सत्यमेव जयते

Report On
Resource Adequacy Plan
(Generation)
For Goa
(2025-26 to 2035-36)

January, 2026

Government of India
Ministry of Power

Contents

Disclaimer

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

Executive Summary

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

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 the 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.

The 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 2034-35, based on the data received from the utility and in compliance with the RPO trajectory specified vide gazette notification dated 20th October 2023. This study has now been updated and extended to cover the period up to FY 2035-36, incorporating the latest data furnished by the utility and planning assumptions. The RPO requirement for the utility has also been assessed in accordance with the gazette-notified trajectory.

The peak electricity demand for the State of Goa is projected to increase with a CAGR of 4.10% from 2025-26 to 2035-36 as per the mid-term review of 20th EPS. The projections as per Goa indicate that peak electricity demand would increase with a CAGR of 5.44% for the same period. For satisfying resource adequacy, i.e. meeting the electricity demand reliably and at an affordable cost, the State 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 panels and technology options like Energy Storage Systems, planning for long-term optimal generation capacity mix gains tremendous importance so that the future generation capacity mix is cost-effective as well as environmentally friendly.

The electricity demand in Goa is higher in non-monsoon months and is maximum during the months of April and May. The electricity demand is less during the monsoon months. The peak electricity demand is generally observed during non-solar hours.

The contracted capacity, together with future planned capacity by the State shows that the state is unlikely to meet its future electricity demand. Considering only the contracted and planned capacity, it is observed that the total unserved energy in the year 2035-36 is expected to be about 1558 MU, which is about 16.5 % of the projected electrical energy requirement during the year 2035-36.

To find out the least cost option for generation capacity expansion for the period 2025-26 to 2035-36, long-term study for the State of Goa has been carried out 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.

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 the RPO notified by the Ministry of Power, considering the fungibility among different sources.

Based on study, the likely total projected contracted capacity for the year 2035-36 is about 4,700 MW which consists of 779 MW from Coal, 25 MW from Gas, 56 MW from Nuclear, 2 MW from Biomass, 800 MW from Wind, 1577 MW from Solar, 591 MW from Distributed Renewable Energy (DRE) sources, 400 MW/1600 MWh of Battery Energy Storage System, 400 MW of PSP and 70 MW of MTOA/STOA arrangement. This capacity shall be able to meet the projected demand with the 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 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 capacity addition, 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 will help in the assessment of capacity requirements to be tied up or contracted on a 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 millions (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 the state of Goa based on inputs furnished by the state. The study recommends an optimal resource mix up to FY 2035-36, taking into account technical and financial parameters associated with various capacities. It aims to optimize long-term power procurement while ensuring resource adequacy to meet demand on a 24x7 basis, considering variations in demand, 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.

Before this, CEA had conducted the RA study for the Utility up to FY 2034-35, based on inputs from the state and in accordance with the RPO trajectory specified in the Ministry of Power's gazette notification dated 20th October, 2023.

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

1. In the earlier Resource Adequacy (RA) study, financial year 2023-24 had been considered as the base year, and the study covered the period from 2024-25 to 2034-35. The fuel-wise contracted capacity as on 31st March, 2024 was 931 MW. The details are given below:

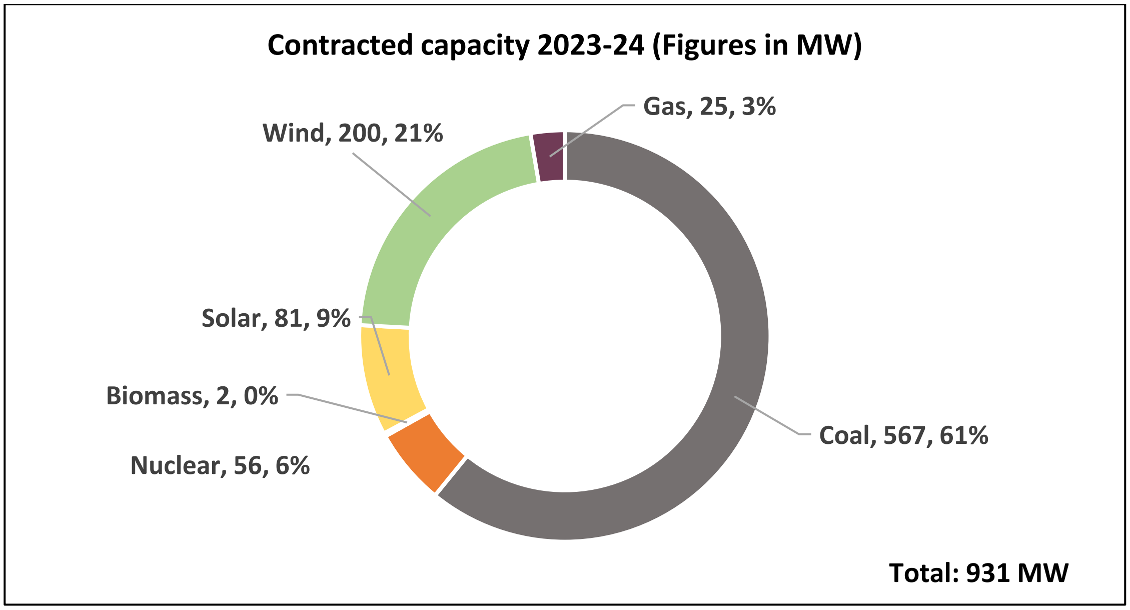


Figure 1: Fuel-wise Contract Capacity (in MW) as on March 2024

2. The hourly demand pattern for 2023-24 had been analysed and considered for the study.

3. The peak electricity demand and electrical energy projections as furnished by the state in consultation with CEA, which had been considered in the study, is tabulated below:

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

	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35
Electrical Energy Requirement Projections (MU)	5327	5700	6099	6525	6982	7471	7994	8554	9152	9793	10478
Year-on-Year Growth		7%	7%	7%	7%	7%	7%	7%	7%	7%	7%
Peak Electricity Demand Projections (MW)	831	897	968	1045	1127	1217	1314	1418	1530	1652	1783
Year-on-Year Growth		7.94%	7.94%	7.94%	7.94%	7.94%	7.94%	7.94%	7.94%	7.94%	7.94%

4. The actual peak electricity demand and electrical energy requirement of the utility observed during 2024-25 is given in Table 2.

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	5411	810

5. To meet the projected peak electricity demand and electrical energy requirement reliably, the source-wise projected capacity (in MW) as outlined in the previous report is given in Table 3.

Table 3: Projected Capacity mix

Year	Coal	Gas	Nuclear	Biomass	Wind	Solar	Storage	DRE	STOA	Total
2024-25	567	25	56	2	350	164	0	98	257	**1519**
2025-26	567	25	56	2	350	251	0	128	323	**1702**
2026-27	567	25	56	2	500	481	100	163	269	**2163**
2027-28	567	25	56	1	600	531	195	203	241	**2419**
2028-29	567	25	56	1	600	625	217	248	310	**2649**
2029-30	861	25	56	1	700	629	217	298	150	**2937**
2030-31	915	25	56	1	800	680	217	326	187	**3208**
2031-32	972	25	56	1	900	719	225	384	221	**3503**
2032-33	1029	25	56	0	1000	764	247	448	248	**3817**
2033-34	1090	25	56	0	1100	816	273	519	279	**4159**
2034-35	1157	25	56	0	1200	916	373	598	241	**4567**

*****The STOA/MTOA value represents the peak 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 given in Table 4.

Table 4: Year-wise capacity additions (in MW)

FY	Thermal		SOLAR		Wind		Storage	Yearly STOA	DRE		Total	
	Planned	Additional	Planned	Additional	Planned	Additional	Additional	Additional	Planned	Additional	Planned	Additional
2024-25	0	0	83	0	150	0	0	257	30	0	**263**	**257**
2025-26	0	0	87	0	0	0	0	323	30	0	**117**	**323**
2026-27	0	0	80	150	0	150	100	269	35	0	**115**	**669**
2027-28	0	0	0	100	0	100	95	241	40	0	**40**	**536**
2028-29	0	0	0	100	0	100	23	310	45	0	**45**	**533**
2029-30	24.55	270	0	4	0	100	0	150	50	0	**74.55**	**524**
2030-31	0	54	0	51	0	100	0	187	0	28	**0**	**420**
2031-32	0	57	0	39	0	100	7	221	0	58	**0**	**482**
2032-33	0	57	0	45	0	100	22	248	0	64	**0**	**536**
2033-34	0	61	0	53	0	100	26	279	0	71	**0**	**590**
2034-35	0	67	0	100	0	100	100	241	0	79	**0**	**687**
Total	**24.55**	**566**	**250**	**642**	**150**	**950**	**373**	**2726**	**230**	**300**	**654.55**	**5557**

3.0 Resource Adequacy Study of Goa (2025-26 to 2035-36)

3.1 Present Power Scenario in Goa

As of March 2025, the total contracted capacity for Goa is 1,156 MW. Out of the total contracted capacity (CC), the share of non-fossil fuel-based CC is 48.8%. The fuel-wise contracted capacity as on 31st March, 2025, is given in the Table 5 and Figure 2.

