Report On
Resource Adequacy Plan
For the State of
Goa

(2024-25 to 2034-35)

Government of India
Ministry of Power
Central Electricity Authority

Contents

Executive Summary

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

The electricity demand for the State of Goa is increasing with a CAGR of 4.5 % from 2024-25 to 2034-35 as forecasted by 20th EPS. The projections of Goa also indicate that electricity demand may increase with a CAGR of 7 % from 2024-25to 2034-35. For satisfying resource adequacy i.e., meeting the electricity demand reliably and at affordable cost, the State need to methodically plan its capacity expansion either by investing or by procuring power. In view of the reduction in cost of solar panels and newer technology options like battery energy storage systems, planning for long term optimal generation capacity mix gains tremendous importance so as the future generation capacity mix is cost effective as well as environment friendly.

The electricity demand is more in non-monsoon months and is maximum during the months of April, May. The electricity demand is less during the monsoon months (July to September). The peak electricity load is generally observed during non-solar hours.

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

To find out the least cost option for generation capacity expansion for the period 2024-25 to 2034-35, long-term study for the State of Goa was carried with an objective to minimize the total system cost of generation including the cost of anticipated future investments while fulfilling all the technical/financial constraints associated with various power generation technologies.

The study was carried out considering existing capacity, planned capacity & capacity required to fulfil the Renewable Purchase Obligations (RPO). It was found that the state's likely contracted capacity along with the trajectory of the banking arrangement is not sufficient to meet projected demand. It was observed that the total unserved energy in the year 2034-35 is expected to be about 4921 MU which is about 47 % annual energy during the year 2034-35.

Generation capacity expansion pathways have been considered for the long-term study based on the yearly capacity addition plans of the state along with RPO constraints for solar and wind technologies. The Renewable capacities have been assessed in view of adherence to RPO notified by Ministry of power considering the fungibility among different sources.

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

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

1.0 Introduction

Ministry of Power has notified Electricity (Amendment) Rules, 2022 in December 2022. Rule 16 (I) of the said rules stipulates that "A guideline for assessment of resource adequacy during the generation planning stage (one year or beyond) as well as during the operational planning stage (up to one year) shall be issued by the Central Government in consultation with the Authority". Accordingly, the Resource Adequacy Guidelines have been notified in June, 2023 by Ministry of Power in consultation with Central Electricity Authority.

Resource Adequacy is generally defined as a mechanism to ensure that there is an adequate supply of generation resources to serve expected demand reliably at least cost. A key aspect of resource adequacy planning is to ensure that adequate generation capacities are available, round-the-clock, to reliably serve demand, under various scenarios. This naturally translates into the need for ensuring adequate reserve margin, which could cater to varying levels of demand and supply conditions in the grid. In the wake of high RE generation, it is important to understand demand-supply situation in the grid precisely due to high seasonality and intermittency in RE generation. Resource Adequacy exercise may also help in assessment of capacity requirement to be tied up or contracted on long term, medium term, and short-term basis.

Further, Ministry of Power vide order dated 22nd July 2022 had notified the RPO trajectory for the states. Based on the trajectory specified, the hydro, wind and other (solar, biomass etc.) RPO quantum in million units (MUs) has been calculated to find additional quantum of renewable capacity that the states have to contract in addition to its existing/planned capacity to meet their RPO targets.

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

2.0 Goa RA Study

2.1 Present Power Scenario in Goa

As of March 2024, the total contracted capacity for Goa is 931 MW. Out of the total contracted capacity (CC), the share of non-fossil fuel-based CC is 36.4%.

The fuel-wise contracted capacity as on 31st March, 2024 is given in Table and Figure below:

Table 1 Fuel-wise Contracted Capacity as on March 2024

Source	Contracted Capacity (MW)	Percentage
Coal	567	60.9%
Gas	25	2.7%
Nuclear	56	6%
Wind	200	21.5%
Solar*	81	8.7%
Biomass	2.34	0.3%
Total	**931**	**100%**

*Note: Solar Net-metering capacity (59 MW) is not considered in contracted capacity

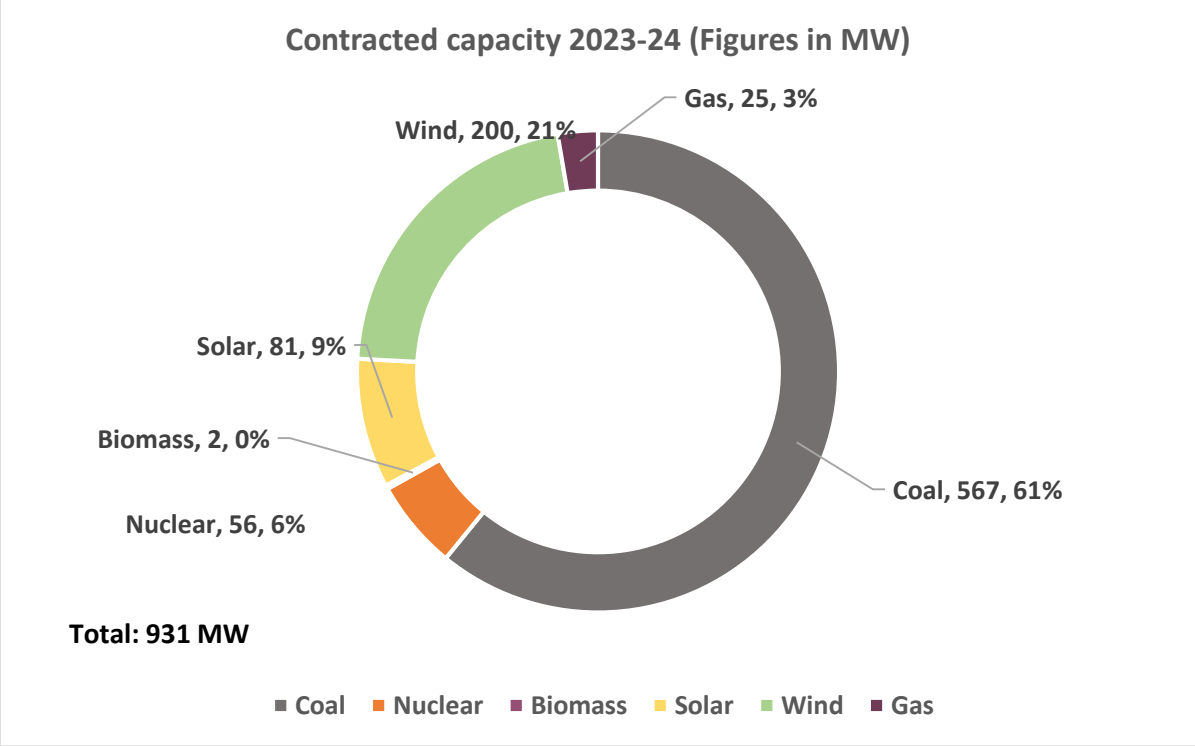


Figure 1 Fuel-wise Contracted Capacity (in MW) as on 31st March, 2024

2.2 Present Demand Analysis (2023-24)

Hourly demand pattern of 2023-24 was analyzed and it was observed that the peak demand season for Goa is during the months of April, May. Goa witnesses peak demand during night hours. Optimal utilization of resources through short-term contracts like banking or STOA can be practiced for managing the seasonal variation in demand and is one of the effective ways for ensuring resource adequacy.

