Report On
Resource Adequacy Plan
For the State of
Maharashtra
(MSEDCL)

(2024-25 to 2033-34)

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 Maharashtra (MSEDCL) is increasing with a CAGR of 4.08 % from 2024-25 to 2033-34 as forecasted by 20th EPS. The projections of MSEDCL also indicate that electricity demand may increase with a CAGR of 4.03 % from 2024-25 to 2033-34. 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 starts increasing from the month of November and is maximum during the months of February, March and April months. The electricity demand is significantly less during the monsoon months (July, August, September, and October). The peak electricity load is generally observed during 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 Maharashtra (MSEDCL) 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 2033-34, long-term study for the State of Maharashtra (MSEDCL) 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 and 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 2033-34 is expected to be about 10397 MU which is about 4.3 % annual energy during the year 2033-34 and primarily observed in the months from November to May.

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 other than the planned addition in nuclear capacity has been considered in the studies.

The Resource adequacy studies have projected likely optimal capacity mix for future years till 2033-34 which is able to meet anticipated demand reliably at every instance.

1.0 Introduction

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

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

Further, Ministry of Power vide notification dated 20th October, 2023 had notified the RPO trajectory for the states. Based on the trajectory specified the hydro, wind and other (solar, biomass etc.) RPO quantum in million units (MUs) has been calculated to find additional quantum of renewable capacity that the states have to contract in addition to its existing/planned capacity to meet their RPO targets.

Resource Adequacy studies has been carried out for Maharashtra (MSEDCL) based on the inputs received from MSEDCL and fulfilling RPO trajectory. The study suggests the optimal resource mix till 2033-34 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 24 X 7 considering variation in demand, RE generation and forced outages of thermal capacities. The study has also assessed the requirement of Planning Reserve margin for Maharashtra (MSEDCL) for catering to above highlighted uncertainties so that demand can be met reliably throughout the year.

2.0 Maharashtra RA Study

2.1 Present Power Scenario in Maharashtra (MSEDCL)

As of March 2023, the total contracted capacity for Maharashtra (MSEDCL) is 35,328 MW. Out of the total contracted capacity (CC), the share of non-fossil fuel-based CC is 38.1 %.

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

Table 1 Fuel-wise Contracted Capacity as on March 2023

Source	Contracted Capacity (MW)	Percentage
Coal	20782	58.8%
Gas	1076	3.0%
Nuclear	740	2.1%
Biomass	2569	7.3%
Hydro	2886	8.2%
Solar	4159	11.8%
Small Hydro	311	0.9%
Wind	2805	7.9%
Total	**35328**	**100%**

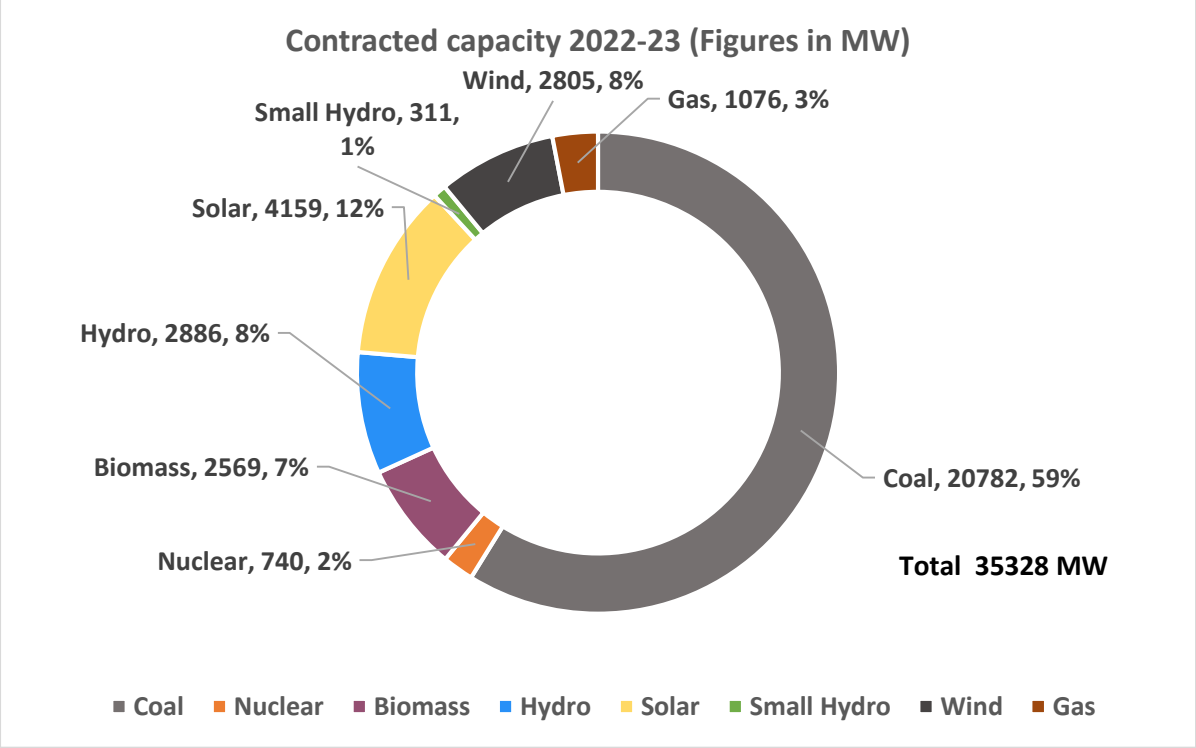


Figure 1 Fuel-wise Contracted Capacity (in MW) as on Mar 2023

2.2 Present Demand Analysis (2022-23)

Hourly demand pattern of 2022-23 was analyzed and it was observed that the peak demand season for Maharashtra (MSEDCL) is during the months of February, March and April. Maharashtra (MSEDCL) witnesses peak demand during solar hours. Optimal utilization of resources through short-term contracts like banking or STOA as currently practiced for managing the seasonal variation in demand is one of the effective ways for ensuring resource adequacy.

