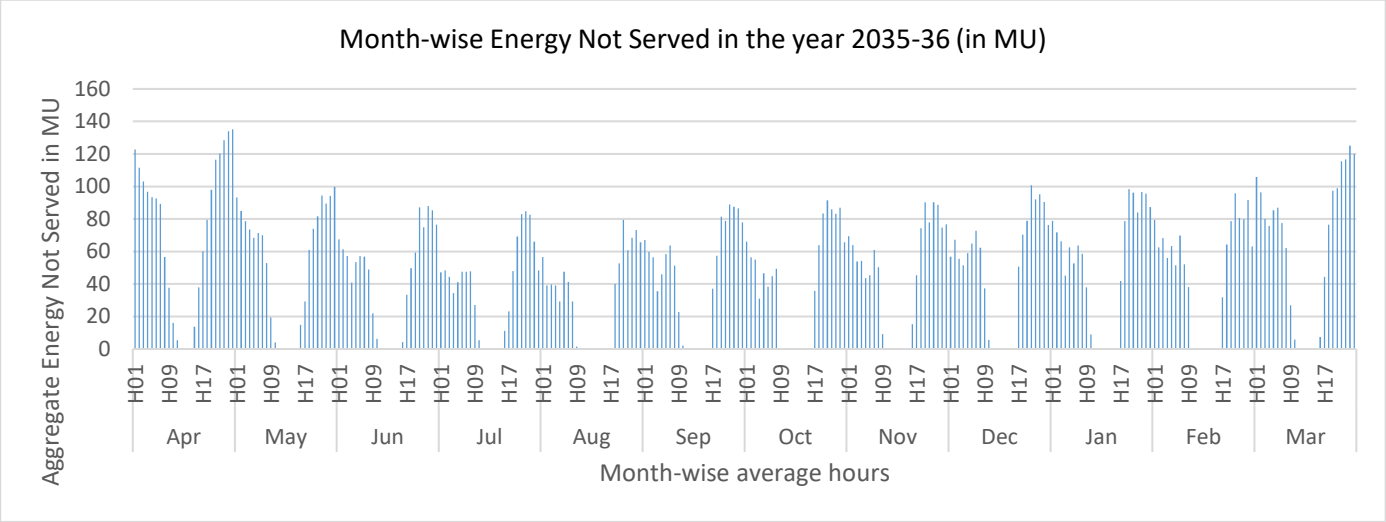


Figure 9: Block-wise Unserved Electrical Energy Pattern MU (2035-36)

The unmet demand occurs mainly during non-solar hours throughout the year. Additionally, the utility is expected to face unmet demand even during solar hours in the months of March and April, when electricity demand is higher compared to other months. To meet unserved energy, the utility needs to tie up additional capacity.

7.2 Options to meet the unserved electrical energy

To meet unserved electrical energy, candidate capacities have been given to the model to find the least cost optimal capacity mix required to meet the demand in compliance with the Renewable Purchase Obligation. It may be noted that different generating source-wise candidate capacities have been introduced from 2028-29 onwards.

The candidate capacities incorporate the recent market price discoveries and tariff offers received by the utility as communicated by Kerala SLDC/ KSEBL. The capacity projections for Kerala are given below in Table 12 and Figure 10:

Table 12: Likely requirement of contracted capacity (existing + planned + additional) (in MW)

	Coal	Gas	Nuclear	Hydro	Wind	Solar	BESS	DRE	RTC	STOA
2025/26	2471	360	371	2155	159	797	0	1795	0	1988
2026/27	2471	360	371	2179	359	1347	125/500	2245	0	1973
2027/28	2471	360	371	2179	659	1447	300/1100	2695	0	1909
2028/29	2871	360	371	2179	859	1647	550/1600	3145	300	1278
2029/30	3271	360	371	2179	1059	1847	550/1600	3603	425	1022
2030/31	3271	360	371	2243	1159	1899	550/1600	3909	513	1140
2031/32	3271	360	371	3283	1159	1947	550/1600	4159	513	566
2032/33	3271	360	371	3283	1159	1947	550/1600	4409	673	699
2033/34	3305	360	371	3283	1159	1947	550/1600	4659	800	821
2034/35	3641	360	371	3283	1159	1947	550/1600	4909	800	821
2035/36	3871	360	371	3283	1159	1947	550/1600	5109	800	897