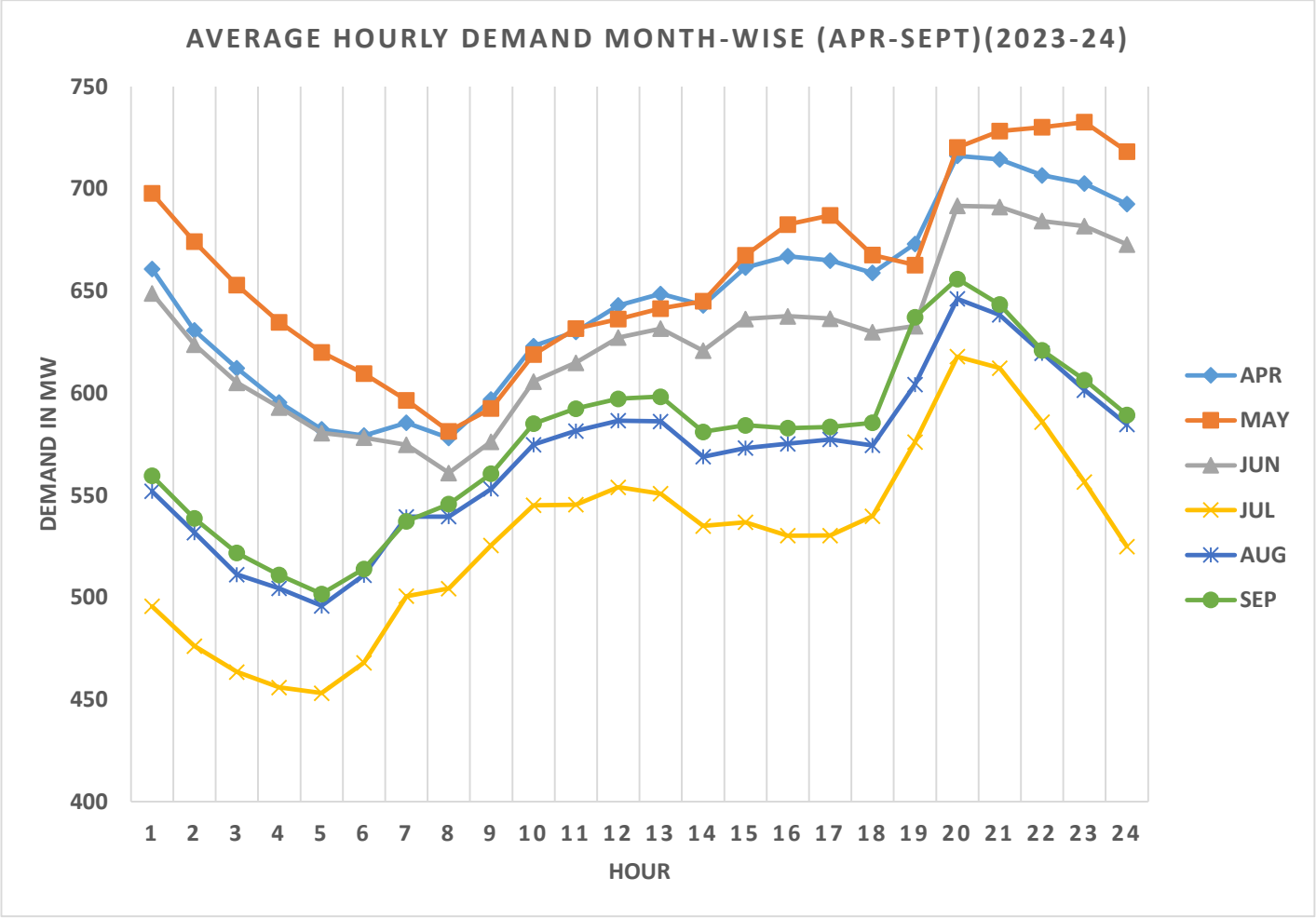


Figure 2(a) Average Hourly Demand Variation (Month-wise) (Apr-Sept) of Goa for 2023-24

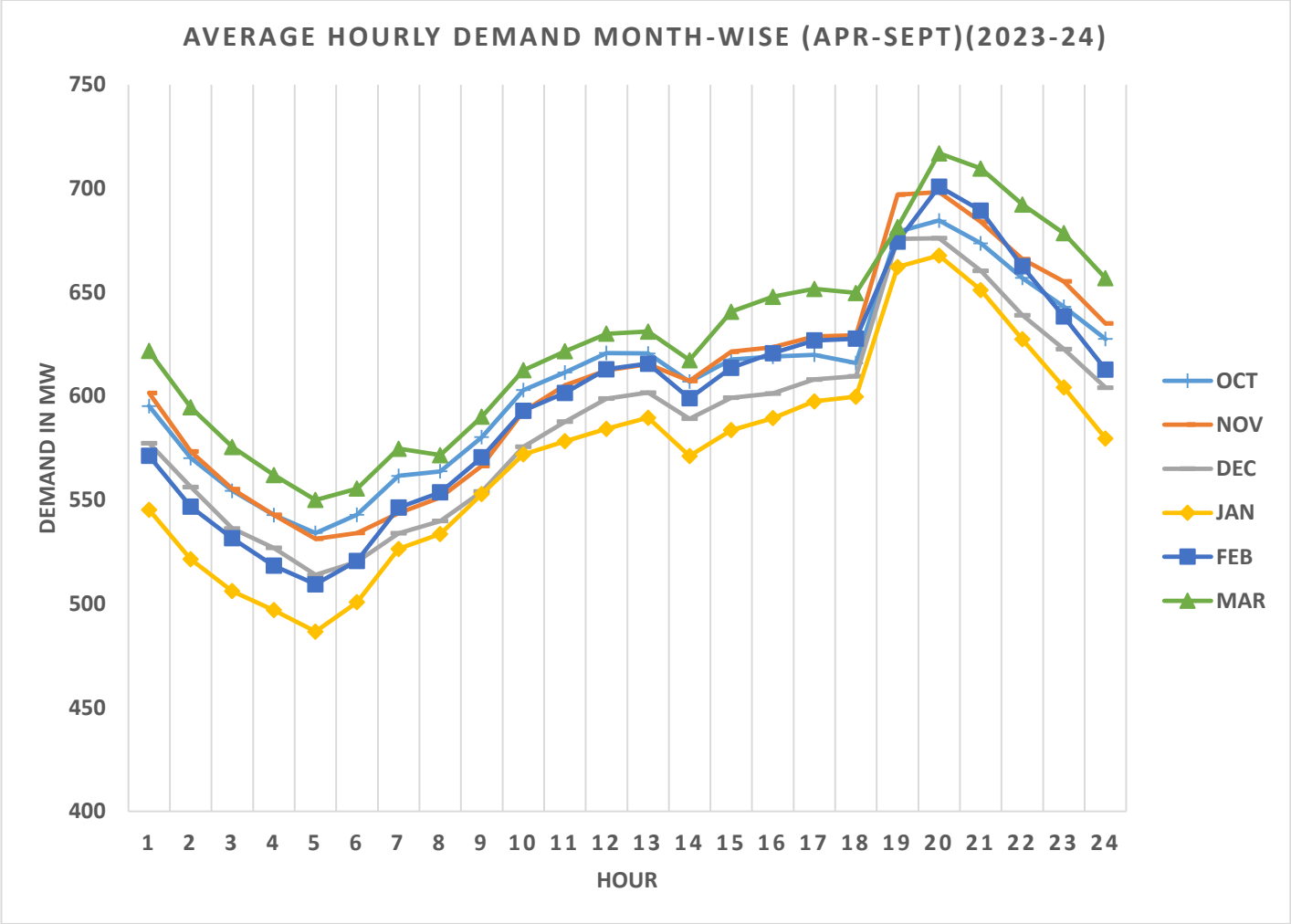


Figure 2(b) Average Hourly Demand Variation (Month-wise) (Oct-Mar) of Goa for 2023-24

Goa sees daily peak during night hours in every month of the year.

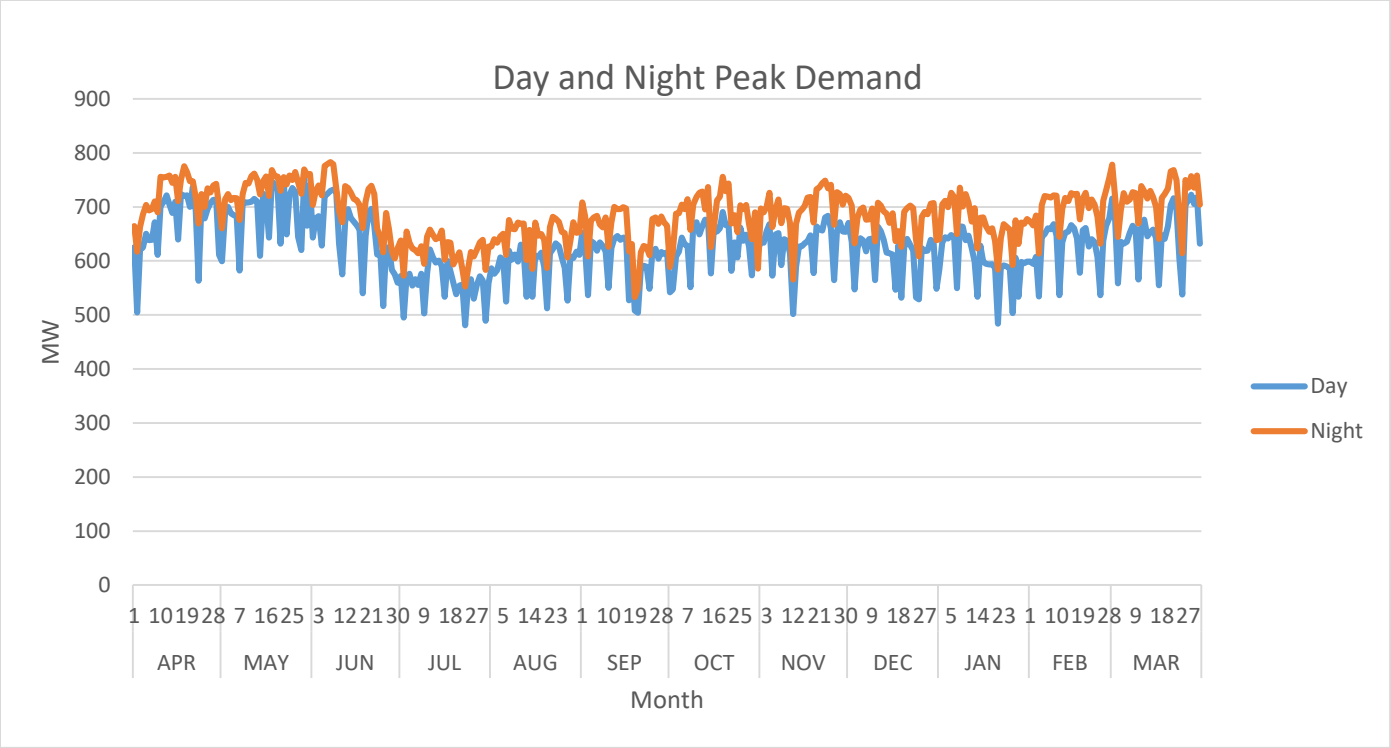


Figure 3 Day and Night Peak in MW of Goa (2023-24)

The hourly demand pattern of 2023-24 was analysed for finding out the number of occurrences of the peak and near peak demand. Such instances are critical for study purpose as it is necessary to ensure resource adequacy during such instances with an optimal mix of long-term, medium-term and short-term contracts.