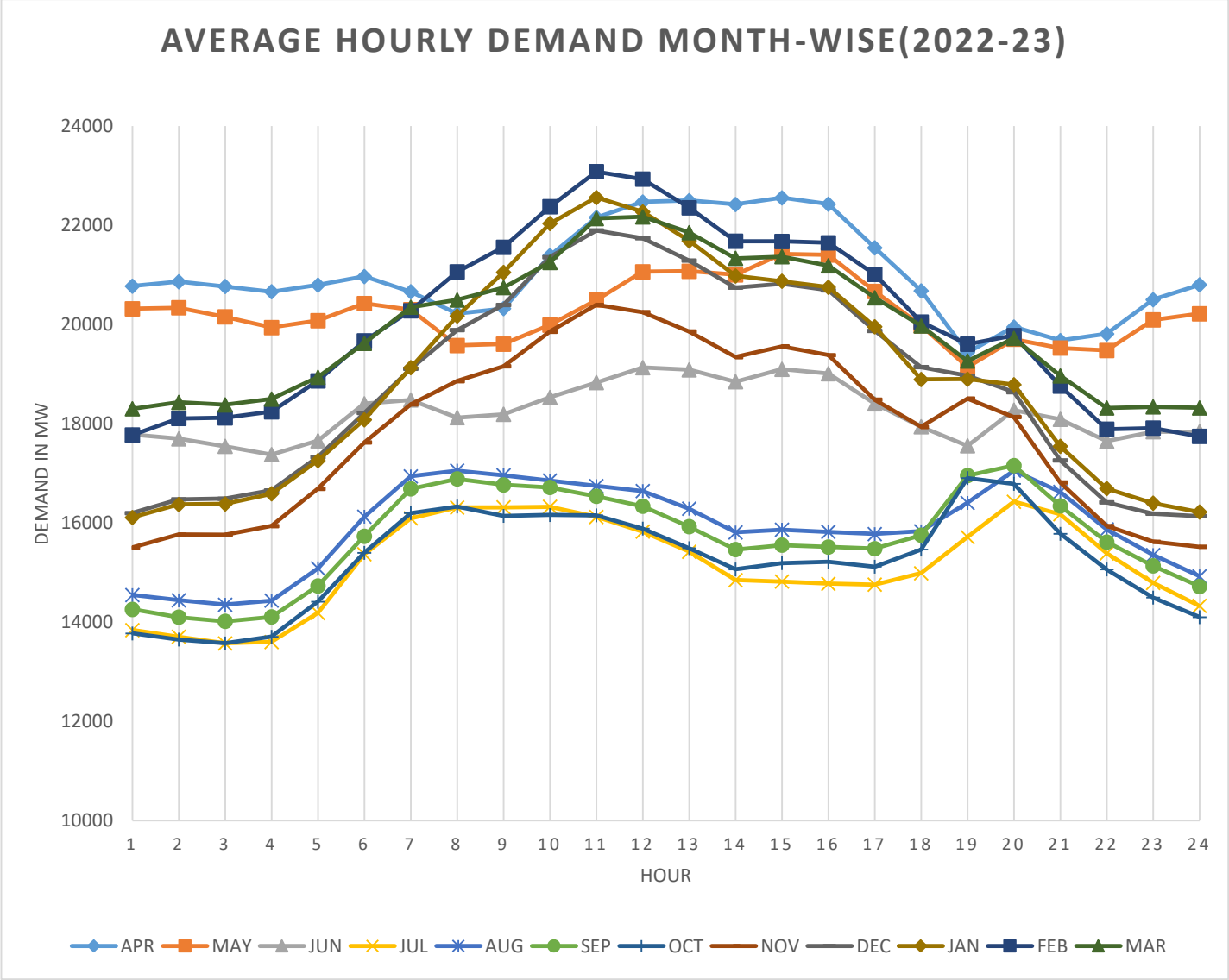


Figure 2 Average Hourly Demand Variation (Month-wise) of Maharashtra for 2022-23

Maharashtra (MSEDCL) has Day Peak in Winter Months from November till May while there is no significant variation in Day and night peak demand for rest of the year.

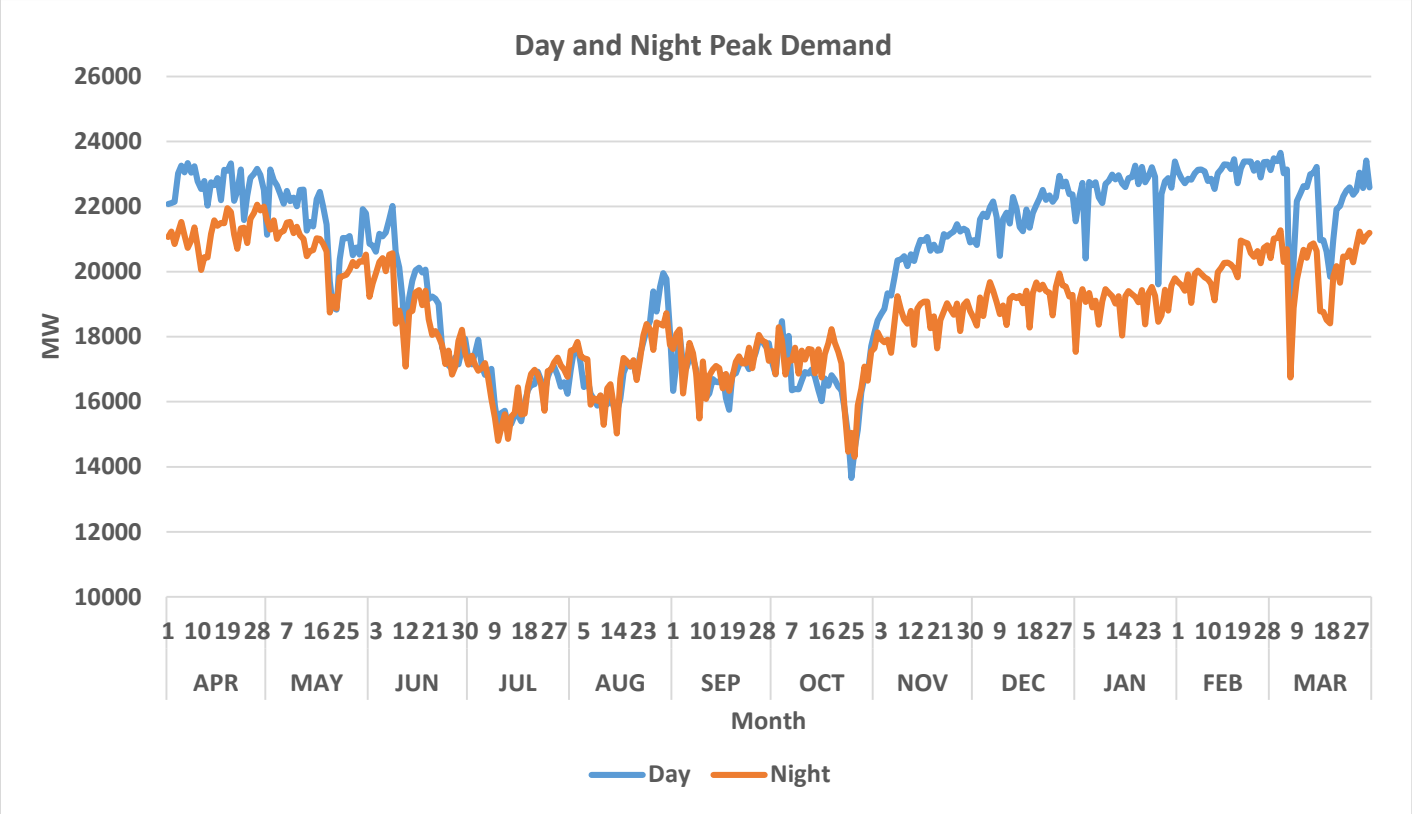


Figure 3 Day and Night Peak in MW of Maharashtra (2022-23)

The hourly demand pattern of 2022-23 was analysed for finding out the number of occurrences of the peak and near peak demand. Such instances are critical for study purpose as it is necessary to ensure resource adequacy during such instances with a optimal mix of long-term, medium-term and short-term contracts.