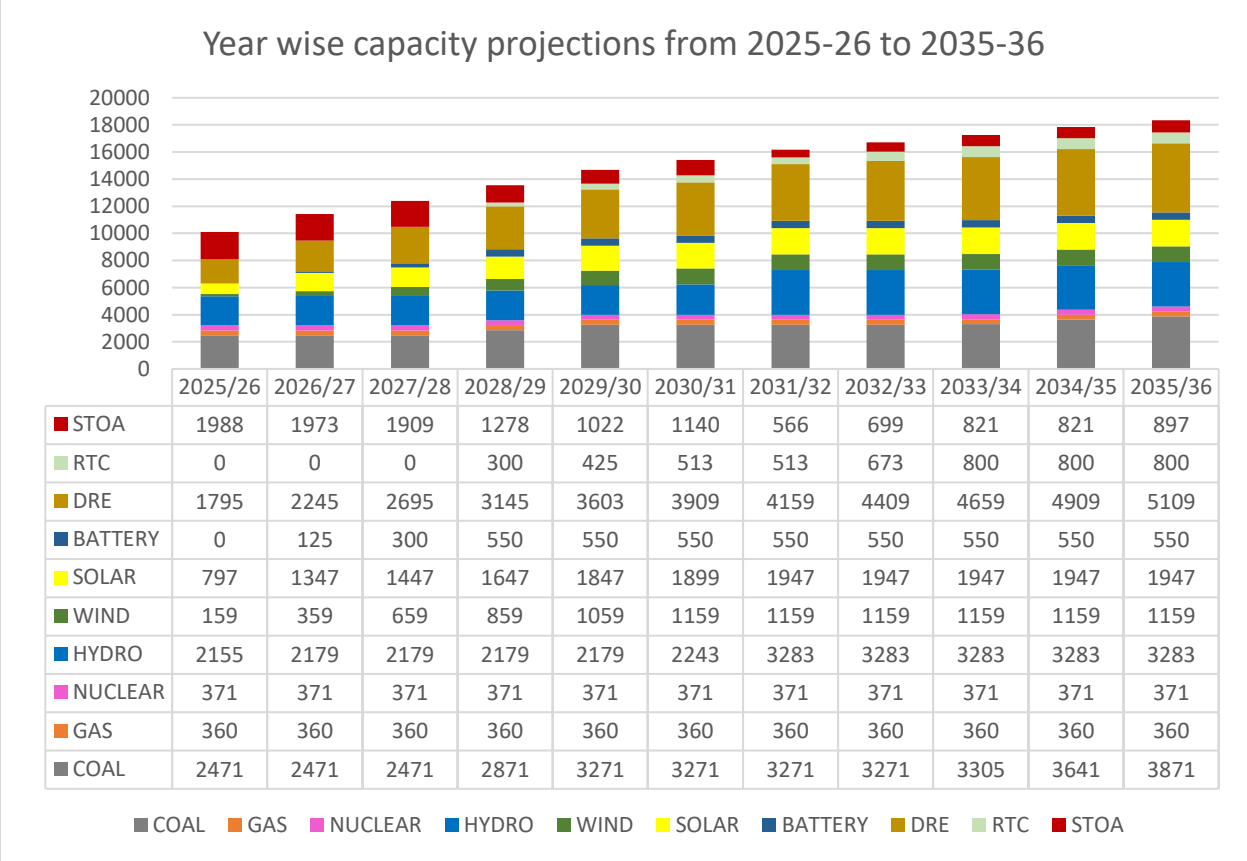


Figure 10: Projected Contracted Capacity Mix Year-wise (MW)

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

Table 13: Likely planned and additional capacity to be contracted by the utility (in MW)

	Coal		Hydro		Solar			
	Planned	**Additional**	**Planned Hydro**	**Additional**	**Planned Inside Kerala**	**Planned Outside Kerala**	**Additional Kerala Solar**	**Additional Outside Solar**
2025/26	300		24					
2026/27			24		50	500		
2027/28					100			
2028/29		400					100	100
2029/30	400						100	100
2030/31			64	1040			50	2
2031/32								48
2032/33								
2033/34		34						
2034/35		335						
2035/36		231						
Total	**700**	**1000**	**112**	**1040**	**150**	**500**	**250**	**250**

	Wind			RTC	BESS		DRE		STOA
	Planned inside Kerala	**Planned outside Kerala**	**Additional outside Wind**	**Additional**	**Planned Battery 2h**	**Planned Battery 4h**	**Planned DRE Hydro**	**Planned Solar Rooftop DRE**	**Yearly Requirement**
2025/26	14							448	1988
2026/27		200				125		450	1973
2027/28	300				50	125		450	1909
2028/29			200	300	250			450	1278
2029/30			200	125			8	450	1022
2030/31			100	88			57	250	1140
2031/32								250	566
2032/33				159				250	699
2033/34				127				250	821
2034/35								250	821
2035/36								200	897
Total	**314**	**200**	**500**	**800**	**300**	**250**	**64**	**3698**	

The STOA/MTOA requirement can be fulfilled through power procurement from markets or bilateral agreements. The STOA/MTOA value reflects the peak electricity demand value requirement and seasonal banking requirements in terms of MW.

Reliability studies have been conducted based on the projected capacity for the year 2035-36. The analysis confirms that the projected capacity meets the reliability criteria specified in the National Electricity Plan (NEP), with the Loss of Load Probability (LoLP) and Not-Served Energy

(NENS) remaining within the permissible limits of 0.2% and 0.05%, respectively (as specified in the National Electricity Plan (NEP)).