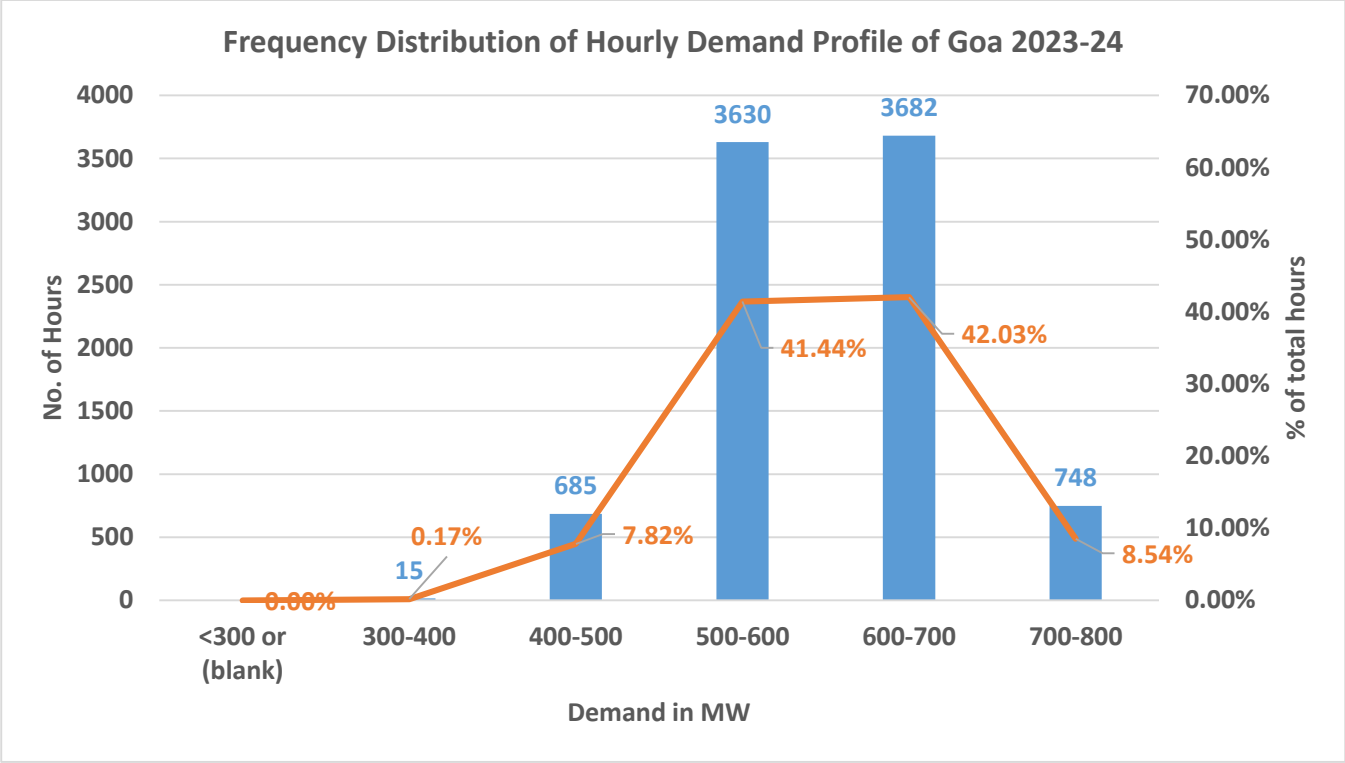


Figure 4 Frequency Distribution of Hourly Demand Profile of Goa 2023-24

3.0 Inputs/Assumptions for the Study

i) Peak and Energy Demand for the State of Goa has been taken as per the projections provided by Goa state department. The Demand estimation by Goa was higher than projected by 20th EPS. Therefore, the Studies have been carried out using projections given by Goa state department.

Table 2 Future Demand Projection as provided by Goa

	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35
Energy Projections (MU)	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 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%

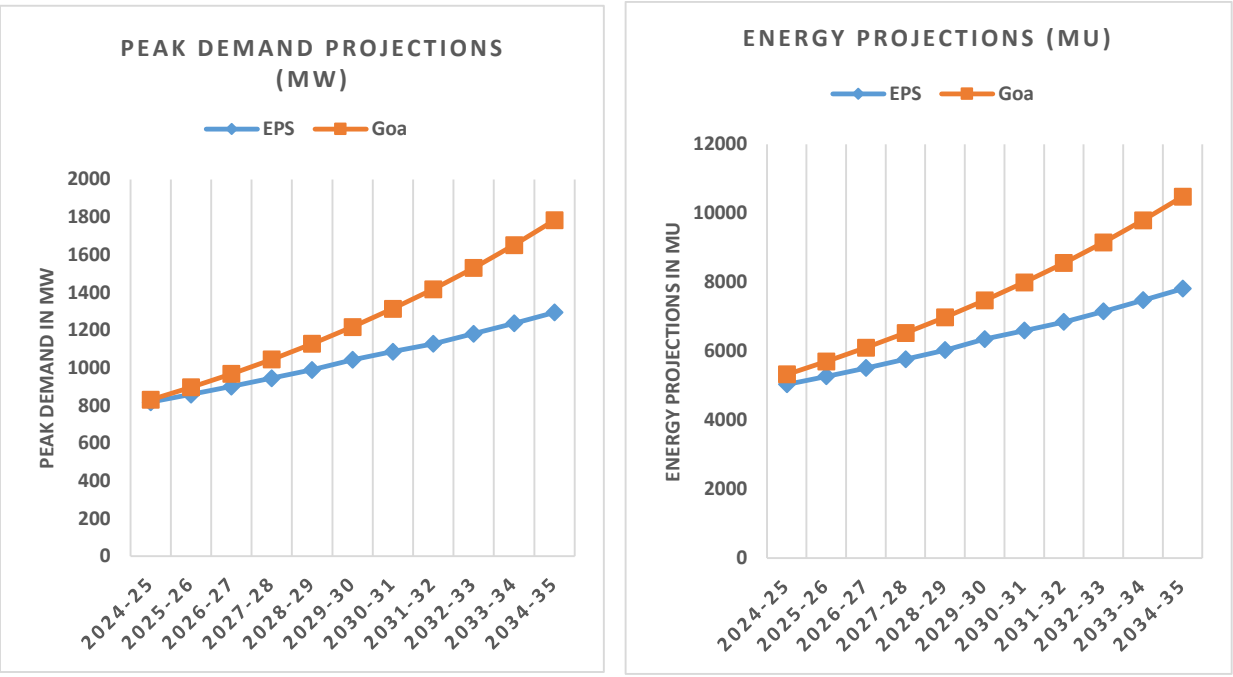


Figure 5 Comparison of Energy Requirement and peak Demand Projections of 20th EPS vs Goa

ii) Future demand profile for the year 2034-35 has been projected using the demand profile for the year 2023-24 as the base profile.

iii) The actual solar and wind generation profiles and CUFs have been referred from National Electricity Plan.

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

v) Existing & Planned Capacity: As per the information received from Goa. (List of Planned Thermal is attached in **Annexure-I**)

vi) According to the data provided by Goa, an additional 24.55 MW of Coal,250 MW of solar(excluding solar metering and KUSUM-C component) and 150 MW of wind is planned till 2030.

vii) Ministry of Power, via gazette notification dated 20th October, 2023, had notified the source wise minimum share of consumption of non-fossil sources (renewable energy) by designated consumers, till the year 2029-30. In view of the country's energy transition 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 increase beyond 2029-30. Therefore, the RPO trajectory is assumed to rise steadily beyond 2029-30 and hence, RPO trajectory till 2034-35 are given below:

*Table 3 Renewable Purchase Obligation (RPO) trajectory as per MoP order**

Sl. No.	Year	Wind renewable energy	Hydro renewable energy	Other renewable energy	Distributed renewable energy	Total renewable energy
(1)	(2)	(3)	(4)	(6)	(5)	(7)
1.	2024-25	0.67%	0.38%	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%	33.10%	3.9%	41.36%
6.	2029-30	3.48%	1.33%	34.02%	4.5%	43.33%
7.	2030-31	40.50%			5.0%	45.50%
8.	2031-32	41.50%			5.5%	47.00%
9.	2032-33	42.30%			6.0%	48.30%
10.	2033-34	43.00%			6.5%	49.50%
11.	2034-35	44.00%			7.0%	51.00%

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

Based on the trajectory specified, RPO quantum in million units (MUs) from hydro, wind, other (solar, biomass etc.) and distributed renewable energy (DRE) is calculated and tabulated below:

*Table 4 Total Energy required to meet RPO (MU)**

Sl. No.	Year	Wind renewable energy (MU)	Hydro renewable energy	Other renewable energy	Distributed renewable energy	Total renewable energy
(1)	(2)	(3)	(4)	(6)	(5)	(7)
1	**2024-25**	36	20	1457	80	1593
2	**2025-26**	83	70	1610	120	1881
3	**2026-27**	120	82	1826	165	2192
4	**2027-28**	160	93	2065	215	2533
5	**2028-29**	206	99	2311	272	2888
6	**2029-30**	260	99	2542	336	3237
7	**2030-31**	3238			400	3637
8	**2031-32**	3550			470	4020
9	**2032-33**	3871			549	4421
10	**2033-34**	4211			637	4847
11	**2034-35**	4611			733	5344

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

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

Table 5 Projected RE capacity addition required (MW) as per RPO trajectory.