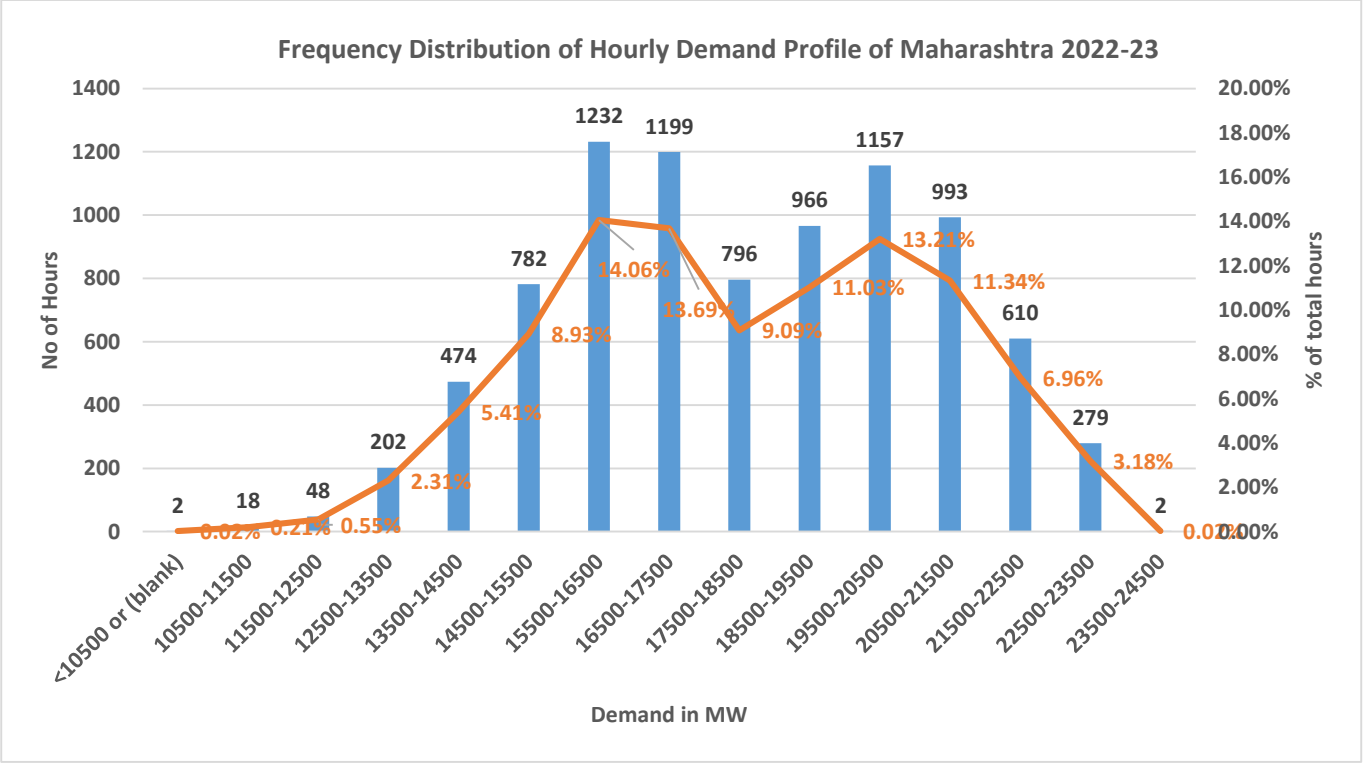


Figure 4 Frequency Distribution of Hourly Demand Profile of Maharashtra 2022-23

3.0 Inputs/Assumptions for the Study

i) Peak and Energy Demand for the State of Maharashtra (MSEDCL) has been taken as per projections provided from Maharashtra (MSEDCL). The Demand estimation by MSEDCL and 20th EPS are almost similar. Therefore, the Studies have been carried out using projections provided from Maharashtra (MSEDCL) after considering Agriculture load shifting.

Table 2 Future Demand Projection by Maharashtra (MSEDCL)

	2024-25	**2025-26**	**2026-27**	**2027-28**	**2028-29**	**2029-30**	**2030-31**	**2031-32**	**2032-33**	**2033-34**
Energy Projections (MU)	167746	175261	183949	192180	200590	210874	216301	221229	230034	239511
Year on Year Growth		4.48%	4.96%	4.47%	4.38%	5.13%	2.57%	2.28%	3.98%	4.12%
Peak Demand Projections (MW)	24963	27621	30892	34298	35596	37163	38726	39000	40414	41956.38

Year on Year Growth		10.65%	11.84%	11.02%	3.79%	4.40%	4.20%	0.71%	3.63%	3.82%

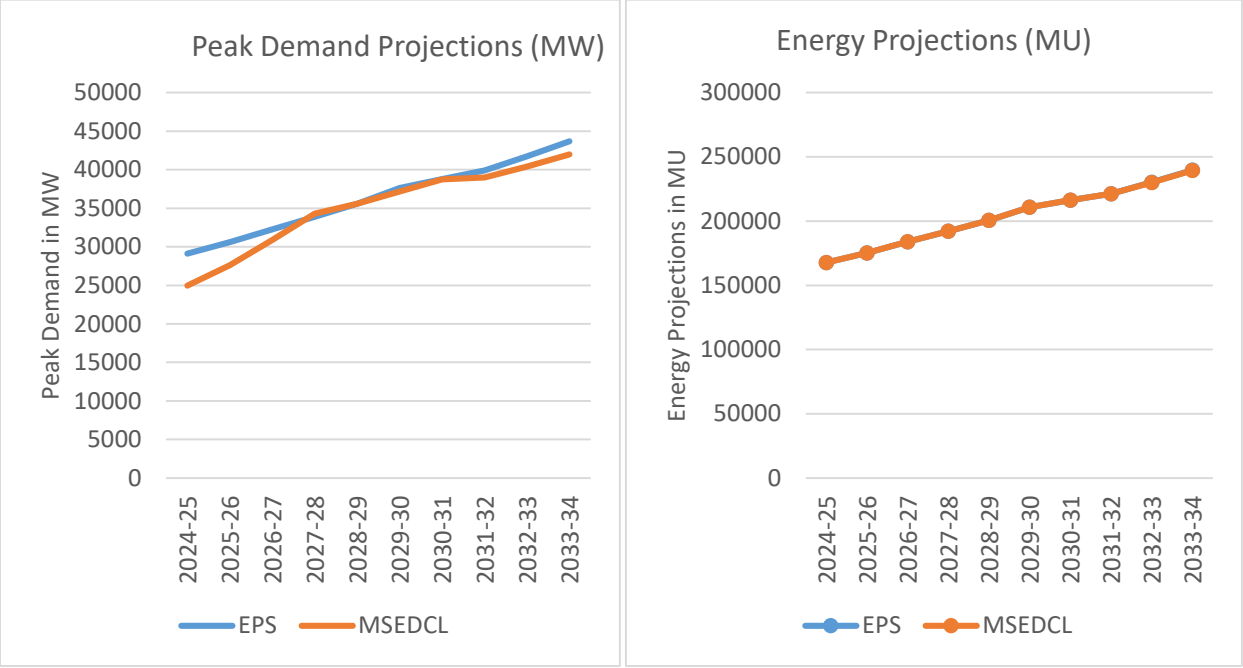


Figure 5 Comparison of Energy Requirement and peak Demand Projections of 20th EPS vs Maharashtra (MSEDCL)

ii) Future demand profile for the year 2033-34 has been projected using the demand profile for the year 2022-23 as the base profile.