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

Source	Contracted Capacity (MW)	%
Coal	567	49.0%
Gas	25	2.2%
Nuclear	56	4.8%
Biomass	2.34	0.2%
Wind	350	30.3%
Solar	85	7.4%
DRE	71	6.1%
Total	**1156.34**	**100%**

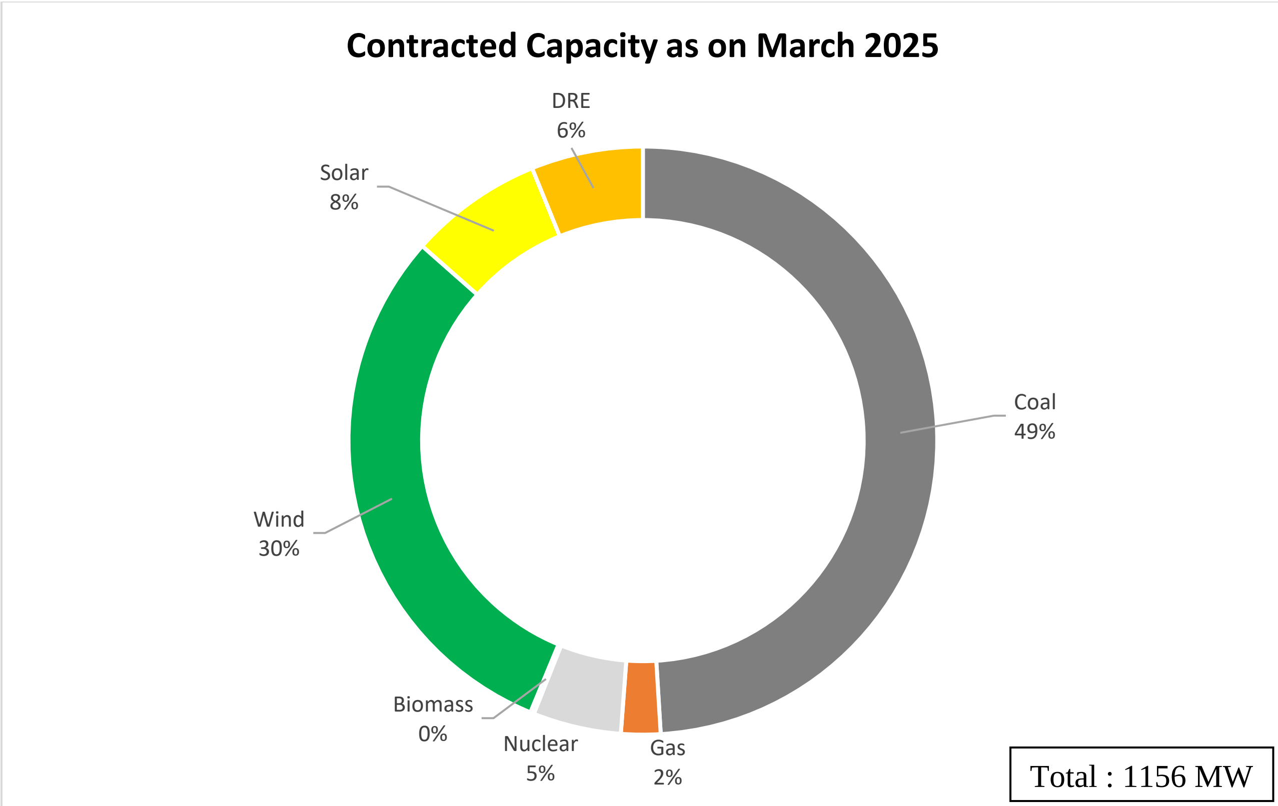


Figure 2: Fuel-wise Contracted Capacity (in MW) as on 31st March, 2025

3.2 Analysis of Present Demand

Block-wise (15-minute) demand pattern of 2024-25 was analyzed, and it was observed that the peak demand season for Goa is during March, April and May. The typical daily load curve shows a minimum load during the early morning hours (around 03:00–05:00 hrs), a gradual rise after sunrise, and a prominent peak between 17:00 and 20:00 hrs, primarily driven by residential, commercial, and cooling loads.

Overall, the annual demand profile exhibits a consistent diurnal pattern across months, with variations mainly in magnitude rather than shape, indicating stable consumption behaviour throughout the year. The data underscores the strong influence of temperature and seasonal load drivers on electricity consumption in Goa and highlights the need for adequate capacity planning and flexible generation resources to manage the pronounced evening peaks and summer load conditions effectively.

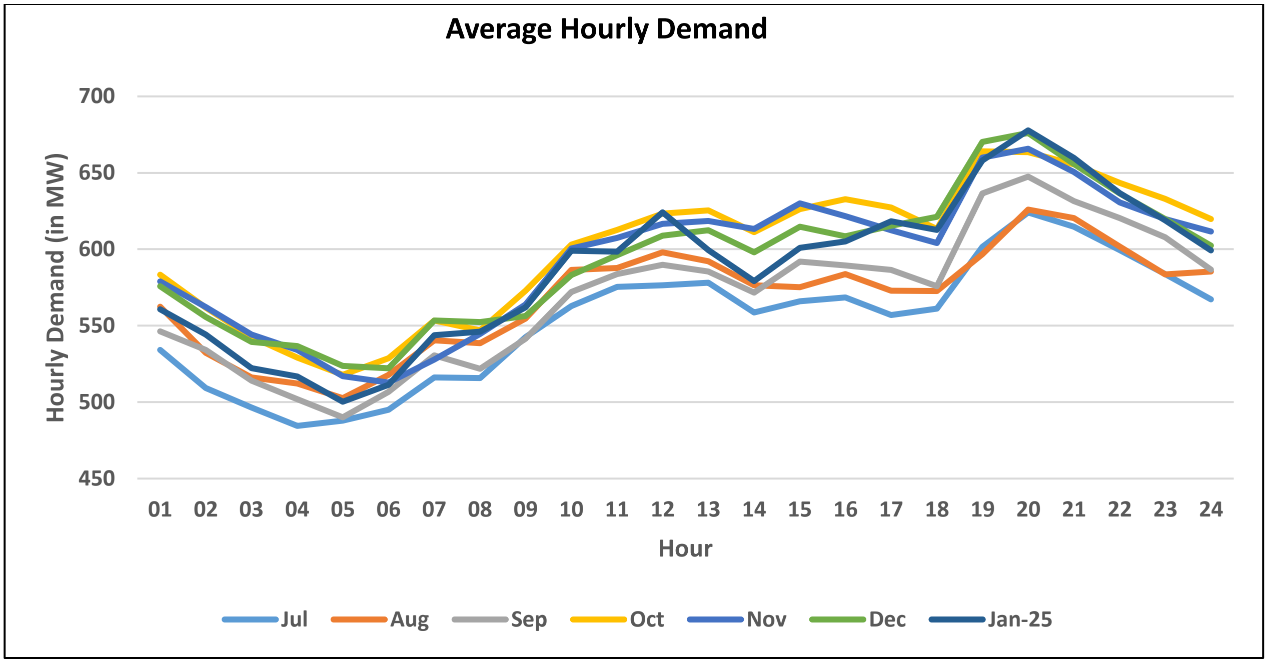


Figure 3: Average Hourly Demand Variation (Month-wise) July-January for 2024-25

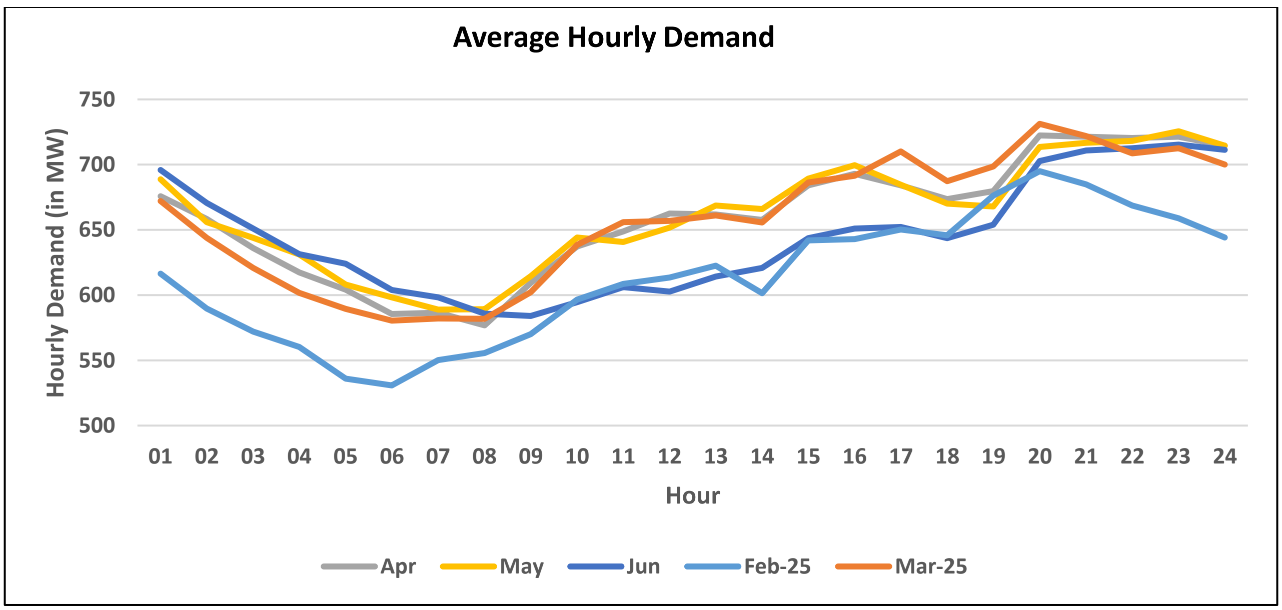


Figure 4: Average Hourly Demand Variation (Month-wise) April to June and February-March for 2024-25