FY	WIND		SOLAR		DRE		TOTAL	
	Planned	Additional	Planned	Additional	Planned	Additional	Planned	Additional
2024/25	150	0	83	0	39	0	**272**	**0**
2025/26	0	0	87	0	30	0	**117**	**0**
2026/27	0	150	80	150	35	0	**115**	**300**
2027/28	0	100	0	100	40	0	**40**	**200**
2028/29	0	100	0	100	45	0	**45**	**200**
2029/30	0	100	0	4	50	0	**50**	**104**
2030/31	0	100	0	51	0	28	**0**	**179**
2031/32	0	100	0	39	0	58	**0**	**197**
2032/33	0	100	0	45	0	64	**0**	**209**
2033/34	0	100	0	53	0	71	**0**	**224**
2034/35	0	100	0	100	0	79	**0**	**279**
TOTAL	**150**	**950**	**250**	**642**	**239**	**300**	**639**	**1892**

It is observed that with existing and planned capacity as shown in Table-1 and Table-5, RPO energy requirement for the years FY 2024-25 & FY 2025-26 could not be met.

4.0 Reliability Analysis

One of the main criteria of resource adequacy studies is to determine the reliability of the system to meet the demand adequately at very instance of time. This reliability is measured via two indices (i.e.) LOLP (Loss of Load Probability) and EENS (Expected Energy Not Served). These indices have been defined in resource adequacy guidelines as below:

- **Loss of Load Probability (LOLP)**: Measure of the probability that a system's load may exceed the generation and firm power contracts available to meet that load in a year. E.g., 0.0274 % probability of load being lost.
- **Expected Energy Not Served (EENS):** Expected amount of energy (MWh) that may not be served for each year within the planning period under study. It is a summation of the expected number of megawatt hours of demand that may not be served for the year. This is an energy-centric metric that considers the magnitude and duration of energy being not served, calculated in Mega Watt hours (MWh). The metric can be normalized (i.e., divided by total system load) to create a Normalized Energy Not Served (NENS) metric.

Monte Carlo /Stochastic simulation has been used to factor-in the uncertainty associated with various generation resources and demand. It is an approach which is used to predict the probability of a variety of outcomes when the potential for random variables is present as compared to deterministic modelling of economic dispatch model. Monte Carlo simulation helps in analysing the randomness associated with RE energy resource, demand pattern changes and forced outages of plant. A large no of random samples of these variables are simultaneously simulated to ascertain system reliability indices (i.e. Loss of load probability LOLP & Energy Not Served (ENS)) & the system robustness in case of above variation of system parameters.

Planning Reserve Margin (PRM): To meet the prescribed standard of LOLP / NENS conditions, sufficient reserve margins need to be maintained in the system for adequately addressing the demand and supply variations. Planning Reserve Margin (PRM) is the predominant metric used to ensure adequacy of generation resources in the system. PRM in a power system is expressed as a certain % of peak load forecast of the system.

4.1 Demand variation:

The variation in demand pattern of Goa for last 5 years has been analyzed. The hourly demand variation for consecutive years (i.e., 2022-23 and 2023-24) has been analyzed. The Demand pattern variation of 2022-23 and 2023-24 is shown below.

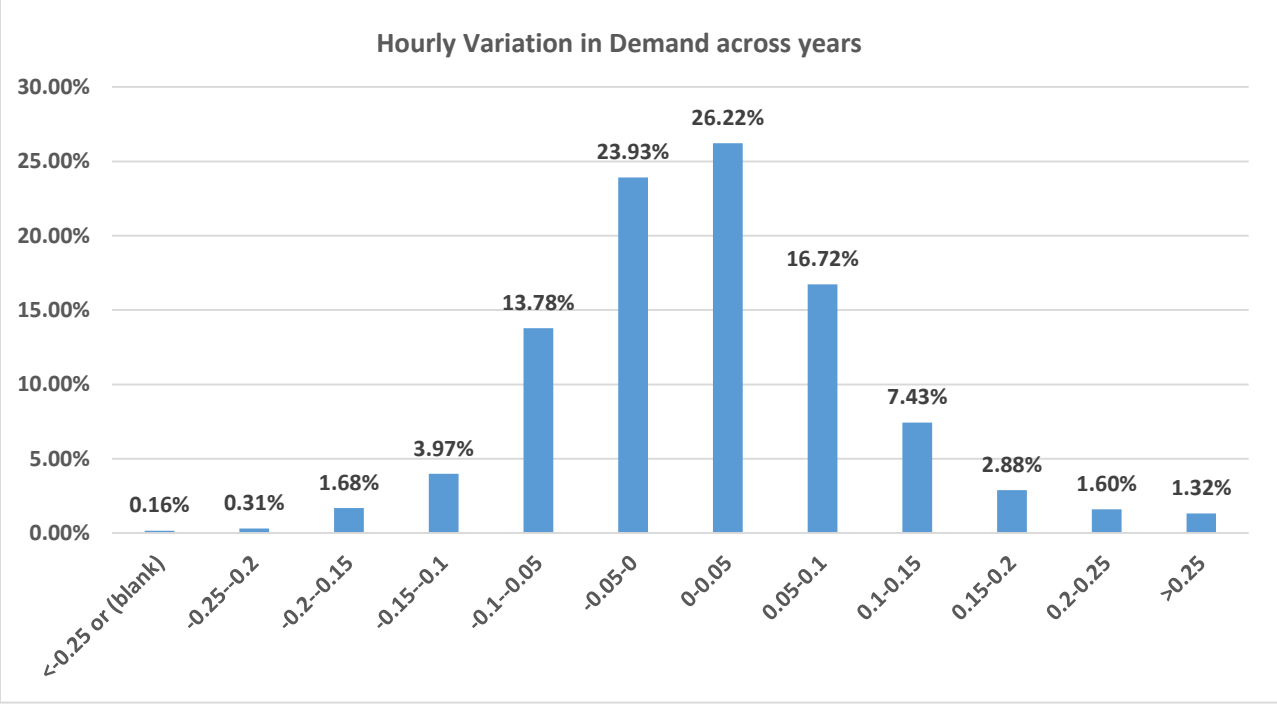


Figure 6 Hourly Variation in Demand across years

It can be observed that the hourly demand typically varies ±10% for 81% of instances. This variation is primarily due to temperature, weather parameter or any random outages of transmission line and generation units etc. This variation has been captured in the reliability study by varying the projected hourly demand for the future years by varying ±15% by introducing a random variable (with normal distribution) for demand as per observed behavior over the years.

4.2 RE variation

In the Long-term capacity expansion planning studies, a particular profile for Solar and Wind Plants are considered based on the observed solar and wind generation data to determine the optimal capacity mix. However, due to intermittent nature of these sources the generation from these non-dispatchable sources may vary across years. As per the analyses carried out based on historical generation data, solar generation and wind generation has been varied by 10 % and 60% respectively to incorporate the variation in these generation sources and plan for requisite measures to mitigate such behavior.

4.3 Forced Outage of Thermal Generators

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

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

5.0 Results of the study

5.1 Unserved Energy Projections

The study was carried out considering existing capacity, planned capacity. It was observed that the total unserved energy in the year 2034-35 is about 4921 MU. The yearly likely unserved energy with the planned capacities is given below.