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

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 MSEDCL. (List of Planned Thermal, Nuclear and Hydro is attached in **Annexure-I**).

vi) According to the data provided by MSEDCL, an additional 5452 MW of Coal,223 MW of Nuclear,1320 MW of Hydro, 766 MW of Biomass, 19070 MW of solar and 1000 MW of wind is planned till 2034.

vii) RPO trajectory: The Government of India has recently notified new Renewable Purchase Obligation (RPO) trajectory till 2029-30 which has allowed compliance even through resource fungibility except distributed renewable energy (DRE).In order to meet its Renewable Purchase Obligation (RPO) Maharashtra (MSEDCL) needs to add/contract additional renewable capacity (MW) as assessed 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%

*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**	1124	637	45879	2516	50173
2	**2025-26**	2541	2138	49494	3680	57854
3	**2026-27**	3624	2465	55074	4967	66130
4	**2027-28**	4708	2729	60806	6342	74585
5	**2028-29**	5917	2848	66395	7823	82964
6	**2029-30**	7338	2805	71739	9489	91372
7	**2030-31**	87602			10815	98417
8	**2031-32**	91810			12168	103978
9	**2032-33**	97304			13802	111106
10	**2033-34**	102990			15568	118558

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	Hydro		WIND		SOLAR		DRE		TOTAL	
	Planned	Additional	Planned	Additional	Planned	Additional	Planned	Additional	Planned	Additional
2024/25	183	0	500	0	4943	0	0	2052	5626	2052
2025/26	0	0	500	0	6410	0	0	949	6910	949
2026/27	109	0	0	1500	4000	500	0	1049	4109	3049
2027/28	313	0	0	1500	3000	500	0	1121	3313	3121
2028/29	104	0	0	1500	717	500	0	1208	821	3208
2029/30	0	0	0	1500	0	0	0	1358	0	2858
2030/31	0	0	0	1500	0	1000	0	1081	0	3581
2031/32	288	0	0	1500	0	1000	0	1103	288	3603
2032/33	323	0	0	1500	0	1000	0	1332	323	3832
2033/34	0	0	0	1500	0	1000	0	1440	0	3940
TOTAL	**1320**	**0**	**1000**	**12000**	**19070**	**5500**	**0**	**12694**	**21390**	**30193**

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

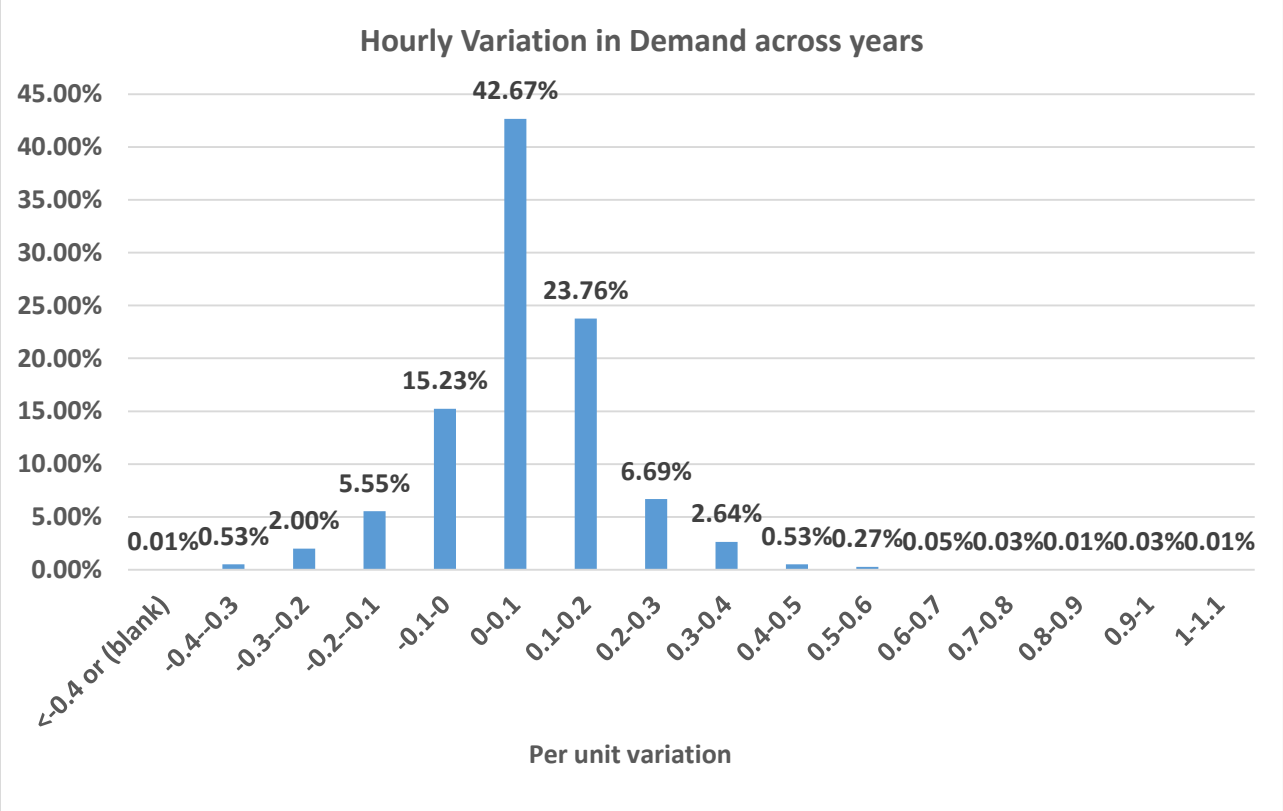


Figure 6 Hourly Variation in Demand across years

It can be observed that the hourly demand typically varies ±10% for 58% 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 ±10% 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 50% 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 & capacity required to fulfil the RPO obligations. It was observed that the total unserved energy in the year 2033-34 is about 10397 MU. The yearly likely unserved energy with the planned capacities is given below.