As per the Resource Adequacy studies, the likely total projected contracted capacity for the year 2035-36 is about 18,348 MW which consists of 3,871 MW from Coal, 360 MW from Gas, 371 MW from Nuclear, 3,283 MW from Hydro, 1,159 MW from Wind, 1,947 MW from Solar, 800 MW from RTC, 5,109 MW from Distributed Renewable Energy (DRE) sources, 550 MW/ 1600 MWh of Energy storage and 897 MW of MTOA/STOA arrangement will be required. This capacity shall be able to meet the projected demand with prescribed reliability criteria. Though Kerala has planned power tie up of 550 MW from BESS, feasibility of power tie-up from Pumped Storage Plants (PSP) may also be explored. Further, it may be noted that the hydro plants proposed by Kerala SLDC/ KSEBL, with a total capacity of 1,040 MW (800 MW Idukki Extension HEP and 240 MW Latchmi HEP) were selected by the model.

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

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 Kerala has been assessed as 5%. In addition, the projected/contracted capacity fulfils the stipulated Renewable Purchase Obligation.

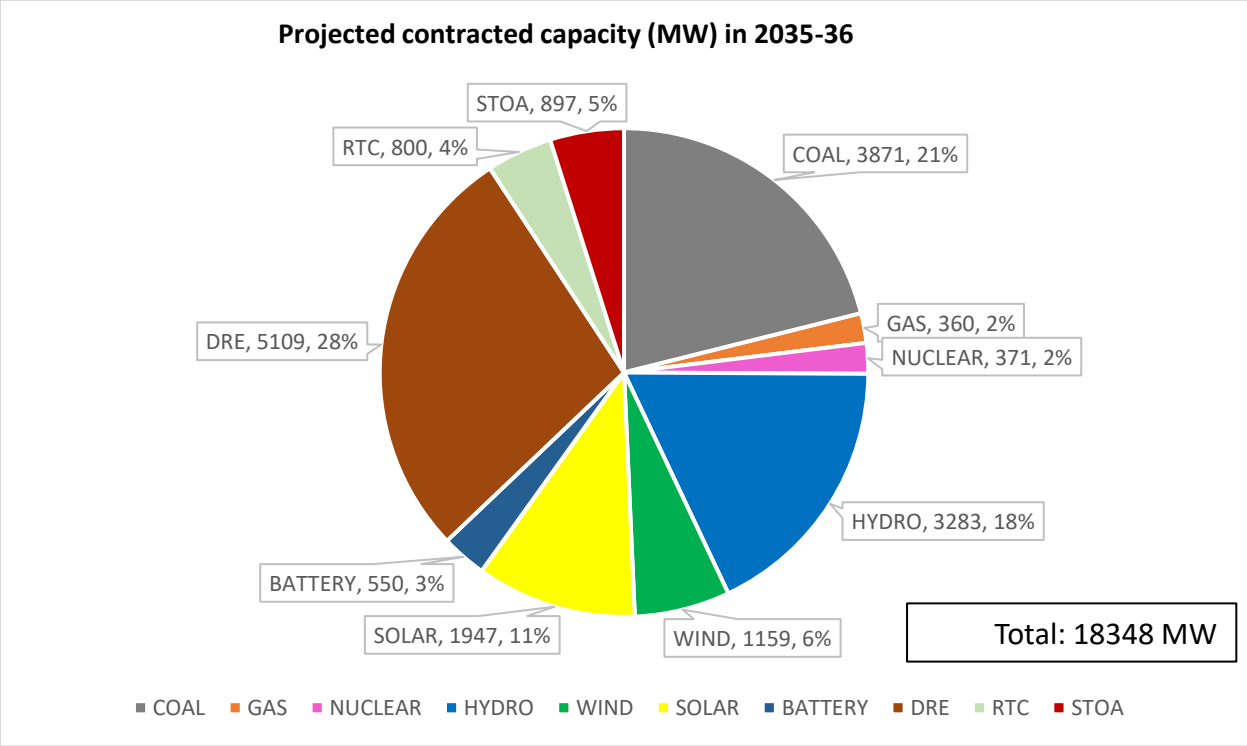


Figure 11: Contracted Capacity Mix in 2035-36

The share of non-fossil fuel-based capacity is projected to increase to around 72% by 2035-36 from 65% in 2024-25. Further, the share of non-fossil fuel-based generation will be around 60% in the year 2035-36. The projected generation mix for the utility is shown in Figure 12.