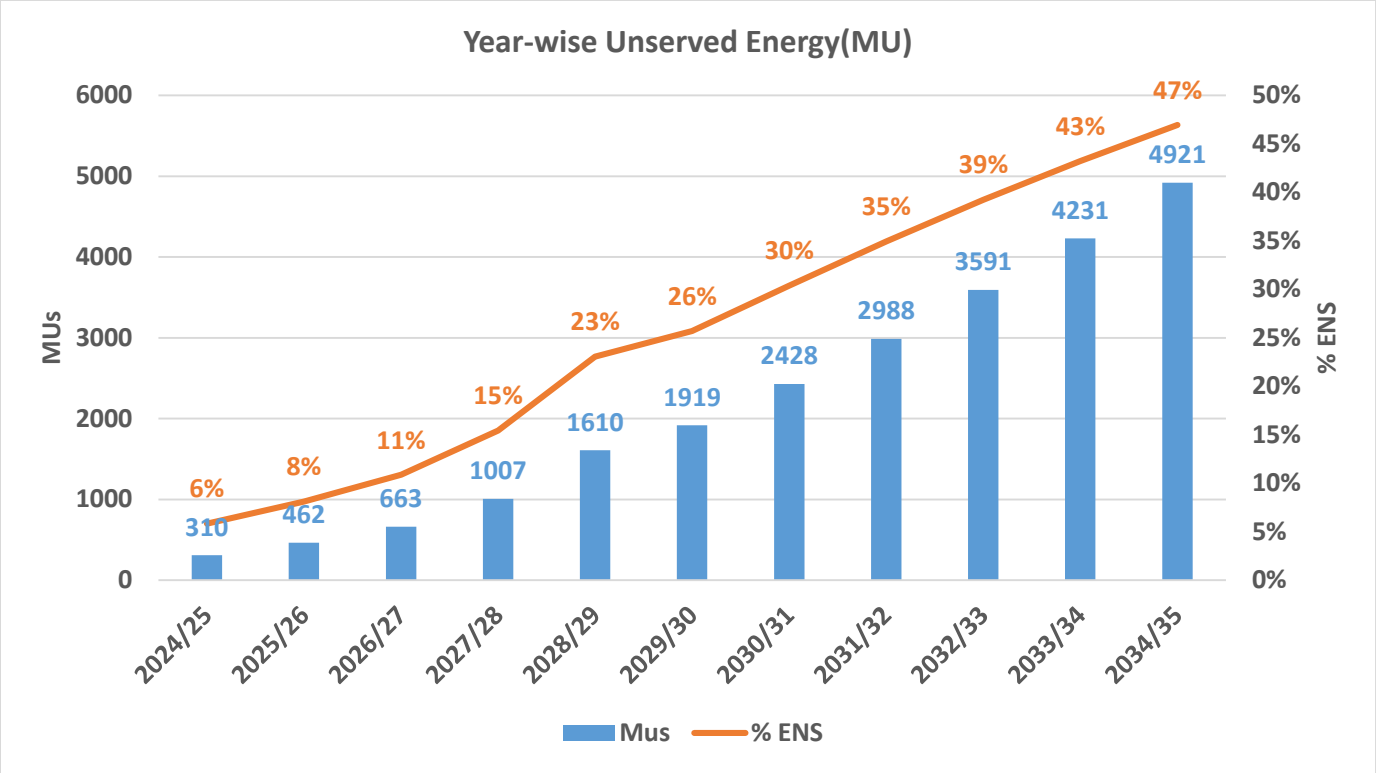


Figure 7 Yearly likely unserved energy with the planned capacities for Goa (in MU)

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

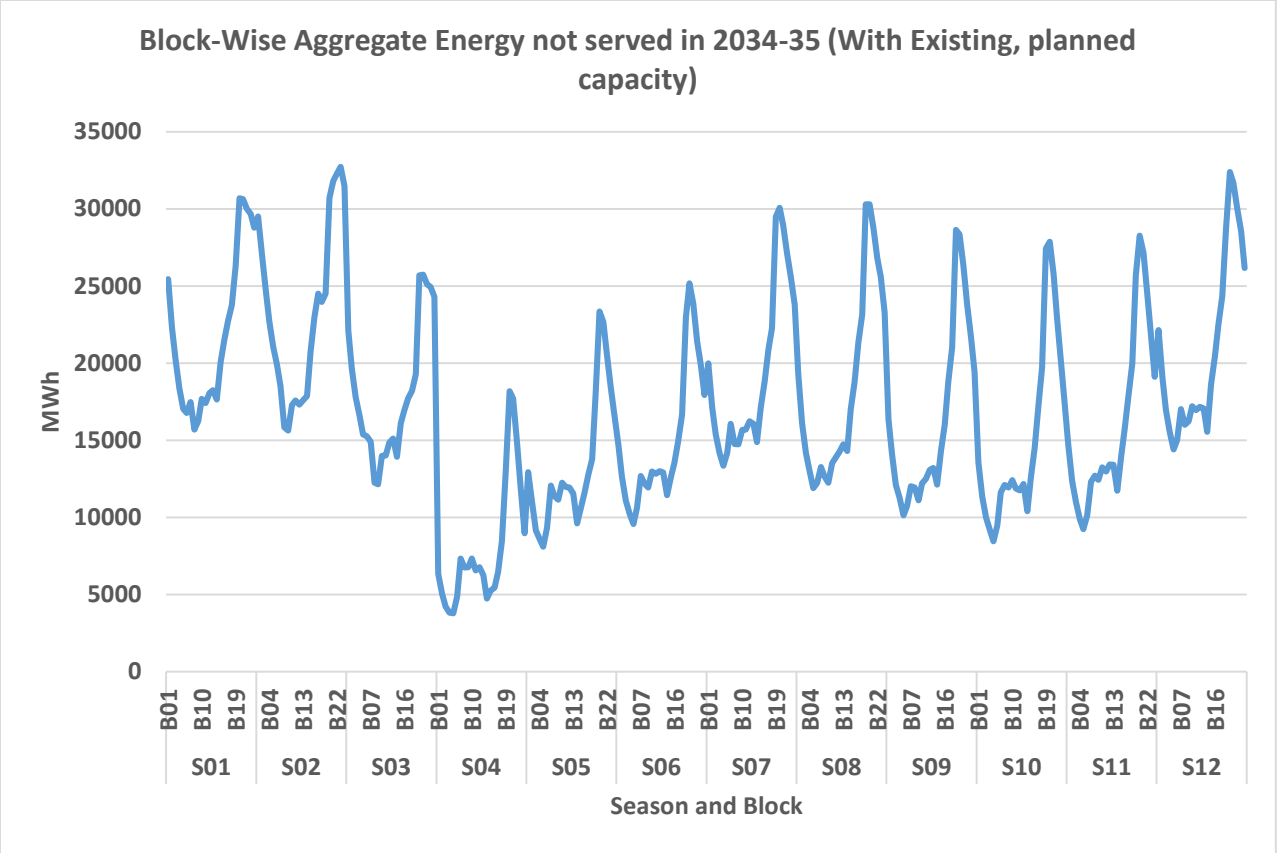


Figure 8 Block-wise Unserved Energy Pattern MWh (2034-35)

5.2 Capacity Mix Projection

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

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

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

The capacity projections for Goa are given below:

Table 6 Year-wise contracted capacity projections (in MW)