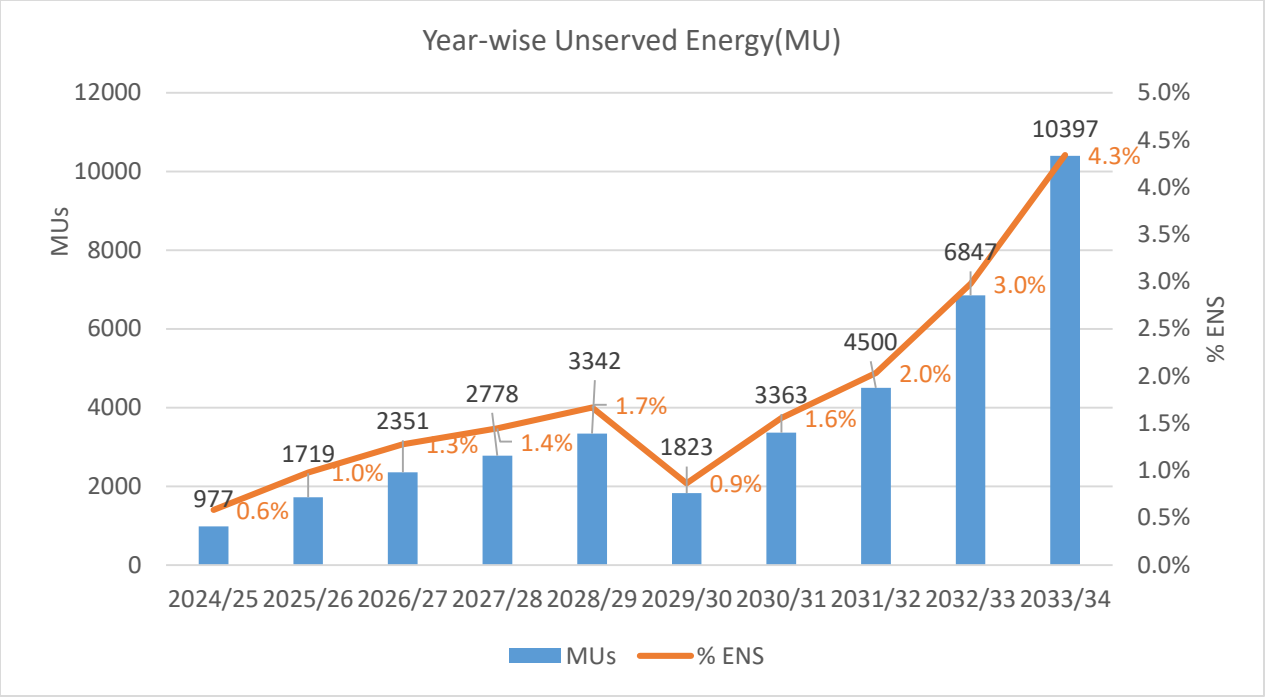


Figure 7 Yearly likely unserved energy with the planned capacities for Maharashtra (MSEDCL) (in MU)

The study has also analyzed the Daily and monthly pattern of unserved energy in the year 2033-34, it can be seen that the unserved energy coincides with peak demand months when the contracted capacity (Existing, planned) is unable to meet the demand.

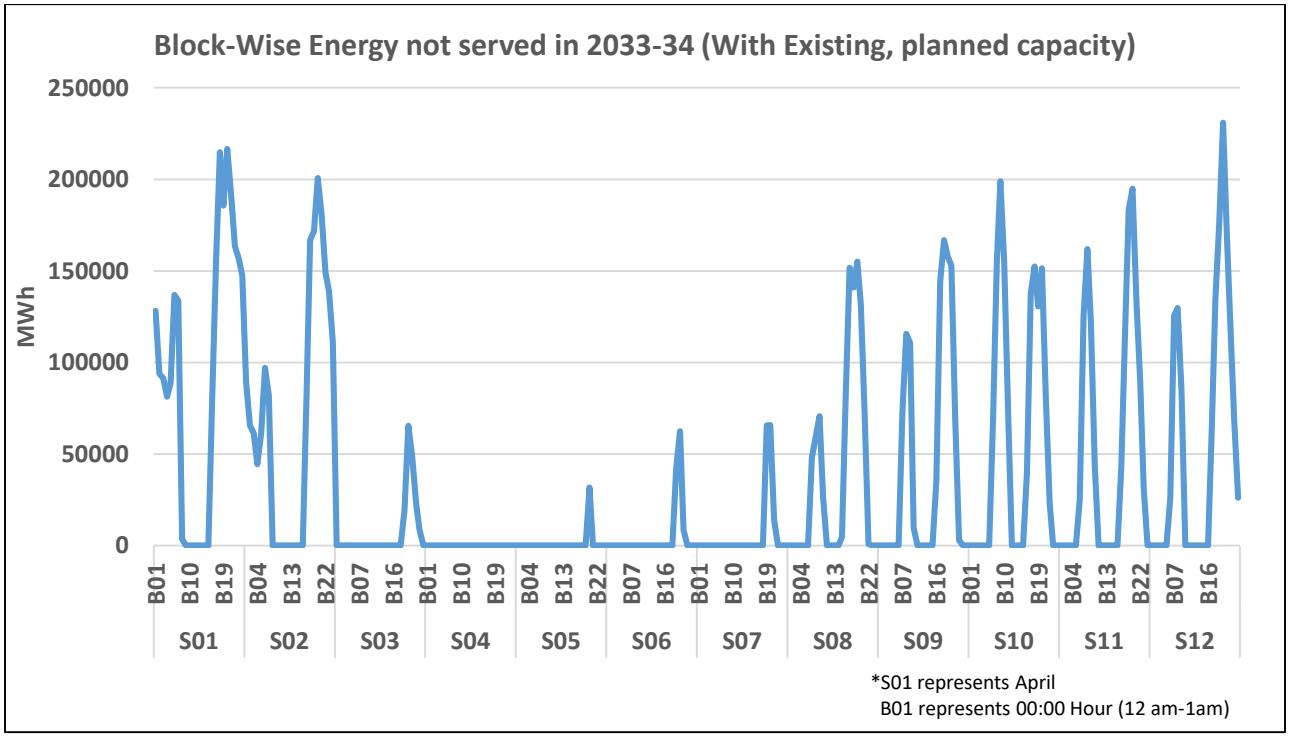


Figure 8 Block-wise Unserved Energy Pattern MWh (2033-34)

5.2 Capacity Mix Projection

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) There is requirement of BESS 2026-27 onwards.
ii) The STOA/MTOA requirement can be fulfilled through power procurement from markets or bilateral agreements.
iii) The STOA/MTOA value reflects the peak value requirement in terms of MW.