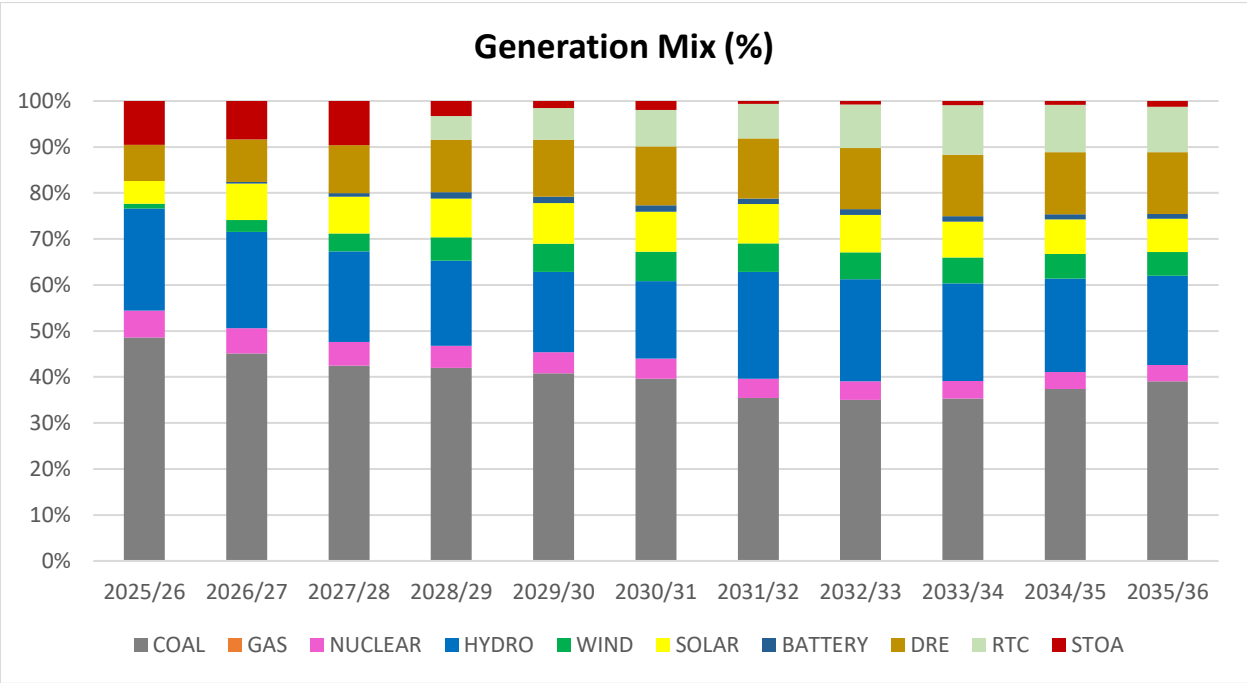


Figure 12: Year-wise projected generation mix (in %)

The year-wise projected generation in MU is depicted below:

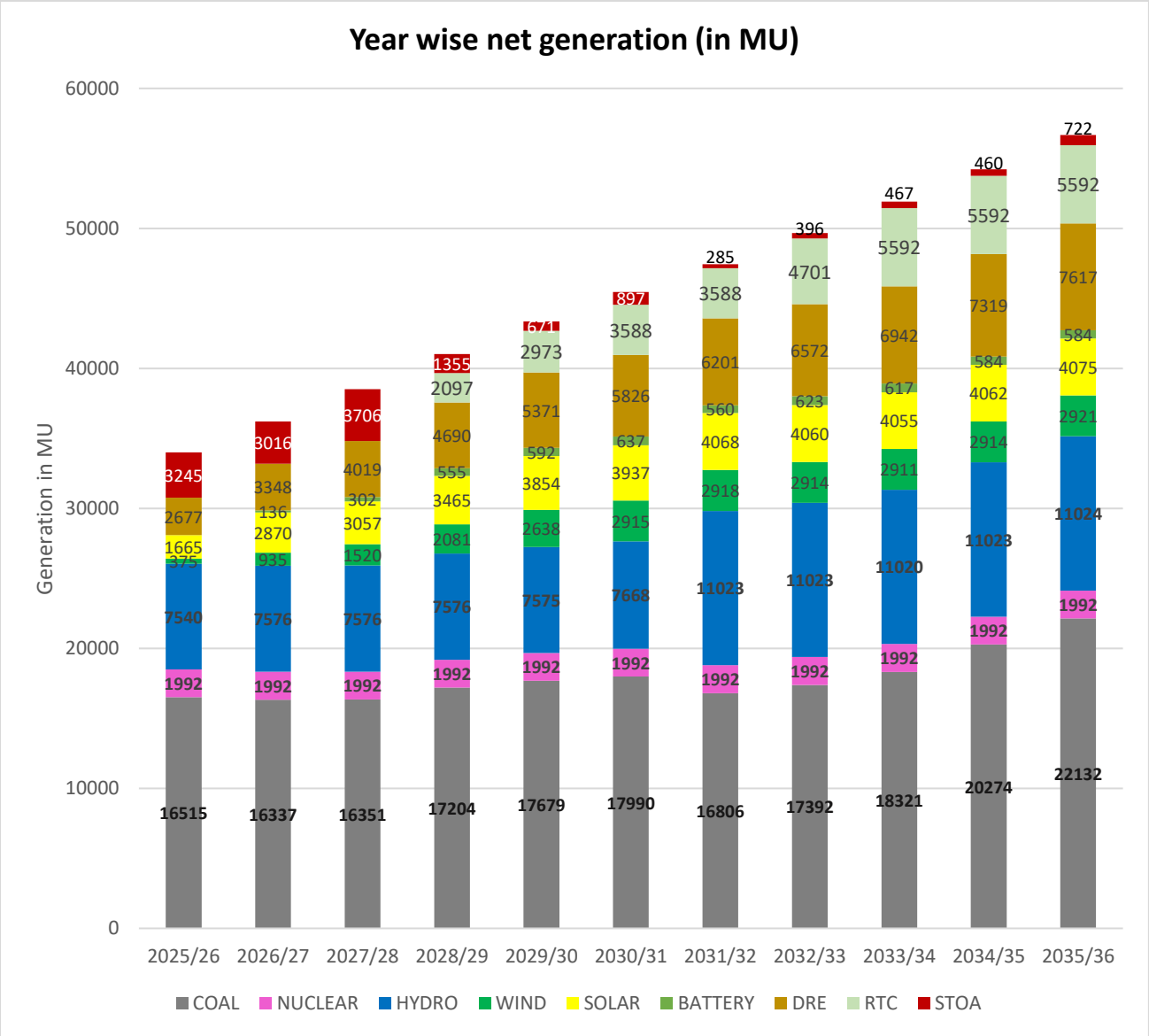


Figure 13: Year-wise projected net generation (in GWh)

7.3 Day-wise Surplus Capacity (in MW)

The pattern of surplus capacities has been observed as given in Figure 14. Available Surplus capacity can be due to seasonal variation in demand. This capacity can be used for banking arrangements or shared with other states through bilateral agreements / Pushp portal, thereby reducing the fixed cost burden on the utility, resulting in a reduction in the cost for the consumer. Kerala is likely to have surplus capacity during the off-peak electricity demand months (June to October), which can be shared with other states. Specifically, the utility is likely to have a

minimum surplus of around 200 MW to 1000 MW during June to August in 2028-29, which can be shared with other states/Discoms.

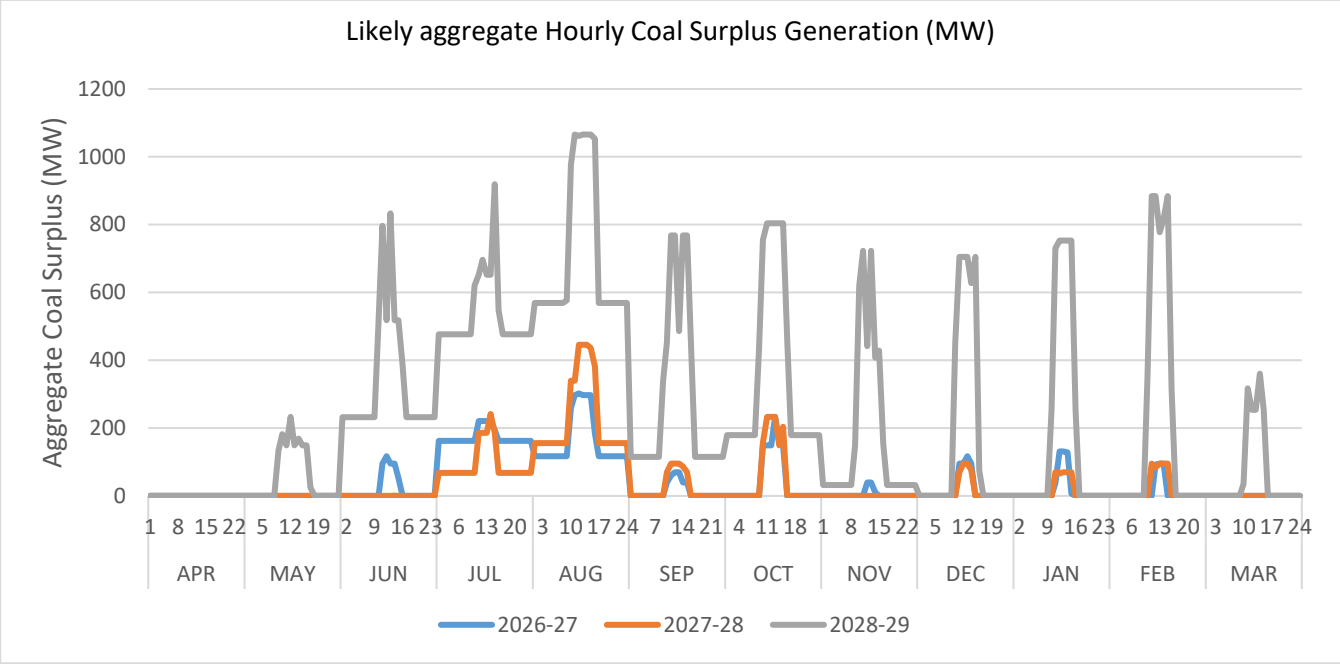


Figure 14: Surplus Coal Capacity Year-wise (MW)

8.0 Alternate Demand Scenarios

In addition to the scenario described above, alternate scenarios considering 10 % higher and 10% lower electricity demand have also been carried out to work out the requirement of capacity to be tied up in each scenario and the same are given below.