The electricity demand of Goa during non-solar hours is consistently higher than during solar hours. This indicates that electricity consumption is driven largely by evening residential loads, lighting, cooling requirements, and heightened night-time activity from tourism and related services.

In contrast, solar hour demand remains lower and more stable, reflecting primarily residential and essential loads such as lighting, domestic appliances, and commercial load. The absence of sharp fluctuations overnight suggests relatively predictable base load behavior. However, rise in electricity demand is observed in the evening and night (around 19:00–22:00 hrs), corresponding to household activity after sunset.

The hourly demand pattern of 2024-25 was analyzed to find out the number of occurrences of the peak and near-peak demand. Such instances are critical for study purposes as it is necessary to ensure resource adequacy during such instances with an optimal mix of long-term, medium-term and short-term contracts.

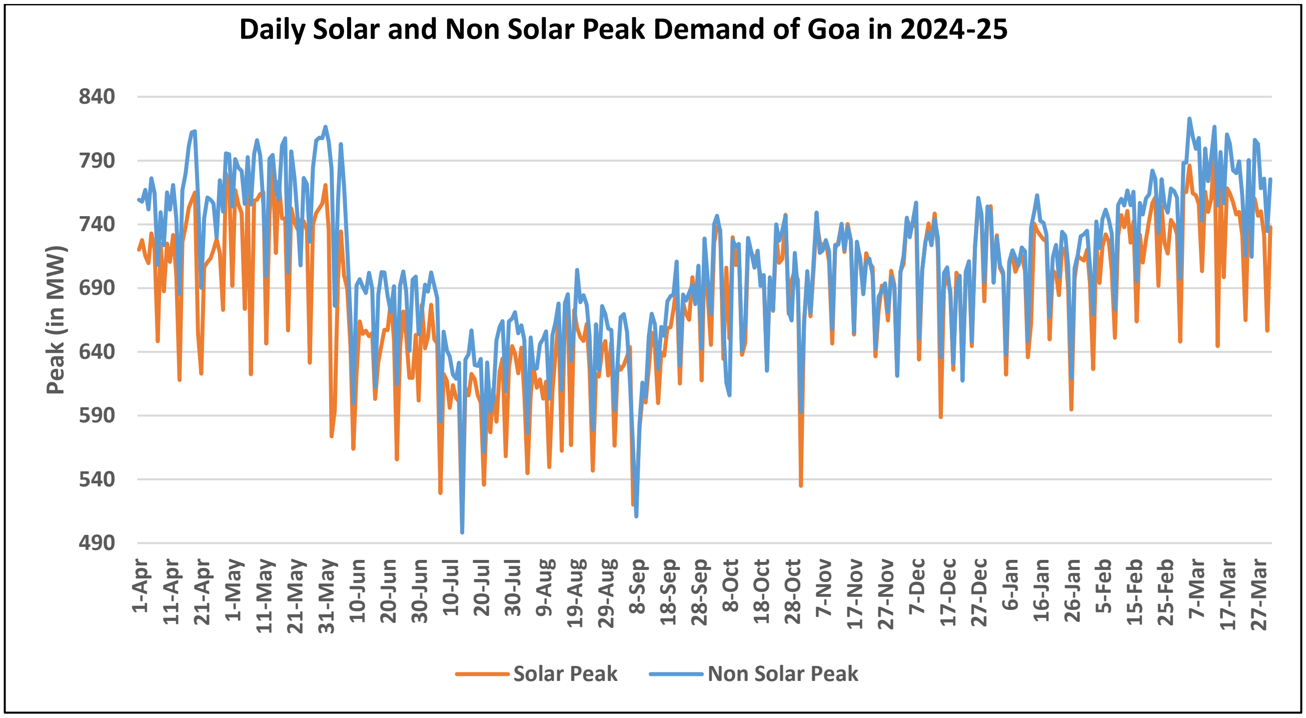


Figure 5: Daily Peak Demand of Goa during Solar and Non-Solar Hours (2024-25)

Figure 5 illustrates the daily Non-Solar Peak and Solar Peak demand across a one-year period from April, 2024 to March, 2025. The Non-Solar Peak consistently remains higher than the Solar Peak, reflecting stronger demand during non-solar hours. Both curves display a clear seasonal pattern: higher values in the summer months, a noticeable decline during the monsoon season, and a gradual rise again through the winter period. Despite day-to-day fluctuations, the two series move in parallel, indicating that Solar Peak demand follows the same seasonal dynamics but at a slightly lower magnitude. This trend highlights overall system behaviour and helps contextualize month-wise variations in peak load.

The Figure 6 shows the frequency distribution of hourly demand for an entire year (8,760 hours). Demand values are grouped into ranges, and the chart displays both the number of hours falling within each demand band and the percentage share of total hours. It forms a bell-shaped pattern, indicating that most hours of the year fall within the mid-demand ranges. The highest concentration occurs in the 600–640 MW band, which accounts for 1,814 hours (21%), followed closely by the

560–600 MW and 640–680 MW ranges. Lower-demand hours (<480 MW) and very high-demand hours (>760 MW) occur far less frequently, together contributing to only a small share of the total.

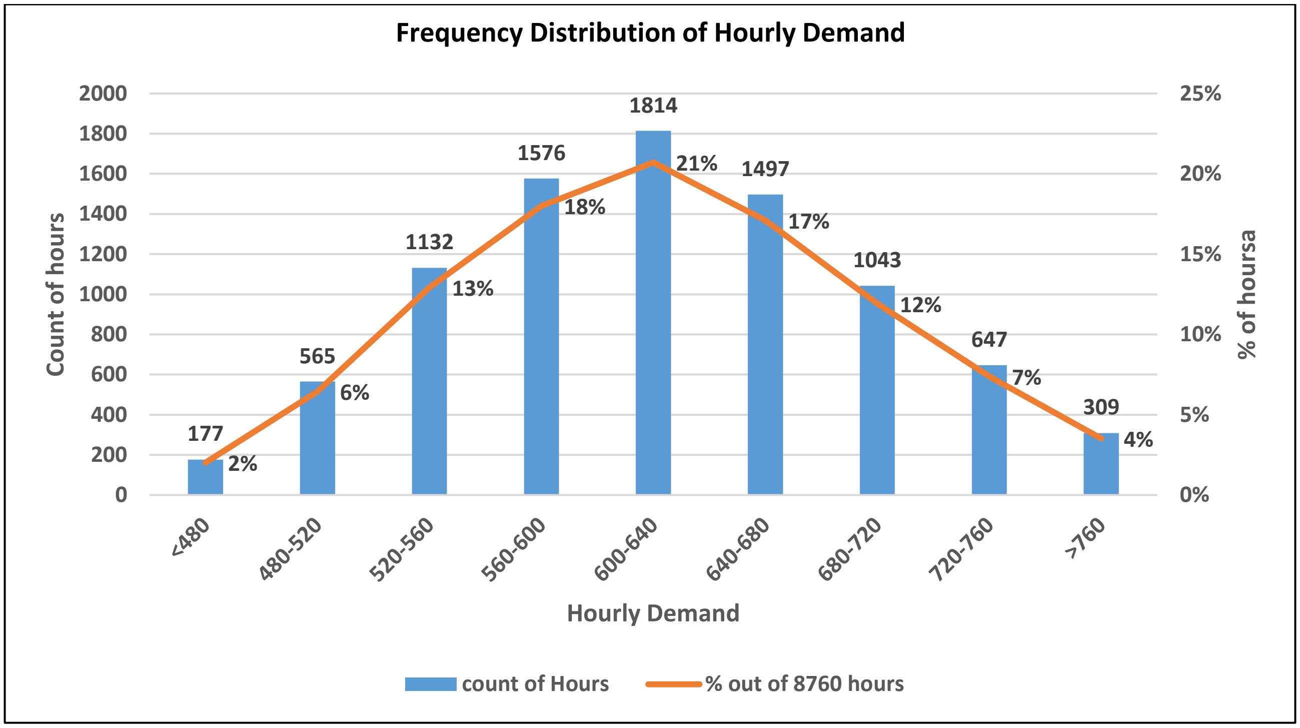


Figure 6: Frequency Distribution of Hourly Demand Profile (2024-25)