The capacity projections for Maharashtra (MSEDCL) are given below:

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

Year	COAL	GAS	NUCLEAR	BIOMASS	HYDRO	WIND	SOLAR	PSP	Storage (4 Hours)	STOA	DRE	Total
2024/25	22442	1076	1186	2749	2812	3405	10658	574	0	2482	2052	**49437**
2025/26	22442	1076	1186	3439	2812	3905	17068	574	0	3310	3001	**58813**
2026/27	22442	1076	1186	3439	2921	5405	21568	574	378	2359	4050	**65399**
2027/28	22442	1076	1186	3439	3234	6905	25068	574	853	1687	5171	**71635**
2028/29	22670	1076	1186	3439	3338	8405	26285	574	1180	2057	6379	**76589**
2029/30	25275	1076	1186	3439	3338	9905	26285	574	1180	1117	7737	**81113**
2030/31	25894	1076	1186	3439	3338	11405	27285	574	1320	1250	8818	**85585**
2031/32	26018	1076	1186	3439	3626	12905	28285	574	1411	1218	9922	**89660**
2032/33	26560	1076	1186	3439	3949	14405	29285	574	1755	1487	11254	**94970**
2033/34	27562	1076	1186	3439	3949	15905	30285	574	2094	1457	12694	**100222**

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

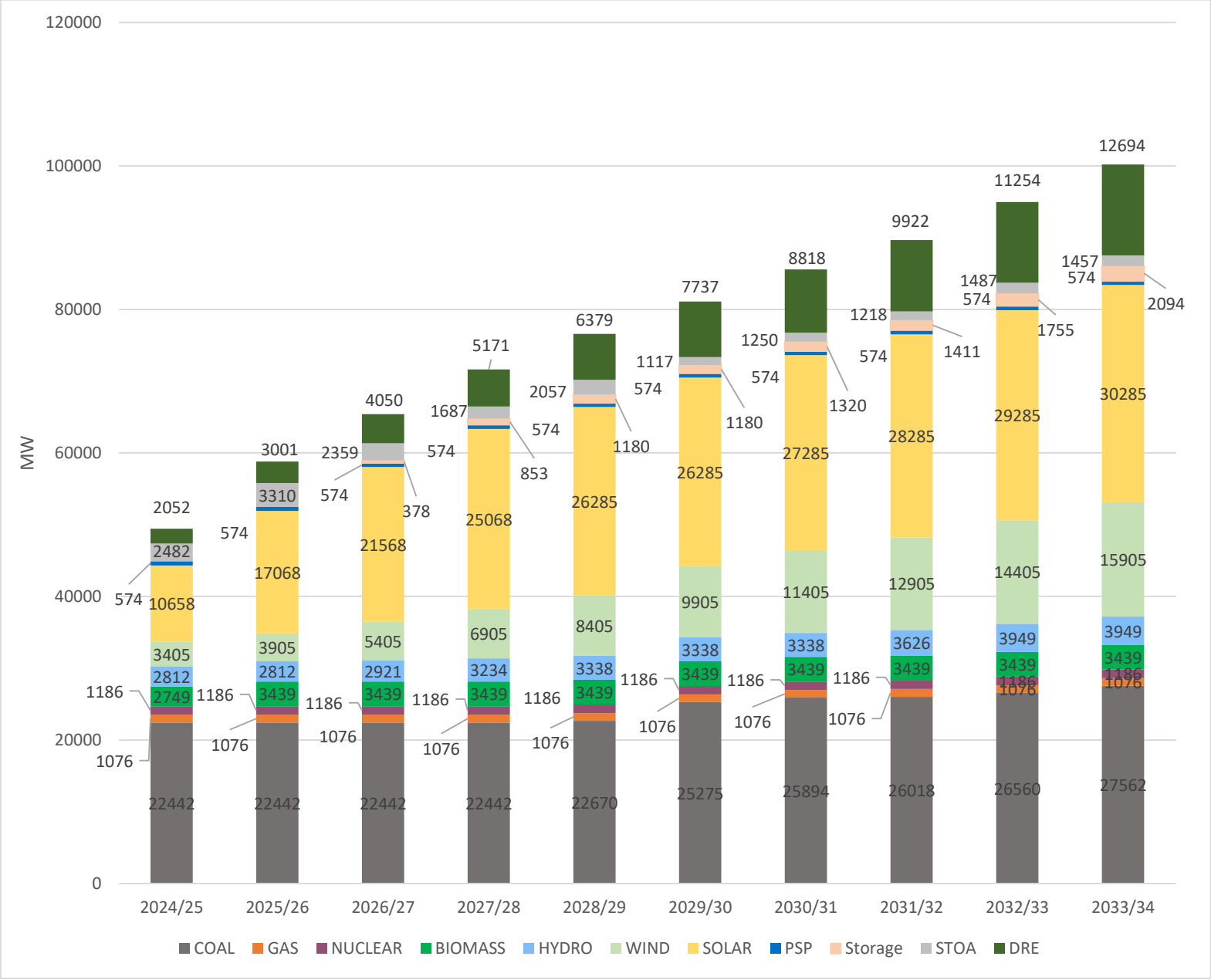


Figure 9 Projected Contracted Capacity Mix Year-wise (MW) for Maharashtra (MSEDCL)

As per the Resource Adequacy studies, the total projected contracted Capacity for the year 2033-34 is 100,222 MW which consists of 27562 MW from Coal, 1076 MW from Gas, 1186 MW from Nuclear, 3949 MW from Hydro, 15905 MW from Wind, 30285 MW from Solar, 574 MW of PSP, 2094 MW from Storage, 3439 MW from Biomass, and 1457 MW from STOA. The requirement of storage can be fulfilled either through PSP or Battery Energy Storage System. 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 Maharashtra (MSEDCL) has been assessed as 7%. In addition, the projected/contracted capacity fulfils the stipulated Renewable Purchase Obligation.