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

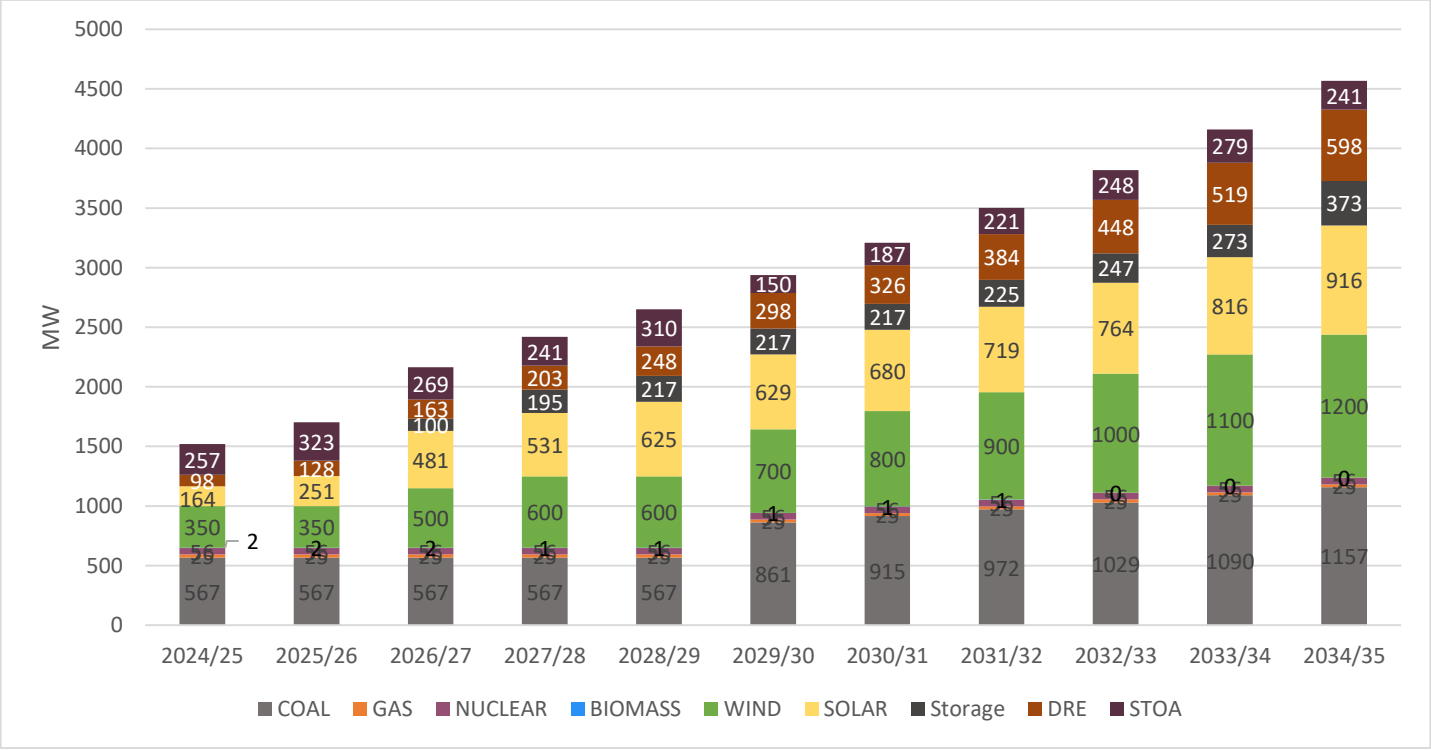


Figure 9 Projected Contracted Capacity Mix Year-wise (MW) for Goa

As per the Resource Adequacy studies, the total projected contracted Capacity for the year 2034-35 is 4567 MW which consists of 1157 MW from Coal, 25 MW from Gas, 56 MW from Nuclear, 1200 MW from Wind, 916 MW from Solar, 241 MW from STOA,598 MW from DRE. This IC shall be able to meet the projected demand with prescribed reliability criteria.

The Reliability studies have been carried out to adhere to the reliability criteria of LoLP and NENS as provided in NEP (0.2% and 0.05% respectively). The PRM for the state of Goa has been assessed as 3.2%. In addition, the projected/contracted capacity fulfils the stipulated Renewable Purchase Obligation.

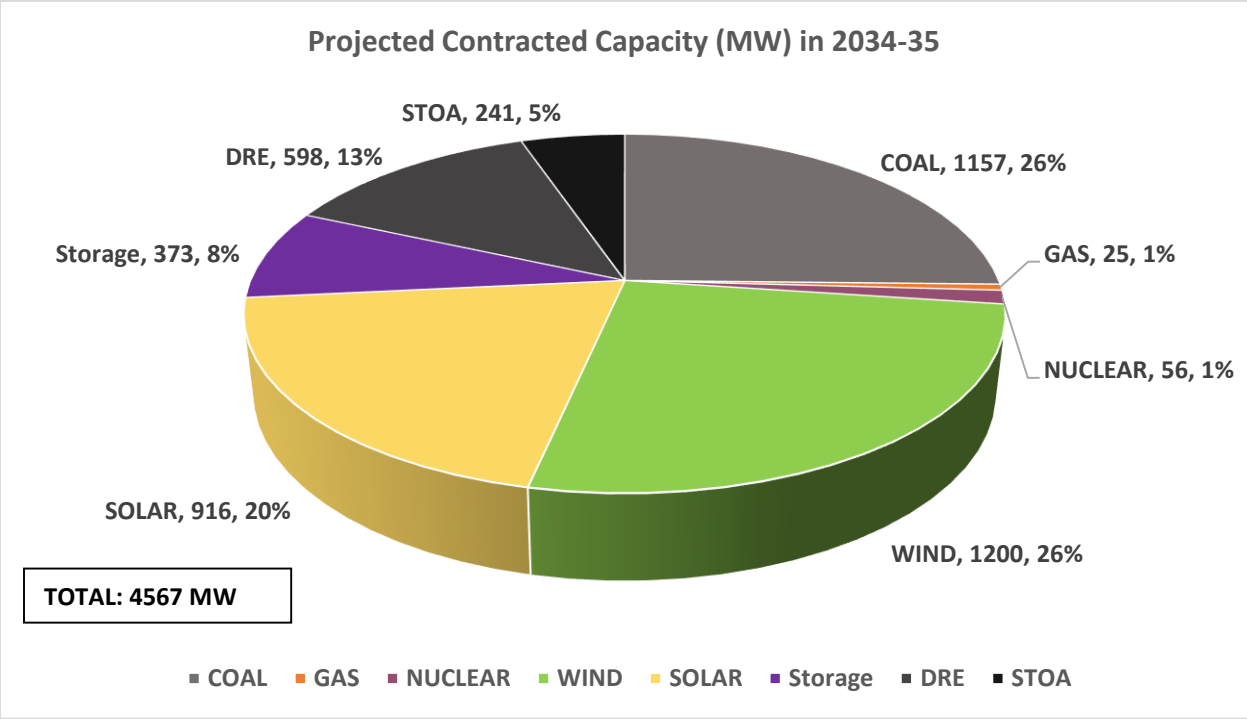
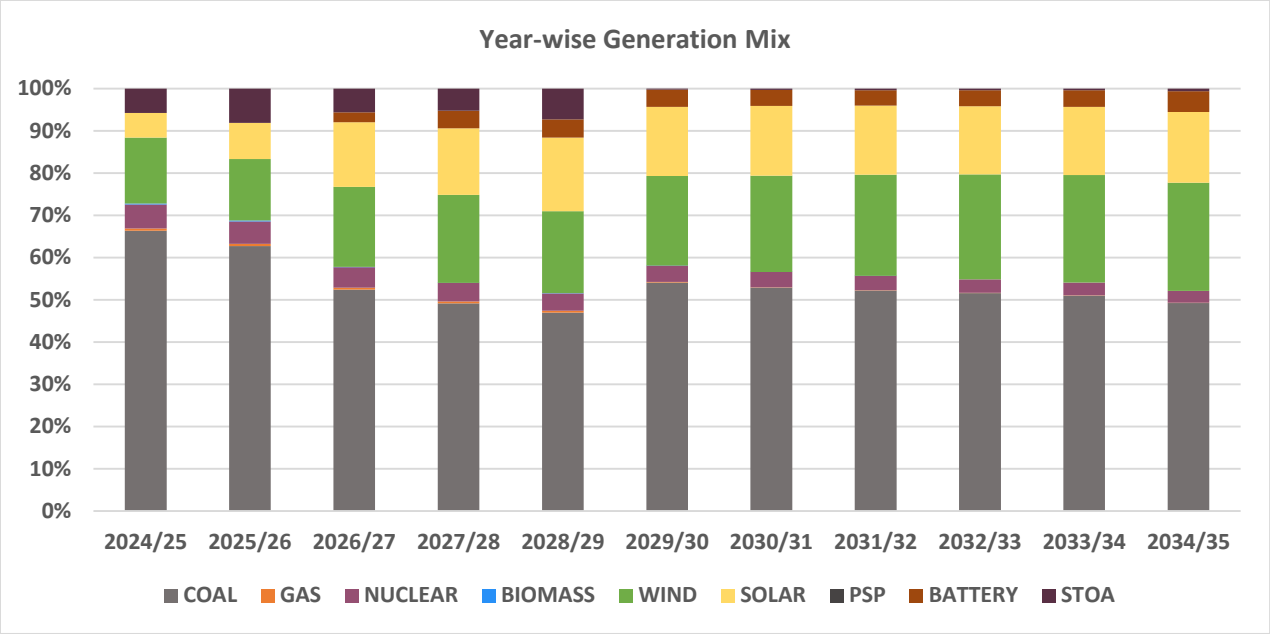
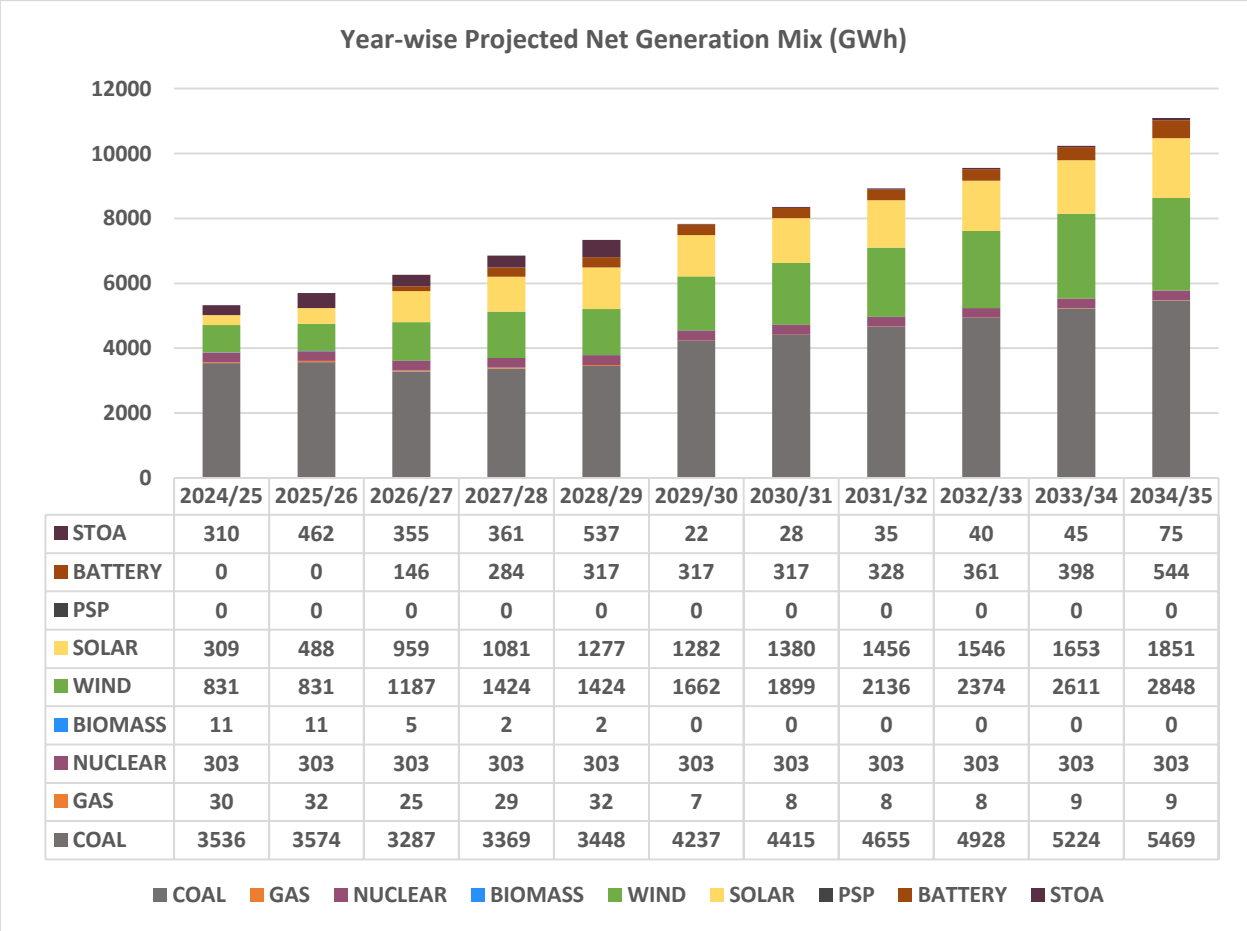