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. 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 a generation expansion planning model, 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 **Figure 7.**

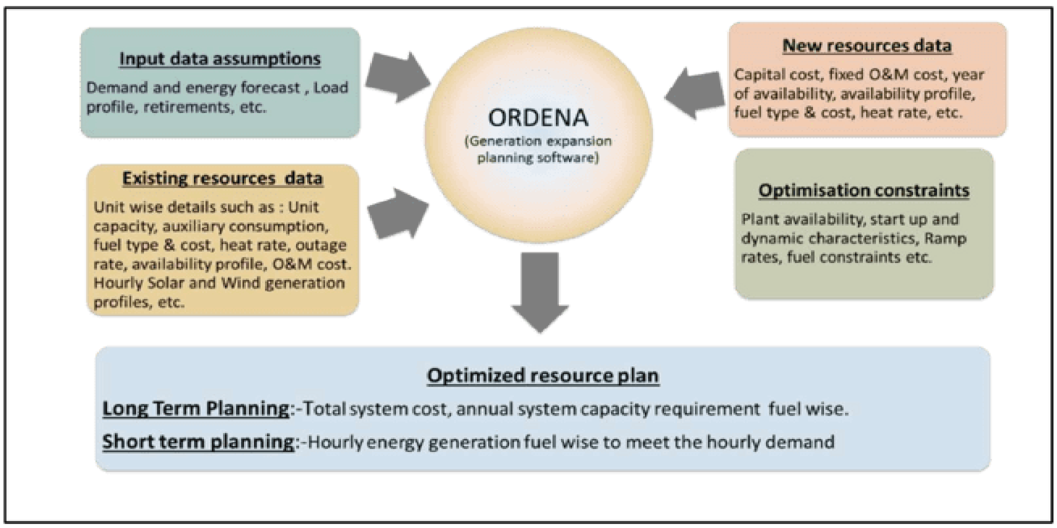


Figure 7: Schematic Diagram -Ordena

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 per cent of the projected peak electricity demand of the system.

5.1 Variation in Electricity Demand

The hourly demand variation for consecutive years (i.e. 2023-24 and 2024-25, considering 2023-24 as the base) has been analyzed. The demand pattern variation of 2023-24 and 2024-25 is shown in Fig. 8.

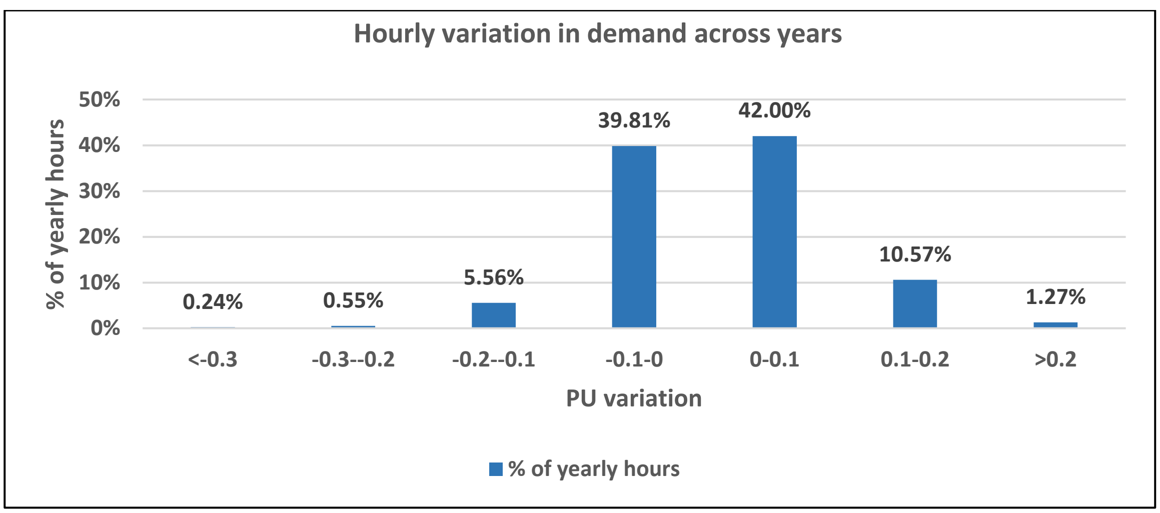


Figure 8: Hourly Variation in Demand across years

It can be observed that the hourly demand typically varies ±10% for around 82% 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 ±10% by introducing a random variable (with normal distribution) for demand as per observed behavior over the years.

5.2 Variation in RE

In the Long-term capacity expansion planning studies, a particular profile for solar and wind is considered based on the observed solar 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 has 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 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 are carried out to ascertain robustness of the system.

6.0 Inputs/Assumptions for the Study

i) The projected electrical energy requirement and peak electricity demand as estimated by the electricity department of Goa and as per mid-term review of 20th EPS is given in Table 6. For the study, projections as per Goa has been considered.

Table 6: Electricity Demand Projections

Year	Electrical Energy Requirement projections as per Goa (MU)	Electrical Energy Requirement projections as per mid-term review of 20th EPS (MU)	Peak Electricity Demand projection as per Goa (MW)	Peak Electricity Demand projection as per mid-term review of 20th EPS (MW)
2025-26	5564	5606	856	865
2026-27	6168	5922	916	914
2027-28	6344	6227	976	951
2028-29	6733	6548	1036	1000
2029-30	7123	6860	1096	1048
2030-31	7512	7128	1156	1089
2031-32	7900	7376	1216	1127
2032-33	8291	7689	1275	1175
2033-34	8680	7967	1335	1217
2034-35	9070	8239	1395	1258
2035-36	9460	8463	1455	1293

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 Goa, while the hydro generation profiles have been considered as per data available in CEA.

iv) The capital costs of candidate plants for coal, wind, solar, and battery technologies are 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 Goa. Source-wise planned capacity is given below:

Table 7: Source-wise planned capacity addition

FY	Coal	Solar	DRE Solar	Wind	BESS
2024-25	0	0	0	0	0
2025-26	0	22	30	0	0
2026-27	0	75	35	50	0
2027-28	0	115	45	50	13
2028-29	0	105	50	0	0
2029-30	25	100	60	50	0
2030-31	0	100	50	50	0
2031-32	0	200	50	50	0
2032-33	0	100	50	50	0
2033-34	0	100	50	50	0
2034-35	0	100	50	50	0
2035-36	0	100	50	50	0

Note: As per the information received from the state of Goa, a tender of 75 MW of Hydro power is floated for FY 2025-26. And for another 200 MW, Goa had given consent to SJVN for procuring from the following three projects in the following priority:

- Sunni Dam HEP, Himachal Pradesh
- Luhri Stage-I HEP, Himachal Pradesh
- Arun-3 HEP, Nepal

However, for carrying out the study, allocation of power to Goa from the above projects has been considered as Nil as power allocation from these projects is yet to be done. Based on final allocation order, the share of Goa from these projects will be considered while preparing the subsequent RA Plans.

vi) **Renewable Purchase Obligation (RPO) trajectory**: RPO trajectory considered for this study is given below in Table 8: Renewable Purchase Obligation Trajectory with future projections considered.

Table 8: Renewable Purchase Obligation Trajectory

Sl. No.	Year	Wind renewable energy	Hydro renewable energy	Other renewable energy	Distributed renewable energy	Total renewable energy
1	2025-26	1.45%	1.22%	28.24%	2.10%	33.01%
2	2026-27	1.97%	1.34%	29.94%	2.70%	35.95%
3	2027-28	2.45%	1.42%	31.64%	3.30%	38.81%
4	2028-29	2.95%	1.42%	33.10%	3.90%	41.36%
5	2029-30	3.48%	1.33%	34.02%	4.50%	43.33%
6	2030-31	41.00%			4.50%	45.50%
7	2031-32	42.50%			4.50%	47.00%
8	2032-33	43.80%			4.50%	48.30%
9	2033-34	45.00%			4.50%	49.50%
10	2034-35	46.00%			4.50%	50.50%
11	2035-36	47.00%			4.50%	51.50%

Based on the RPO trajectory considered, the analysis indicates that the utility will not be able to meet its RPO obligations during FY 2025–26 to FY 2035–36, even after considering existing and planned renewable energy contracts. The shortfall persists across the entire study period, necessitating procurement of additional renewable energy sources to ensure compliance with RPO requirements.