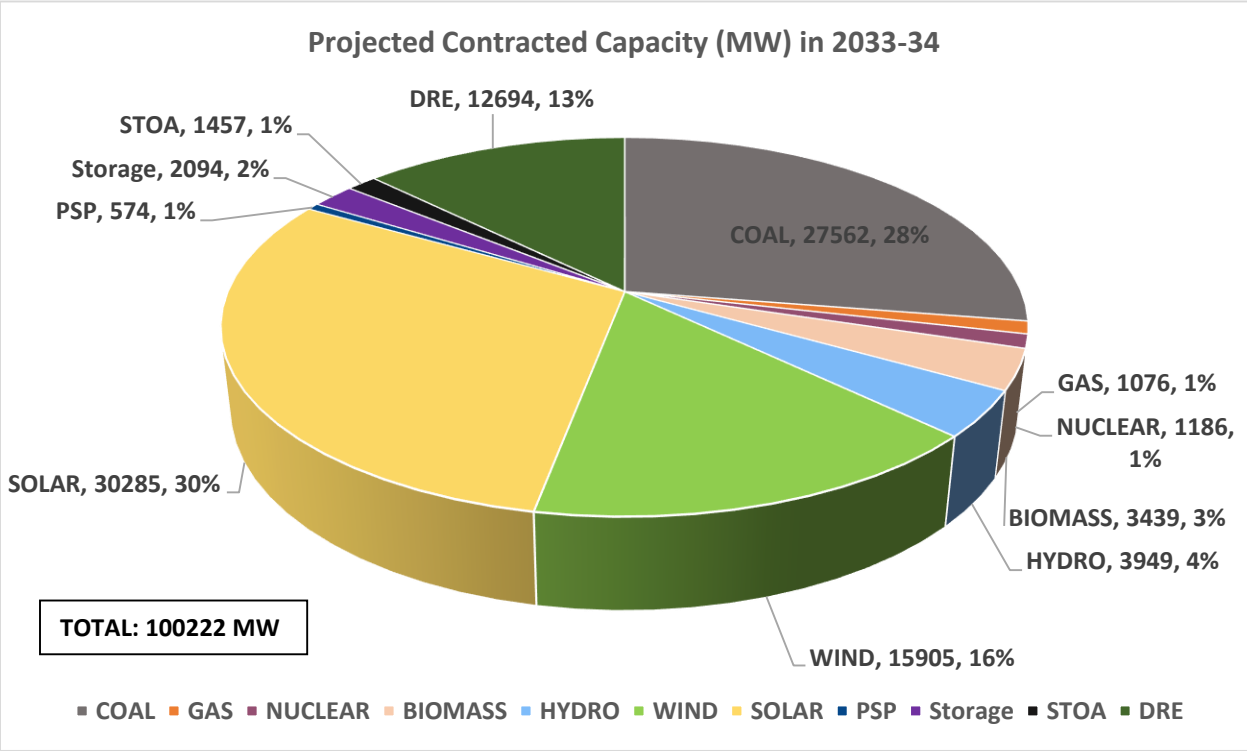
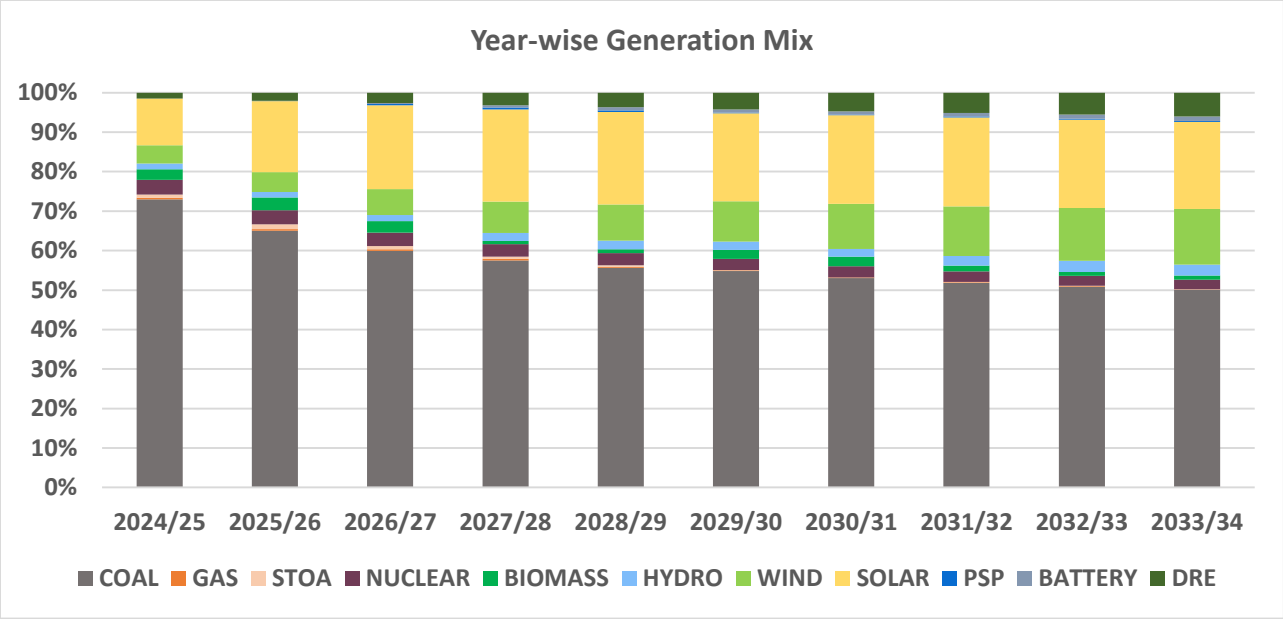
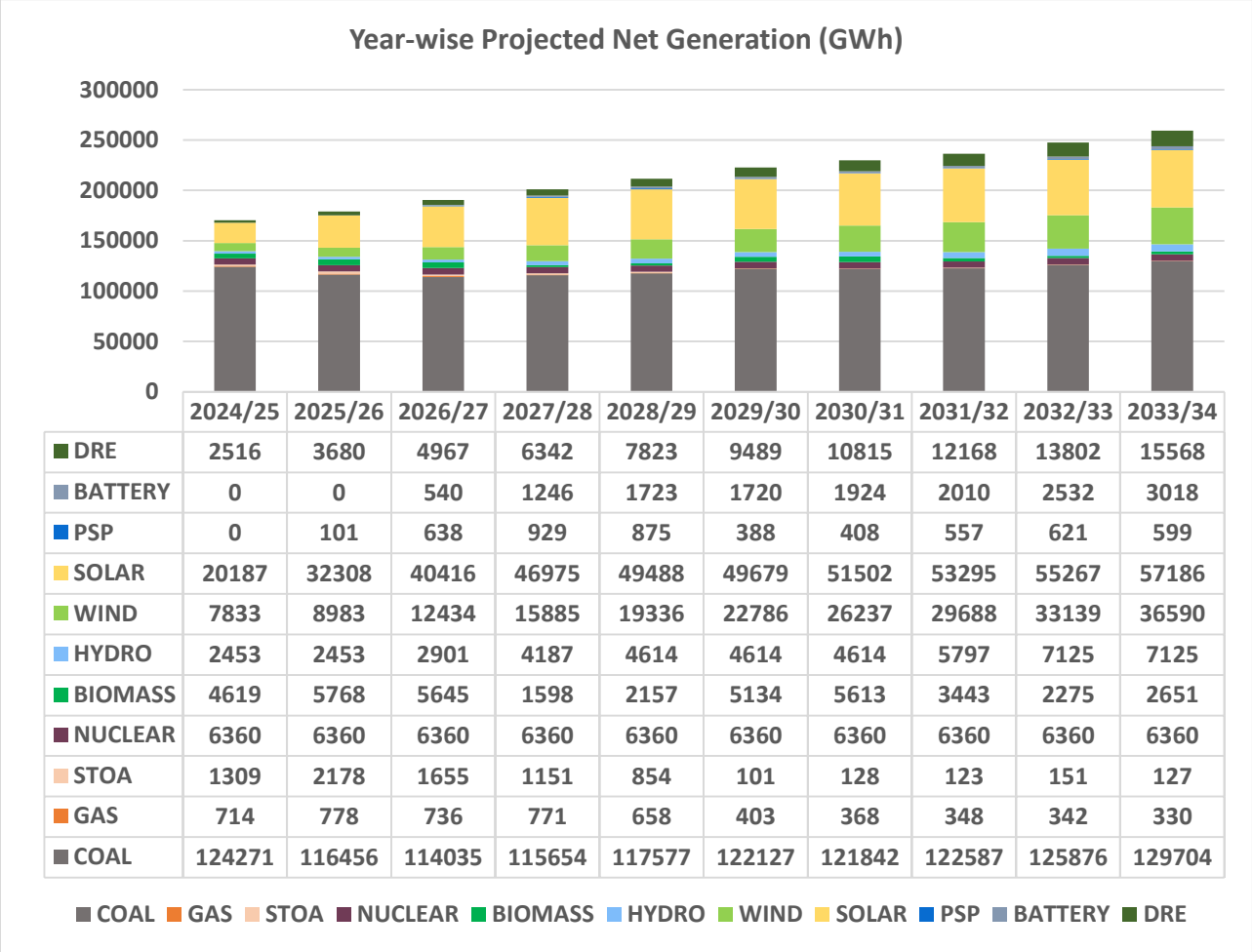