Figure 10 Contracted Capacity Mix in 2034-35 with 3.2% PRM

The share of non-fossil fuel-based capacity in the generation mix is projected to increase to around 61% by 2034-35 with higher contribution from non-fossil fuel-based capacities in alignment with RPO trajectory.





	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32	2032/33	2033/34	2034/35
STOA	310	462	355	361	537	22	28	35	40	45	75
BATTERY	0	0	146	284	317	317	317	328	361	398	544
PSP	0	0	0	0	0	0	0	0	0	0	0
SOLAR	309	488	959	1081	1277	1282	1380	1456	1546	1653	1851
WIND	831	831	1187	1424	1424	1662	1899	2136	2374	2611	2848
BIOMASS	11	11	5	2	2	0	0	0	0	0	0
NUCLEAR	303	303	303	303	303	303	303	303	303	303	303
GAS	30	32	25	29	32	7	8	8	8	9	9
COAL	3536	3574	3287	3369	3448	4237	4415	4655	4928	5224	5469

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

5.3 Capacity contract requirement for future

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

Table 7 Year wise Capacity Addition for Goa (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**

5.4 Coal Capacity Performance

The coal capacity PLF is expected to remain in the range of 57%- 76% for the years till 2035 (reducing from 75% in 2024-25 to 57 % in 2034-35) ensuring higher absorption of higher renewable energy.

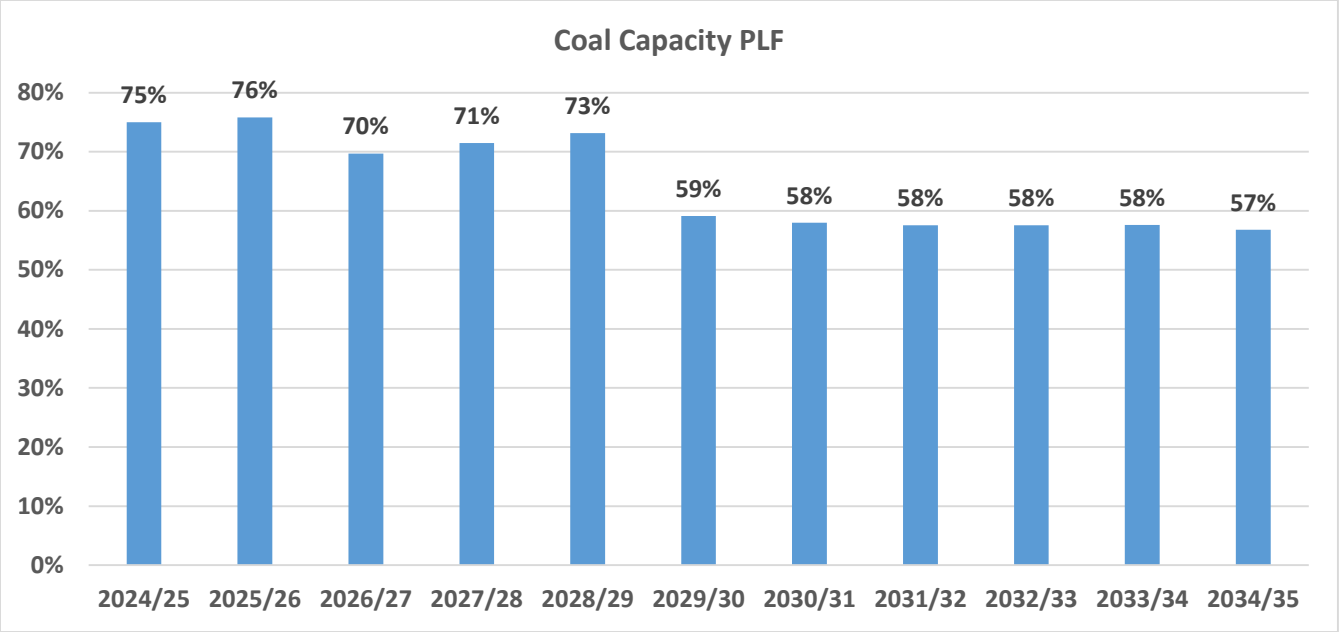


Figure 12 Year-wise coal capacity PLF for Goa (in %)

5.5 Day-wise Surplus Capacity Goa (MW)

Surplus capacity is available with states due to RE availability, Demand variation etc. The pattern of surplus capacities for Goa has been observed as below. This capacity can be shared with other states and reduce the fixed cost burden on the utilities resulting in reduction in the cost for consumer. Goa has likely surplus capacity available during the solar hours (during June, July, August) in the range of 30-300 MW for 2026-27 as shown below which can be shared with other states.