8.1 Scenario-I: 10% Higher Electricity Demand

Scenario-I was considered wherein Demand projections were increased by 10% while keeping all other inputs the same as in the Base Case. The electricity demand in this scenario is given in Table 14:

Table 14: Electricity Demand Projection in Scenario-I (in MW)

Electrical Energy Requirement (MU) and Peak electricity demand (MW) projections		
	Energy Projections (MU)	Peak Demand Projections (MW)
2025-26	37409	6824
2026-27	39661	7090
2027-28	41997	7346
2028-29	44422	7655
2029-30	46940	7956
2030-31	49198	8250
2031-32	51484	8521
2032-33	53862	8850
2033-34	56337	9169
2034-35	58913	9501
2035-36	61596	9819

For the given Scenario-I, the capacity projections that would meet the demand are given in Table:

Table 15: Contracted capacity projection in Scenario-I (in MW)

	Coal	**Gas**	**Nuclear**	**Hydro**	**Wind**	**Solar**	**BESS**	**DRE**	**RTC**	**STOA**
2025/26	2471	360	371	2155	359	797	0	1795	0	2574
2026/27	2471	360	371	2179	559	1347	125/500	2245	0	2583
2027/28	2471	360	371	2179	859	1447	300/1100	2695	0	2543
2028/29	2871	360	371	2179	1109	1747	550/1600	3145	300	1985
2029/30	3408	360	371	2179	1359	2047	550/1600	3603	600	1438
2030/31	3408	360	371	2243	1459	2047	550/1600	3909	889	1424
2031/32	3408	360	371	3283	1459	2047	550/1600	4159	889	876
2032/33	3459	360	371	3283	1459	2047	550/1600	4409	1000	1038
2033/34	3712	360	371	3283	1459	2047	550/1600	4659	1000	1119
2034/35	4067	360	371	3283	1459	2047	550/1600	4909	1000	1133
2035/36	4071	360	371	3283	1459	2047	550/1600	5109	1000	1417

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

Table 16: Likely planned and additional capacity to be contracted in Scenario-I (in MW)

	Coal		Hydro		Solar			
	Planned	**Additional**	**Planned Hydro**	**Additional**	**Planned Inside Kerala**	**Planned Outside Kerala**	**Additional Kerala Solar**	**Additional Outside Solar**
2025/26	300		24					
2026/27			24		50	500		
2027/28					100			
2028/29		400					150	150
2029/30	400	136					150	150
2030/31			64	1040				
2031/32								
2032/33		51						
2033/34		253						
2034/35		355						
2035/36		5						
Total	**700**	**1200**	**112**	**1040**	**150**	**500**	**300**	**300**

	Wind			RTC	BESS		DRE		STOA
	Planned inside Kerala	**Planned outside Kerala**	**Additional outside Wind**	**Additional**	**Planned Battery 2h**	**Planned Battery 4h**	**Planned DRE Hydro**	**Planned Solar Rooftop DRE**	**Yearly Requirement**
2025/26	14		200					448	2574
2026/27		200				125		450	2583
2027/28	300				50	125		450	2543
2028/29			250	300	250			450	1985
2029/30			250	300			8	450	1438
2030/31			100	289			57	250	1424
2031/32								250	876
2032/33				111				250	1038
2033/34								250	1119
2034/35								250	1133
2035/36								200	1417
Total	**314**	**200**	**800**	**1000**	**300**	**250**	**64**	**3698**	

8.2 Scenario-II: 10% lower Electricity Demand

Scenario-II was considered wherein Demand projections were decreased by 10% while keeping all other inputs the same as the Base Case. The demand in this scenario is as follows:

Table 17: Electricity Demand Projection in Scenario-II (in MW)

Electrical Energy Requirement (MU) and Peak Electricity Demand (MW) projections		
	Electrical Energy Projections (MU)	Peak Electricity Demand Projections (MW)
2025-26	30607	5584
2026-27	32450	5801
2027-28	34361	6010
2028-29	36345	6263
2029-30	38405	6510
2030-31	40253	6750
2031-32	42123	6971
2032-33	44069	7241
2033-34	46094	7502
2034-35	48202	7773
2035-36	50396	8033

For the given Scenario-II, the capacity projections that would meet the demand are given in Table 18:

Table 18: Contracted capacity projection in Scenario-II (in MW)

	COAL	GAS	NUCLEAR	HYDRO	WIND	SOLAR	BATTERY	DRE	RTC	STOA
2025/26	2471	360	371	2155	159	797	0	1795	0	1367
2026/27	2471	360	371	2179	359	1347	125/500	2245	0	1328
2027/28	2471	360	371	2179	659	1447	300/1100	2695	0	1242
2028/29	2583	360	371	2179	809	1647	550/1600	3145	200	897
2029/30	2983	360	371	2179	959	1747	550/1600	3603	200	728
2030/31	2983	360	371	2243	1059	1747	550/1600	3909	200	892
2031/32	2983	360	371	3283	1059	1847	550/1600	4159	200	387
2032/33	2983	360	371	3283	1059	1847	550/1600	4409	289	549
2033/34	3071	360	371	3283	1059	1847	550/1600	4659	396	547
2034/35	3371	360	371	3283	1059	1847	550/1600	4909	439	514
2035/36	3671	360	371	3283	1059	1847	550/1600	5109	600	404

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

Table 19: Likely planned and additional capacity to be contracted in Scenario-II (in MW)

	Coal		Hydro		Solar			
	Planned	**Additional**	**Planned Hydro**	**Additional**	**Planned Inside Kerala**	**Planned Outside Kerala**	**Additional Kerala Solar**	**Additional Outside Solar**
2025/26	300		24					
2026/27			24		50	500		
2027/28					100			
2028/29		112					100	100
2029/30	400						100	
2030/31			64	1040				
2031/32								100
2032/33								
2033/34		88						
2034/35		300						
2035/36		300						
Total	**700**	**800**	**112**	**1040**	**150**	**500**	**200**	**200**

	Wind			RTC	BESS		DRE		STOA
	Planned Inside Kerala	**Planned Outside Kerala**	**Additional Outside Wind**	**Additional**	**Planned Battery 2h**	**Planned Battery 4h**	**Planned DRE Hydro**	**Planned Solar Rooftop DRE**	**Yearly Requirement**
2025/26	14							448	1367
2026/27		200				125		450	1328
2027/28	300				50	125		450	1242
2028/29			150	200	250			450	897
2029/30			150				8	450	728
2030/31			100				57	250	892
2031/32								250	387
2032/33				89				250	549
2033/34				108				250	547
2034/35				43				250	514
2035/36				161				200	404
Total	**314**	**200**	**400**	**600**	**300**	**250**	**64**	**3698**	

9.0 Conclusions

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

1. Based on the demand pattern of the last few years, it is seen that the high electricity demand is typically in the months of March and April, with peak electricity demand occurring during night. The demand during the months from June to August remains significantly low compared to other months, reflecting the seasonality in demand. Optimal utilisation of resources through short-term contracts like banking or MTOA/STOA for managing the seasonal variation in demand is one of the effective ways for ensuring resource adequacy in such periods.
2. The study has considered electrical energy requirement projections and peak electricity demand projections as prepared by Kerala SLDC/ KSEBL which envisages that the annual electrical energy requirement of the utility is likely to grow at a CAGR of 5.1% while the peak electricity demand for the utility is likely to grow at a CAGR of 3.7% for the period of 2025-26 to 2035-36.
3. Kerala is likely to witness energy deficit ranging from 2603 MUs to 13868 MUs in different years from 2025-26 to 2035-36 with the existing and planned capacity addition only. The deficit may reduce depending upon the banking or MTOA/STOA arrangement, etc.
4. As per the Resource Adequacy studies, the likely total projected contracted capacity for the year 2035-36 is around 18,348 MW (in Base Case) which consists of 3,871 MW from Coal, 360 MW from Gas, 371 MW from Nuclear, 3,283 MW from Hydro, 1,159 MW from Wind, 1,947 MW from Solar, 800 MW from RTC, 5,109 MW from Distributed Renewable Energy (DRE) sources, 550 MW/ 1600 MWh of Energy storage and 897 MW of MTOA/STOA arrangement. This capacity shall be able to meet the projected demand with prescribed reliability criteria. Though Kerala has planned power tie up of 550 MW from BESS, feasibility of power tie-up from Pumped Storage Plants (PSP) may also be explored.
5. The current capacity mix of the utility has 35% of contracted capacity from fossil fuel sources (Coal + Gas). The share of fossil fuel-based capacity (including STOA) is likely to reduce to 28% in 2035-36. In 2035-36, the RE-based contract capacity (that includes hydro, solar, wind and RTC) is likely to constitute around 67% of the total contract capacity.
6. It is likely that Kerala may have surplus capacity available during the months from June to August, which can be shared with other utilities/states through banking/bilateral arrangements, including the Pushp portal.
7. 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, utilities are strongly encouraged to adopt scientific tools and robust methodologies for demand forecasting.