Table 9: Renewable Energy Surplus (+)/ Deficit (-)

Sl. No.	Year	Wind renewable energy	Hydro renewable energy	Other renewable energy	Distributed renewable energy	Total Renewable Energy
1	2025-26	11%	-1%	-25%	1%	-14%
2	2026-27	11%	-1%	-25%	1%	-14%
3	2027-28	12%	-1%	-23%	1%	-12%
4	2028-29	10%	-1%	-23%	1%	-12%
5	2029-30	10%	-1%	-22%	2%	-11%
6	2030-31	-13%			3%	-10%
7	2031-32	-10%			3%	-7%
8	2032-33	-10%			4%	-6%
9	2033-34	-9%			4%	-5%
10	2034-35	-9%			5%	-4%
11	2035-36	-9%			5%	-4%

7.0 Results of the Resource Adequacy Study

7.1 Unserved Electrical Energy Projections

Initially, the study was carried out considering only the existing and planned capacity contracts by Goa and does not include any banking arrangements or short-term contracts. The total unserved electrical energy for the year 2035-36 would be 1558 MU. Year-wise likely unserved electrical energy with only existing and planned capacities is given in Figure 9.

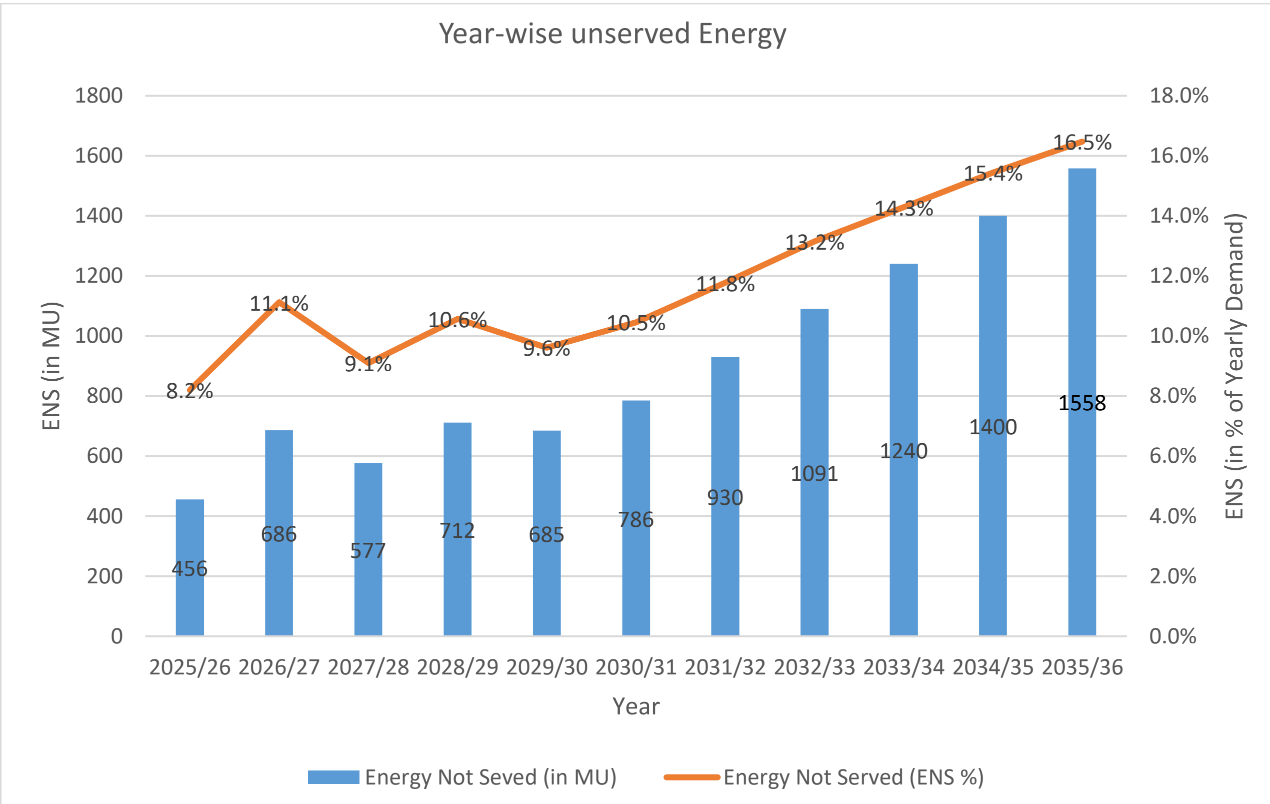


Figure 9: Yearly likely unserved electrical energy (in MU) with the existing and planned capacities

The study has also analyzed the daily and monthly pattern of unserved electrical energy in the year 2035-36 as shown below in Figure 10.

The analysis of unmet demand indicates that the quantum of non-served energy is substantially higher during non-solar hours, particularly during late evening and early morning periods when solar generation is unavailable. As a result, the majority of the deficit is concentrated outside daylight hours, whereas solar hours generally show lower unmet demand due to partial support from solar generation. Seasonal variations are clearly visible in the data. The highest levels of unmet demand occur in two major periods: (i) the early summer months of April and May, when system load increases due to rising temperatures, and (ii) the October to January period, where multiple high-magnitude peaks are observed. The latter is driven by reduced solar availability in winter, and increased evening demand, which jointly intensify the supply–demand imbalance. Overall, unmet demand persists across the year but is disproportionately higher in non-solar hours, with April–May and October–March emerging as the most critically affected months.

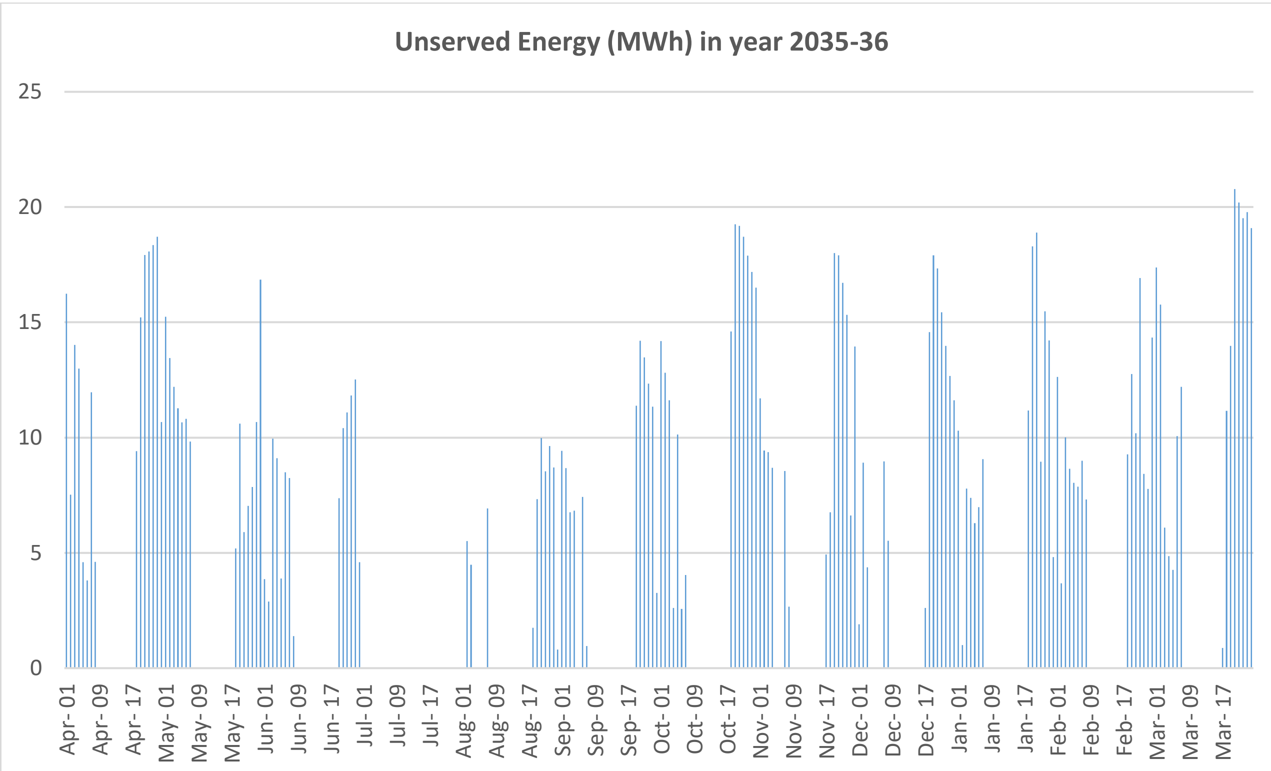


Figure 10: Block-wise Unserved Electrical Energy Pattern GWh (2035-36)

Table 10: Heatmap of Energy Not Served for the study period

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
2025-26	76	54	22	0	5	21	53	38	30	34	44	80
2026-27	102	77	25	0	10	42	85	64	51	57	67	106
2027-28	90	61	34	0	2	23	72	51	41	44	63	96
2028-29	103	77	49	0	11	36	83	64	55	58	69	106
2029-30	98	71	45	0	6	34	84	64	54	57	68	103
2030-31	108	81	48	0	11	47	96	74	63	66	77	114
2031-32	121	98	54	0	21	60	112	89	77	80	90	130
2032-33	136	111	55	0	32	82	129	104	92	96	108	146
2033-34	151	119	83	0	43	80	147	120	107	111	118	162
2034-35	167	134	94	0	54	94	164	135	121	126	133	179
2035-36	184	148	106	0	64	106	181	151	136	141	147	196

As seen from Table 10, ENS remains negligible during the monsoon months (July), reflecting adequate system capacity, while consistently higher values are observed during the summer and winter peak periods, particularly from March to May and from October to February. A clear increasing trend in ENS is evident over the study horizon, with a sharp escalation after 2030–31, highlighting a growing demand–supply gap.