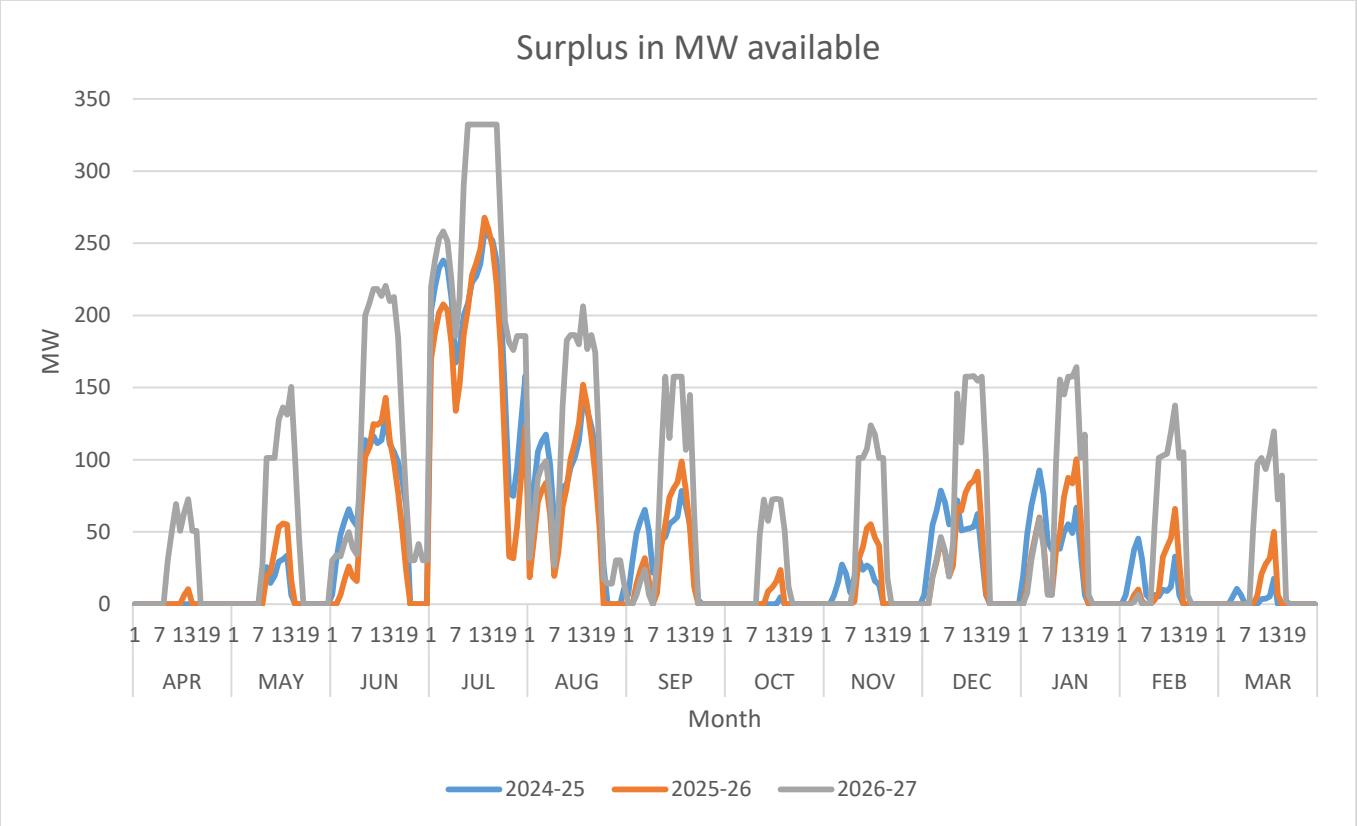


Figure 13 Surplus Coal Capacity Year-wise (MW)

6.0 Alternate Resilient Scenario Analysis

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

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

- Peak and Energy Demand- 5% increase compared to demand submitted by Goa.
- Capacity Addition being delayed from their anticipated year as follows:

Table 8 Time Delay in commissioning of contracted capacity

Contracted Capacity Type	Years Delayed
Hydro	2
Nuclear	2

Renewable Energy Capacity	1
Coal	1

6.1 Capacity Mix Projections

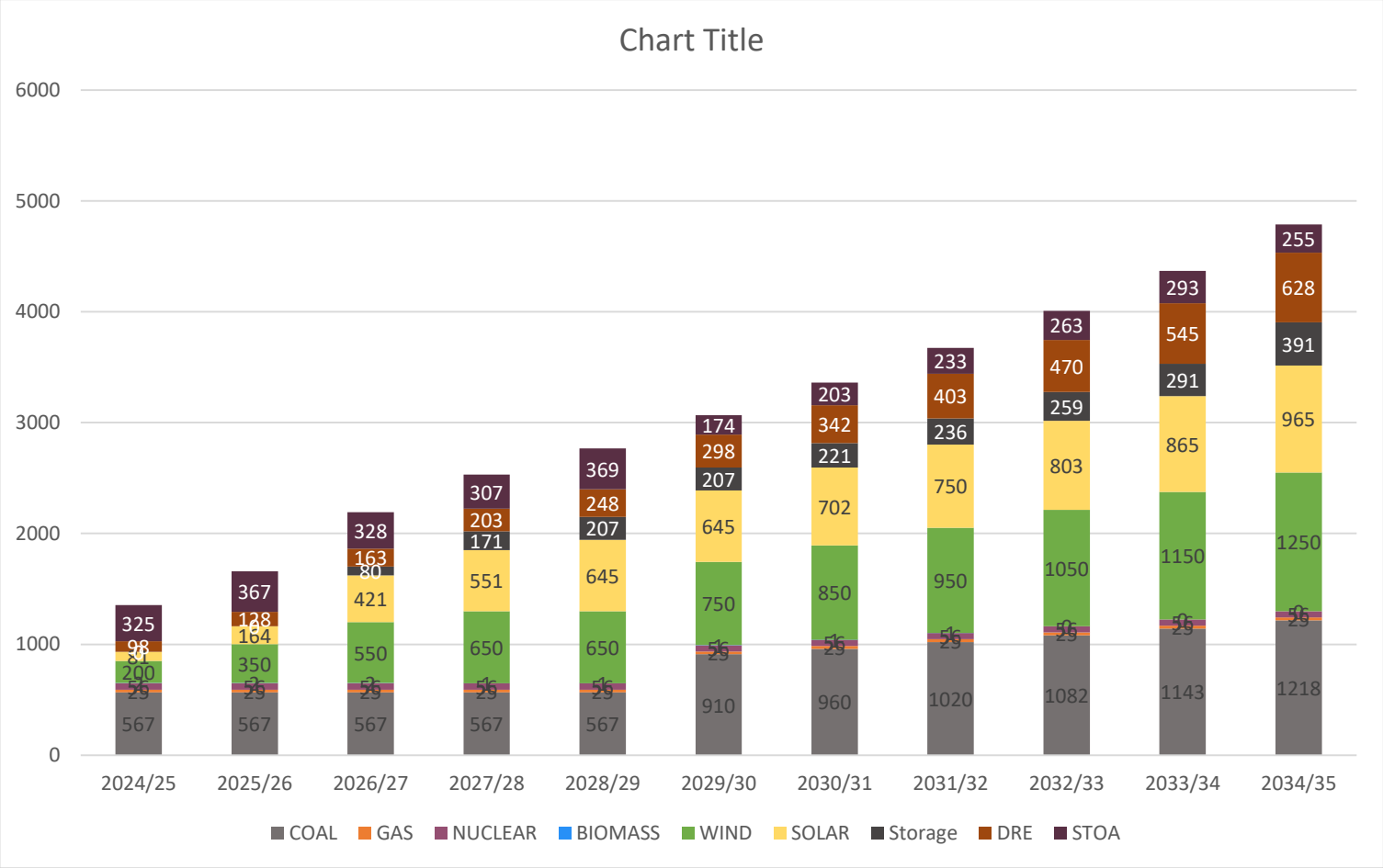


Figure 14: Year-wise capacity projections (in MW) for Alternate Resilient Scenario

In this scenario, coal requirement increases by around 60 MW, Solar requirement increases by 50 MW, Wind requirement increases by 50 MW, Storage requirement increases by 18 MW compared to the base case in terminal year 2034-35. The STOA requirement increases by around 15-70 MW in case of Alternate Resilient scenario from 2024/25 compared to the base case.

If Additional Capacity required for meeting RPO in Alternate Resilient scenario is only 70% realized due to delay in commissioning of RE projects, then, coal capacity requirement may further increase by 120-235 MW ,starting from year 2029-30 and STOA requirement may further increase by 75-220 MW ,starting from year 2026-27.

7.0 Conclusion

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

- The demand projections by Goa are higher compared to the demand projections by 20th Electric Power Survey (EPS).
- The current capacity mix in Goa has 36.4% of IC from non-fossil fuel sources. The electricity demand is more in non-monsoon months and is maximum during the months of April, May. The study is based on the hourly load pattern of the year 2023-24.
- Goa is likely to witness energy deficit ranging from 310 MUs to 4921 MUs in different years from 2024-25 to 2034-35 with the existing and planned capacity addition. Goa is deficit in fulfilment of its Renewable Purchase Obligations (RPO) and needs to contract renewable capacities for fulfilling them. The projected capacity and generation mix fulfils the RPO by 2030 as per the Ministry of Power notification dated 20th October, 2023.
- Goa is likely to have unserved energy in coming years and may need to contract non-fossil capacities for meeting energy requirements other than the planned capacities. The additional quantum of capacities required (other than already planned) to be contracted is about 566 MW from Coal,642 MW from solar, 950 MW from Wind, 373 MW from Storage, 300 MW of DRE till 2034-35.
- STOA value reflects the peak value (MW) requirement in the capacity mix. However, in energy terms, the requirement from STOA is quite less.
- The coal capacity PLF is expected to remain in the range of 57%- 76% for the years till 2035 (reducing from 75% in 2024-25 to 57 % in 2034-35) ensuring higher absorption of higher renewable energy.
- In Alternate Resilient scenario, coal requirement increases by around 60 MW, Solar requirement increases by 50 MW, Wind requirement increases by 50 MW, Storage requirement increases by 18 MW compared to the base case. The STOA requirement increases by around 15-70 MW in case of Alternate Resilient scenario from 2024/25 compared to the base case.
- It is likely that Goa may have surplus capacity available during the solar hours (during June, July, August) in the range of 30-300 MW for 2026-27 as shown below which can be shared with other states.

Annexure-I

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

SR. NO	POWER PLANT	GOA'S SHARE (MW)	TYPE OF GENERATION	EXPECTED COD/ REMARK
1	NTPC SIPAT STAGE-III	10	THERMAL	FY 2029-30
2	NTPC GADARWARA STAGE-II	14.55	THERMAL	FY 2029-30
	TOTAL	**24.55**		

Assumption for Resource Adequacy Studies for the State of Goa

1. Electricity Demand & peak requirement: As per projections given by Goa
2. Demand Profile: Based on hourly demand profile of 2023-24
3. Existing & Planned Capacity: As per the information received from Goa
4. Future Capacity addition: based on RPO trajectory
5. Cost parameters: based on information in National Electricity Plan

Technical Parameters

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

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

Transmission Parameters

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

Financial Parameters

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

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

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

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

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