8. Timely commissioning of planned capacities is critical to ensure that the utility can meet the projected peak electricity demand and electrical 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 utility's power demand.

Annexure

Planned Future Contracted (MW) considered in the study

S No	Tied capacity name	Type of generation	Expected CoD	Kerala share (in MW)
1	DBFOO 25 years contract (B IV - Coal allocation)	Thermal	2025/26	300
2	Chinnar HEP	Hydro	2025-26	24
3	Boothathenkettu HEP	Hydro	2026-27	24
4	Talabira STPS	Thermal	2029-30	400
5	Pazhassiagar SHEP	Hydro DRE	2029-30	7.5
6	Upper Sengulam HEP	Hydro	2030-31	24
7	Peechad SHEP	Hydro DRE	2030-31	3
8	Western Kallar SHEP	Hydro DRE	2030-31	5
9	Ladrum SHEP	Hydro DRE	2030-31	3.5
10	Maramala SHEP	Hydro DRE	2030-31	7
11	Pasukkadavu SHEP	Hydro DRE	2030-31	4
12	Valanthode SHEP	Hydro DRE	2030-31	7.5
13	Marippuzha SHEP	Hydro DRE	2030-31	6
14	Chembukadavu III SHEP	Hydro DRE	2030-31	7.5
15	Chathankottunada SHEP - Stage I	Hydro DRE	2030-31	5
16	Olikkal SHEP	Hydro DRE	2030-31	5
17	Poovaramthodu SHEP	Hydro DRE	2030-31	3
18	Mankulam HE Project	Hydro	2030-31	40

Assumption for Resource Adequacy Studies

1. Electrical energy requirement & peak electricity demand requirement: As per projections of Kerala.
2. Demand Profile: Based on the 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 the National Electricity Plan, recent market trends, and existing tariff information received from Kerala SLDC/ KSEBL.

RE CUF considered

Hydro	Kerala Wind	Outside Wind	Kerala Solar	Outside Solar	DRE	RTC
38-40 %	22%	32%	21%	25%	17%	80%

Technical Parameters

Technology	Type	Availability (%)	Ramping (%/min)	Min. Technical (%)
Coal/ Lignite	Existing/Planned	85	1	55
	Candidate	88	1	55
Gas	Existing	90	5	40
Nuclear	Existing/Planned	68	Const. Load	-
Biomass	Existing/Planned	60	2	50
Hydro	Existing/Planned/ Candidate	As per available hourly generation profile	100	-
Solar	Existing/Planned		-	-
	Candidate		-	-
Wind	Existing/Planned		-	-
	Candidate		-	-
Pumped storage	Existing/Planned	95	50	-
	Candidate		50	-
Battery Energy Storage	Candidate	98	NA	-

Technology	Type	Heat Rate (MCal/MWh)		Aux. Consum. (%)
		At max loading	At min loading	
Coal	Existing/ Planned	2300 to 2879	2438 to 3052	7.0
	Candidate (SC & USC)	2300	2438	6.5
Gas	Existing	2000	2260	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	-	-	
Battery Energy Storage	Candidate	-	-	Round-trip losses 12%

Transmission Parameters

A two-node system with one node as Kerala and the other node being the Outside Node representing the rest of India, was considered for the purpose of study, with the generating units connected to the respective node depending on their geographical location. The two nodes were connected with a Transmission Line with the ATC limits as received from Kerala SLDC/ KSEBL.

FY	Existing and Planned Available Interstate Transmission Capacity (in MW)
2024-25	4260
2025-26	4760
2026-27	4760
2027-28	6260
2028-29	7260
2029-30	7260
2030-31	7760
2031-32	7760
2032-33	7760
2033-34	7760
2034-35	8760
2035-36	8760

Financial Parameters

The following cost parameters have been assumed:

Resource	Capex (in ₹/MW)	O&M Fixed Cost (in ₹/MW)	Construction Time (in years)	Amortization /Lifetime (in years)
Coal	11.5 Cr	19.54 Lakh	4	25
Kerala Solar	4 Cr	1 % of Capex	0.5	25
Outside Solar	5.65 Cr	1 % of Capex	0.5	25
Kerala Wind	5.75 Cr	1 % of Capex	1.5	25
Outside Wind	10.81 Cr	1 % of Capex	1.5	25
Hydro	As per the Project Specified by Kerala SLDC/KSBEL	2.5 % of Capex	5 to 8	40
RTC	36 Cr	1 % of Capex	0.5	25
Battery Energy Storage (2-Hour)	3.3 Cr to 3.13 Cr	1 % of Capex	0.5	14
Battery Energy Storage (4-Hour)	5.02 Cr to 4.72 Cr	1 % of Capex	0.5	14
Battery Energy Storage (6-Hour)	6.74 Cr to 6.3 Cr	1 % of Capex	0.5	14
Pumped Storage	As per the Project Specified by Kerala SLDC/KSBEL	5 % of Capex	5.0	40