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 electricity demand in compliance with the Renewable Purchase Obligation. The capacity projections for Goa are given below:

Table 11: Likely requirement of contracted capacity (existing+ planned+ additional) (in MW)

FY	Coal	Gas	Nuclear	Biomass	Wind	Solar	PSP (6 Hrs Storage)	BESS (4 Hrs Storage)	DRE Solar	STOA
2025-26	567	25	56	2	350	107	0	0	101	336
2026-27	567	25	56	2	400	307	0	60	136	332
2027-28	567	25	56	2	450	547	0	120	181	328
2028-29	567	25	56	2	450	777	50	170	231	296
2029-30	591	25	56	2	500	877	100	220	291	238
2030-31	747	25	56	2	550	977	150	250	341	97
2031-32	758	25	56	2	600	1177	200	280	391	70
2032-33	765	25	56	2	650	1277	250	310	441	58
2033-34	765	25	56	2	700	1377	300	340	491	65
2034-35	772	25	56	2	750	1477	350	370	541	67
2035-36	779	25	56	2	800	1577	400	400	591	70

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 12: Likely planned capacity and capacity to be contracted by the utility year-wise (in MW)

	Coal		Wind	Solar		DRE Solar	BESS (4 Hr)	PSP
Year	Planned	Additional	Planned	Planned	Additional	Planned	Additional	Additional
2025-26	0	0	0	22	0	30	0	0
2026-27	0	0	50	75	125	35	60	0
2027-28	0	0	50	115	125	45	60	0
2028-29	0	0	0	105	125	50	50	50
2029-30	25	0	50	100	0	60	50	50
2030-31	0	156	50	100	0	50	30	50
2031-32	0	11	50	200	0	50	30	50
2032-33	0	6	50	100	0	50	30	50
2033-34	0	0	50	100	0	50	30	50
2034-35	0	7	50	100	0	50	30	50
2035-36	0	7	50	100	0	50	30	50

Total	25	188	450	1117	375	520	400	400

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 around 4701 MW which consists of 779 MW from Coal, 25 MW from Gas, 56 MW from Nuclear, 2 MW from Biomass, 800 MW from Wind, 1577 MW from Solar, 591 MW from DRE solar, 400 MW/1600 MWh of battery storage, 400 MW of PSP and 70 MW of MTOA/STOA arrangement will be required. The storage requirement can be met through PSP or a combination of PSP and BESS. This capacity shall be able to meet the projected demand with prescribed reliability criteria. The Planning Reserve Margin (PRM) for Goa has been assessed as 6%. Year wise capacity projection is given in Figure 11.

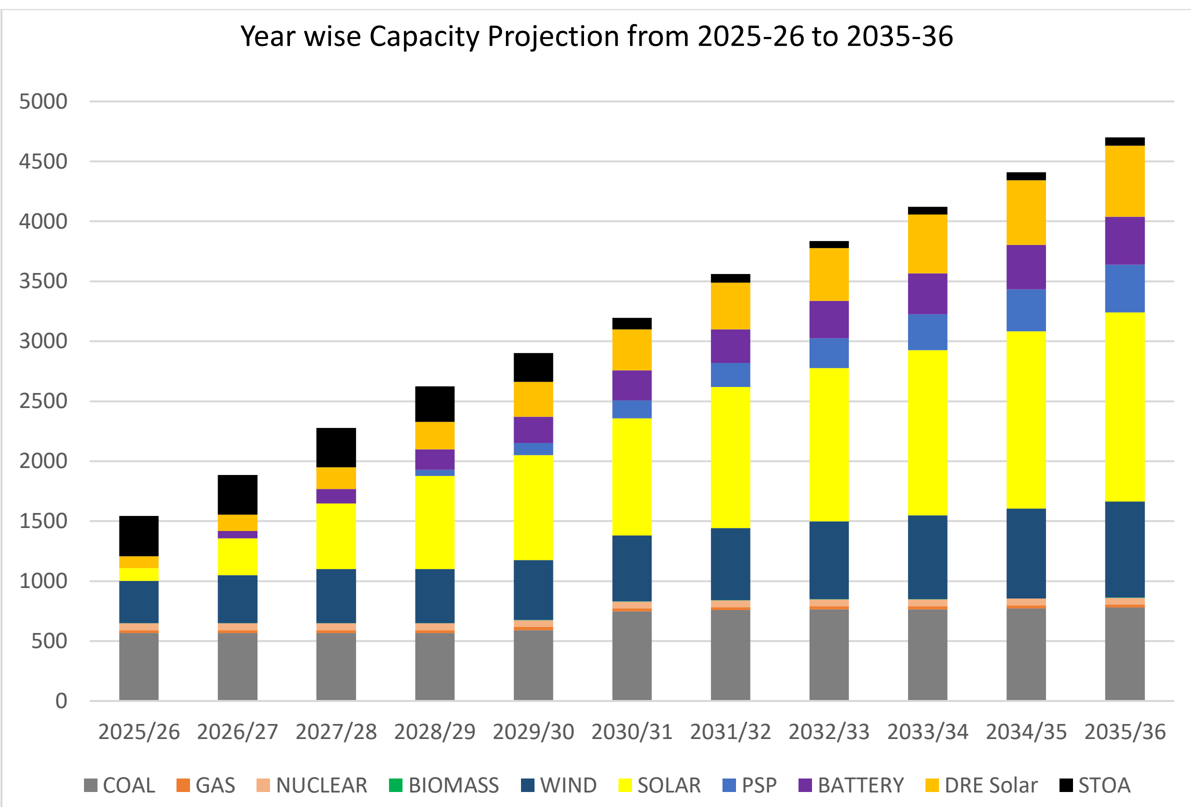


Figure 11: Projected Contracted Capacity Mix Year-wise (MW)

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.

Furthermore, the projected capacity and generation mix presented in the report adequately meet the utility's RPO requirements for the period 2028-29 to 2035-36. For the year 2025-26 to 2027-28, the utility may endeavor short-term or medium-term power purchase agreements, or through any other appropriate mechanisms deemed suitable by the utility in order to meet the RPO trajectory.

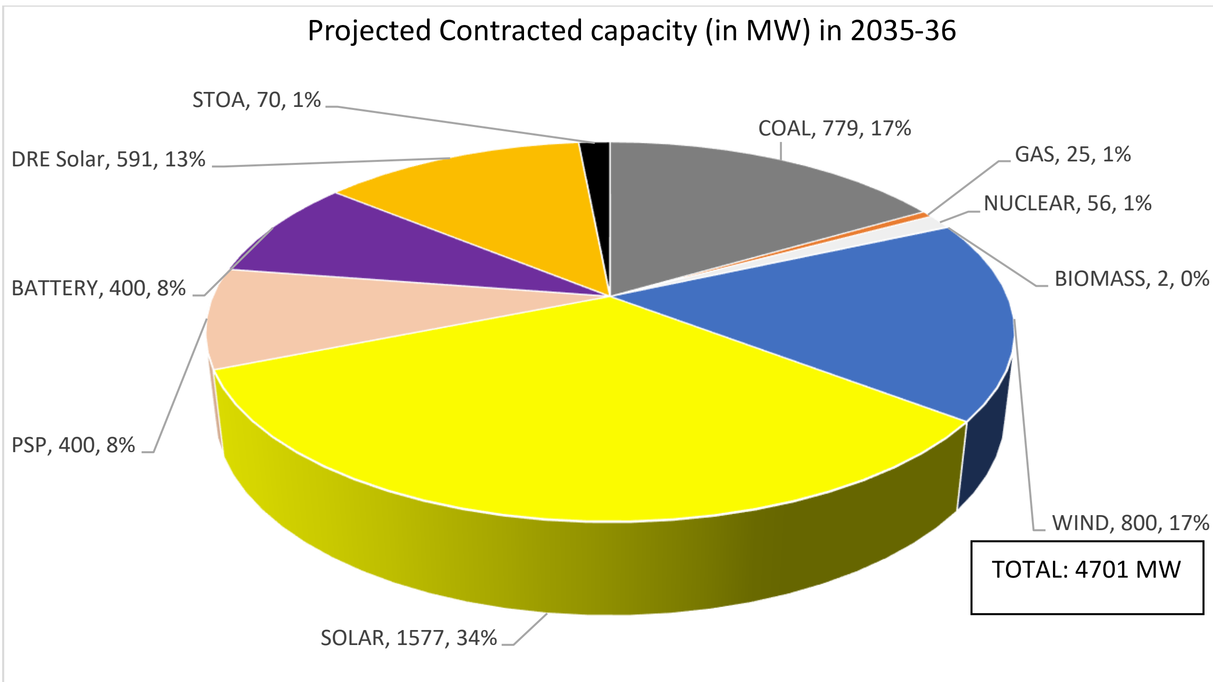
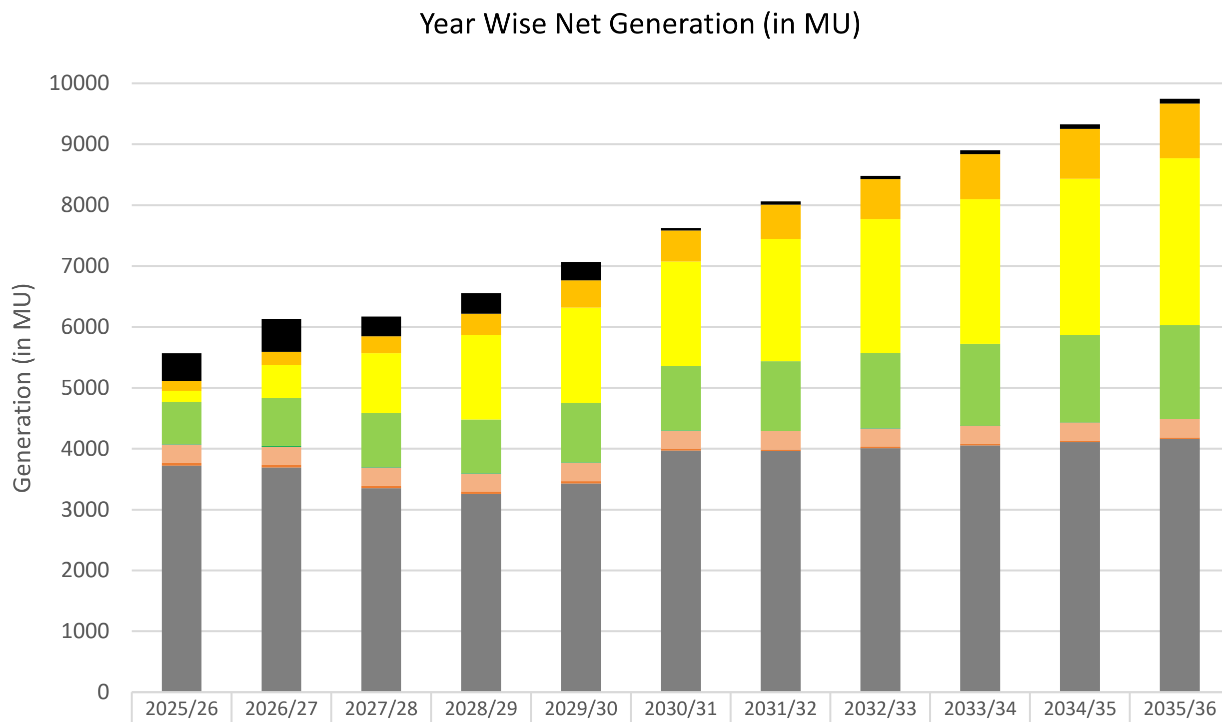


Figure 12: Contracted Capacity Mix in 2035-36

The non-fossil fuel-based contracted capacity is projected to increase to around 3,026 MW by 2035-36 from 564 MW in 2024-25.



	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32	2032/33	2033/34	2034/35	2035/36
STOA	457	541	324	339	306	42	52	57	66	73	79
DRE Solar	157	211	280	353	449	512	561	653	740	819	901
SOLAR	183	547	980	1386	1560	1717	2014	2202	2376	2566	2738
WIND	692	791	889	881	981	1058	1141	1235	1340	1434	1543
BIOMASS	7	7	7	7	6	2	2	2	2	2	2
NUCLEAR	303	303	303	300	303	303	303	303	303	303	303
GAS	41	40	35	37	34	26	27	23	24	24	24
COAL	3725	3691	3351	3253	3431	3968	3959	4007	4053	4105	4159

COAL GAS NUCLEAR BIOMASS WIND SOLAR DRE Solar STOA

Figure 13: Year-wise projected gross generation (in MU)

The year-wise projected generation in MU is depicted in Figure 13, which clearly indicates a structural transition away from fossil fuel–based generation towards renewable and storage-backed sources over the study horizon. Renewable energy generation expands significantly. Wind generation increases nearly threefold from 692 MU to 1,543 MU, while solar generation exhibits the sharpest growth, rising from 183 MU in 2025-26 to 2,738 MU in 2035-36. Distributed renewable energy (DRE solar) also shows consistent growth, reflecting increased rooftop and decentralized adoption.

The role of energy storage becomes increasingly prominent after 2027-28, with pumped storage and battery generation together rising from negligible levels to about 800 MW cumulative capacity by 2035-36, supporting grid flexibility and renewable integration. Nuclear generation remains constant across the horizon, providing a stable base-load contribution.

The net electricity generation mix for Goa is shown in Figure 14.

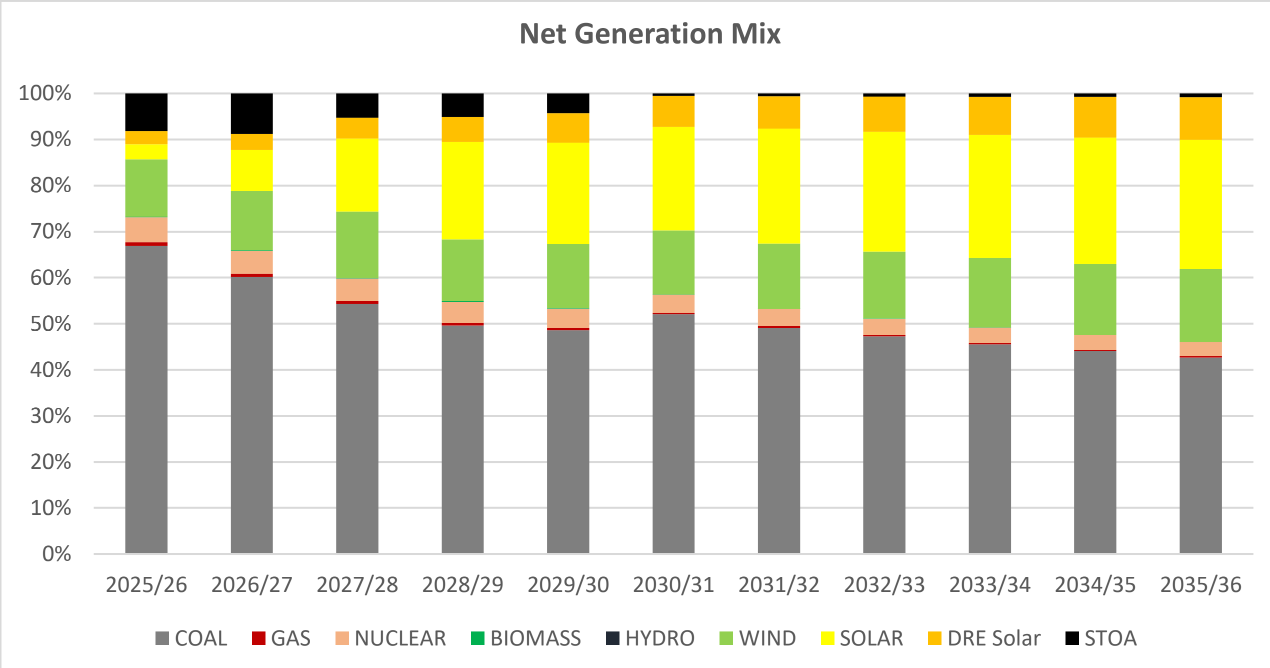


Figure 14: Net Generation mix from 2025-26 to 2035-36

Table 13: Heatmap for Generation from STOA across months

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
2025-26	76	54	22	0	5	21	53	38	30	34	44	80
2026-27	80	62	26	0	11	37	73	56	47	51	59	88
2027-28	75	53	33	6	2	22	65	48	39	41	58	83
2028-29	79	65	38	0	0	31	69	52	49	51	61	86
2029-30	72	48	25	0	0	14	62	43	33	36	48	78
2030-31	23	0	0	0	0	0	10	0	0	0	0	25
2031-32	22	0	0	0	0	0	10	0	0	0	0	25
2032-33	23	0	0	0	0	0	12	0	0	0	1	25
2033-34	25	0	0	0	0	0	15	0	0	0	0	28
2034-35	26	0	0	0	0	0	17	0	0	0	0	30
2035-36	27	0	0	0	0	0	18	0	0	0	0	32

Table 13 shows a heat map for STOA/MTOA having a strong and consistent seasonal cycle. The highest values occur predominantly in March and April, which appear as red zones across most early years. October also shows moderately high values, forming a secondary peak. In contrast, July and August consistently record zero or near-zero values, appearing green throughout the heat map.

September also remains relatively low. This creates a clear mid-year trough, indicating minimal requirement during the monsoon months.

The period from 2025–26 to 2029–30 shows the highest overall intensity, with frequent red and orange cells. The 2026–27 year stands out as the peak, recording the maximum requirement in March, making it the most intense year. From 2030–31 onwards, there is a sharp decline in requirement from STOA. Most months remain at zero, with only small increases in April, October, and March.

7.3 Day-wise Surplus Capacity (in MW)

The pattern of surplus capacities has been observed as given in **Error! Reference source not found.** and **Error! Reference source not found.** below**Error! Reference source not found.**. 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. Goa is likely to have some amount of surplus capacity available every year but mostly during month of July, which can be shared with other states. The utility is likely to have range of the minimum surplus of around 572 MW in the year 2027-28 to 1320 MW during year 2035-36.

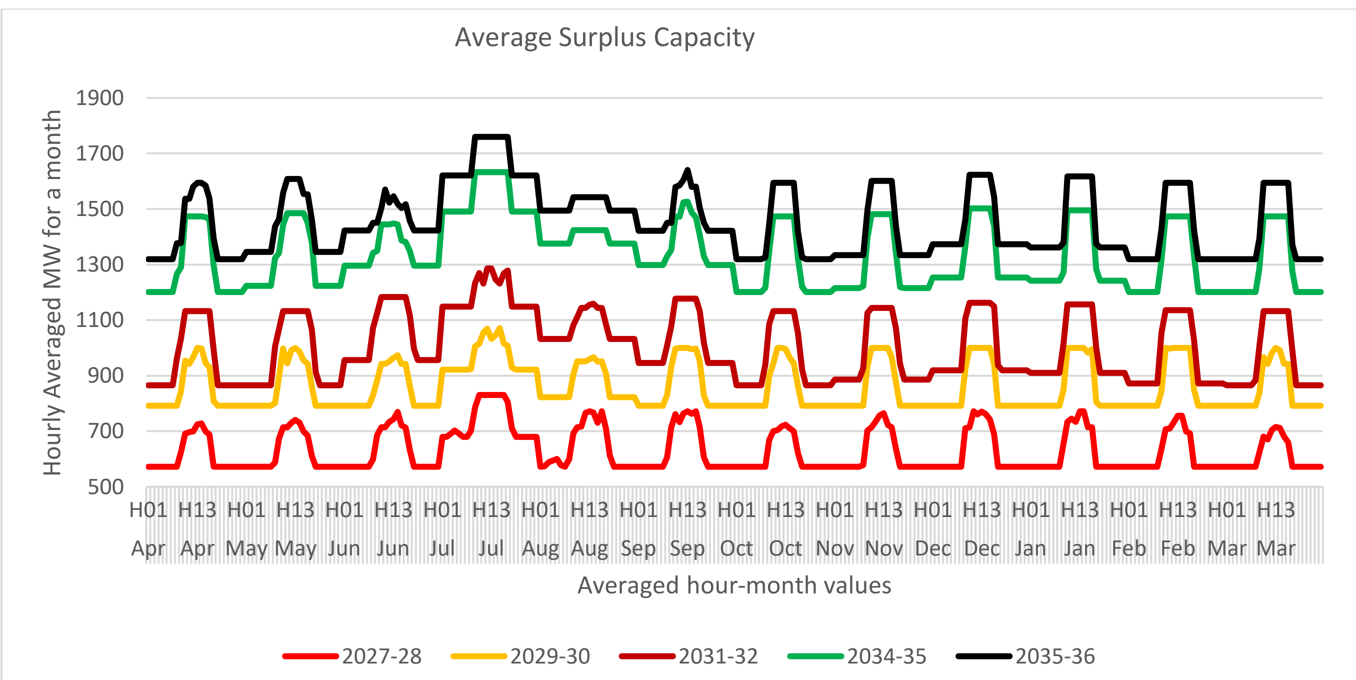


Figure 14: Average Surplus MW available in different years

8.0 Conclusions

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

1. The study has considered electrical energy requirement projections and peak electricity demand projections as per Goa, which envisages that the annual electrical energy requirement and the peak electricity demand of the utility is likely to grow at a CAGR of 5.45% and 5.44% respectively for the period of 2025-26 to 2035-36. The peak electricity demand and electrical energy requirement in 2035-36 is 1455 MW and 9460 MU as per the projections by Goa.
2. Based on the demand pattern of last few years, it is seen that the high electricity demand is typically from March to June with peak electricity demand occurring during night-time. Optimal utilization of resources through short-term contracts like banking or MTOA/STOA as currently practiced for managing the seasonal variation in demand is one of the effective ways for ensuring resource adequacy in such periods.
3. Goa is likely to witness energy deficit ranging from 456 MUs to 1558 MUs in different years from 2025-26 to 2035-36 with the existing and planned capacity addition only.
4. As per the Resource Adequacy studies, the likely total projected contracted capacity for the year 2035-36 is around 4,701 MW which consists of 779 MW from Coal, 25 MW from Gas, 56 MW from Nuclear, 2 MW from Biomass, 800 MW from Wind, 1,577 MW from Solar, 591 MW from DRE solar, 400MW/1600 MWh of BESS, 400 MW of PSP and 70 MW of MTOA/STOA arrangement will be required. The storage requirement can be met from PSP or a combination of PSP and BESS.
5. Goa needs to contract additional renewable capacities including Solar, wind and Energy Storage for meeting electrical energy requirements other than the planned capacities. In addition to this, the utility will likely require MTOA/ STOA arrangement ranging from around 58 MW to 336 MW in different years as outlined in the report. The STOA/MTOA requirement can be fulfilled through power procurement from market or bilateral/banking agreements.
6. The projected capacity and generation mix outlined in the report meet the utility's RPO requirements for the years 2028-29 to 2035-36. To meet the RPO trajectory for the year 2025-26 to 2027-28, the utility may endeavor short-term or medium-term power purchase agreements, or through any other appropriate mechanisms deemed suitable by the utility.
7. The current capacity[1] mix of the utility has 51% of contracted capacity from fossil fuel sources (Coal + Gas). The share of fossil fuel-based capacity[2] is likely to reduce to 17% in 2035-36. In 2035-36, the non-fossil based contracted capacity (that includes solar, wind, biomass, nuclear

[1] Not considering the STOA capacity in the calculation.
[2] Not considering the STOA capacity in the calculation.

and Solar DRE are likely to constitute around 65% of the total contract capacity while the rest is contributed by Storage.

8. The planning reserve Margin for the state has been assessed as 6% for the year 2035-36, the study indicates year-wise short-term/medium-term/bilateral requirements to meet the demand optimally.
9. It is likely that the state may have surplus capacity, which can be shared with other utilities/states through banking/bilateral arrangements, including Pushp portal.
10. 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.
11. Timely commissioning of planned capacities is critical to ensuring 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.

Planned Future Contracted (MW) considered in the study

S No.	Tied capacity name	Type of generation	Expected CoD	Goa Share (in MW)
1	Gadarwara Stage-II	Coal	2029-30	14.55
2	Sipat III CG	Coal	2029-30	10

Assumption for Resource Adequacy Studies

1. Electrical energy requirement & peak electricity demand requirement: As per projections of Goa.
2. Demand Profile: Based on hourly demand profile of 2024-25.
3. Existing & Planned Capacity: As per the information shared by the utility.
4. Cost parameters: based on information in National Electricity Plan and recent market trends.

RE CUF considered

Wind	Solar	DRE
22.6%	19.6%	17.7%

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	10	-
Solar	Existing/Planned		-	-
	Candidate		-	-
Wind	Existing/Planned		-	-
	Candidate		-	-
Pumped storage	Existing/Planned	95	10	-
	Candidate		10	-
Battery Energy Storage	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	Existing/ Planned	-	-	Round Trip efficiency 80%	-	-
	Candidate	-	-		-	-
Battery Energy Storage	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. Inter State ATC limit has not been considered in the study. Additionally, for modelling the charged BESS under the Solar + BESS configuration, the BESS capacity has been created at a separate node, with its charging arranged by the generator, unlike in the standalone BESS setup.

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 - 4 Cr	1 % of Capex	1	25
Battery Energy Storage (4-Hour)	4.98Cr (2025-26) to 3Cr (2035-36)	5.9 Lakhs	1	15
PSP (6 Hr)	6 Cr	30 Lakh	4	40