Figure 10 Contracted Capacity Mix in 2033-34 with 7% PRM

The share of non-fossil fuel-based capacity in the generation mix is projected to increase to around 68 % by 2033-34 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
DRE	2516	3680	4967	6342	7823	9489	10815	12168	13802	15568
BATTERY	0	0	540	1246	1723	1720	1924	2010	2532	3018
PSP	0	101	638	929	875	388	408	557	621	599
SOLAR	20187	32308	40416	46975	49488	49679	51502	53295	55267	57186
WIND	7833	8983	12434	15885	19336	22786	26237	29688	33139	36590
HYDRO	2453	2453	2901	4187	4614	4614	4614	5797	7125	7125
BIOMASS	4619	5768	5645	1598	2157	5134	5613	3443	2275	2651
NUCLEAR	6360	6360	6360	6360	6360	6360	6360	6360	6360	6360
STOA	1309	2178	1655	1151	854	101	128	123	151	127
GAS	714	778	736	771	658	403	368	348	342	330
COAL	124271	116456	114035	115654	117577	122127	121842	122587	125876	129704

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 Maharashtra (MSEDCL) 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 Maharashtra (MSEDCL) (in MW)

FY	Thermal		Nuclear	Hydro		SOLAR		Wind		Biomass	Storage (4 Hours)	Yearly STOA	DRE	Total	
	Planned	Additional	Planned	Planned	Additional	Planned	Additional	Planned	Additional	Planned	Additional	Additional	Additional	Planned	Additional
2024/25	1660*	0	223	183	0	4943	0	500	0	76	0	2482	2052	**7585**	**4534**
2025/26	0	0	0	0	0	6410	0	500	0	690	0	3310	949	**7600**	**4259**
2026/27	0	0	0	109	0	4000	500	0	1500	0	378	2359	1049	**4109**	**5786**
2027/28	0	0	0	313	0	3000	500	0	1500	0	475	1687	1121	**3313**	**5283**
2028/29	228	0	0	104	0	717	500	0	1500	0	327	2057	1208	**1049**	**5592**
2029/30	3564	42	0	0	0	0	0	0	1500	0	0	1117	1358	**3564**	**4017**
2030/31	0	619	0	0	0	0	1000	0	1500	0	140	1250	1081	**0**	**5590**
2031/32	0	124	0	288	0	0	1000	0	1500	0	91	1218	1103	**288**	**5036**
2032/33	0	542	0	323	0	0	1000	0	1500	0	344	1487	1332	**323**	**6205**
2033/34	0	1002	0	0	0	0	1000	0	1500	0	339	1457	1440	**0**	**6738**
Total	**5452**	**2329**	**223**	**1320**	**0**	**19070**	**5500**	**1000**	**12000**	**766**	**2094**		**12693**	**27831**	

5.4 Coal Capacity Performance

The coal capacity PLF is expected to remain in the range of 85%- 72% for the years till 2033-34 ensuring efficient utilization of coal resources and higher absorption of higher renewable energy.

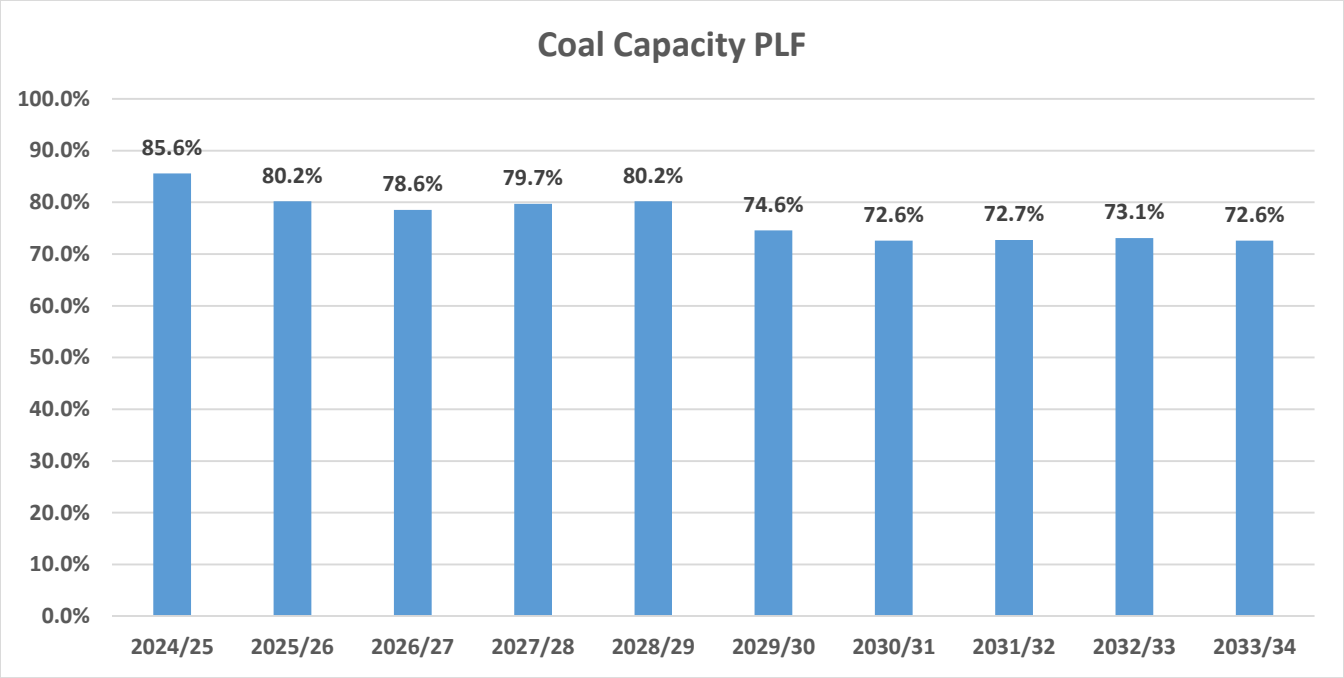


Figure 12 Year-wise coal capacity PLF for Maharashtra (MSEDCL) (in %)

5.5 Day-wise Surplus Capacity Maharashtra (MSEDCL) (MW)

Surplus capacity is available with states due to RE availability, Demand variation etc. The pattern of surplus capacities for Maharashtra (MSEDCL) 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. Maharashtra (MSEDCL) has likely surplus capacity available during the months from June to October (tentatively) in the range of 1500-12500 MW for 2024-25 as shown below) which can be shared with other states.

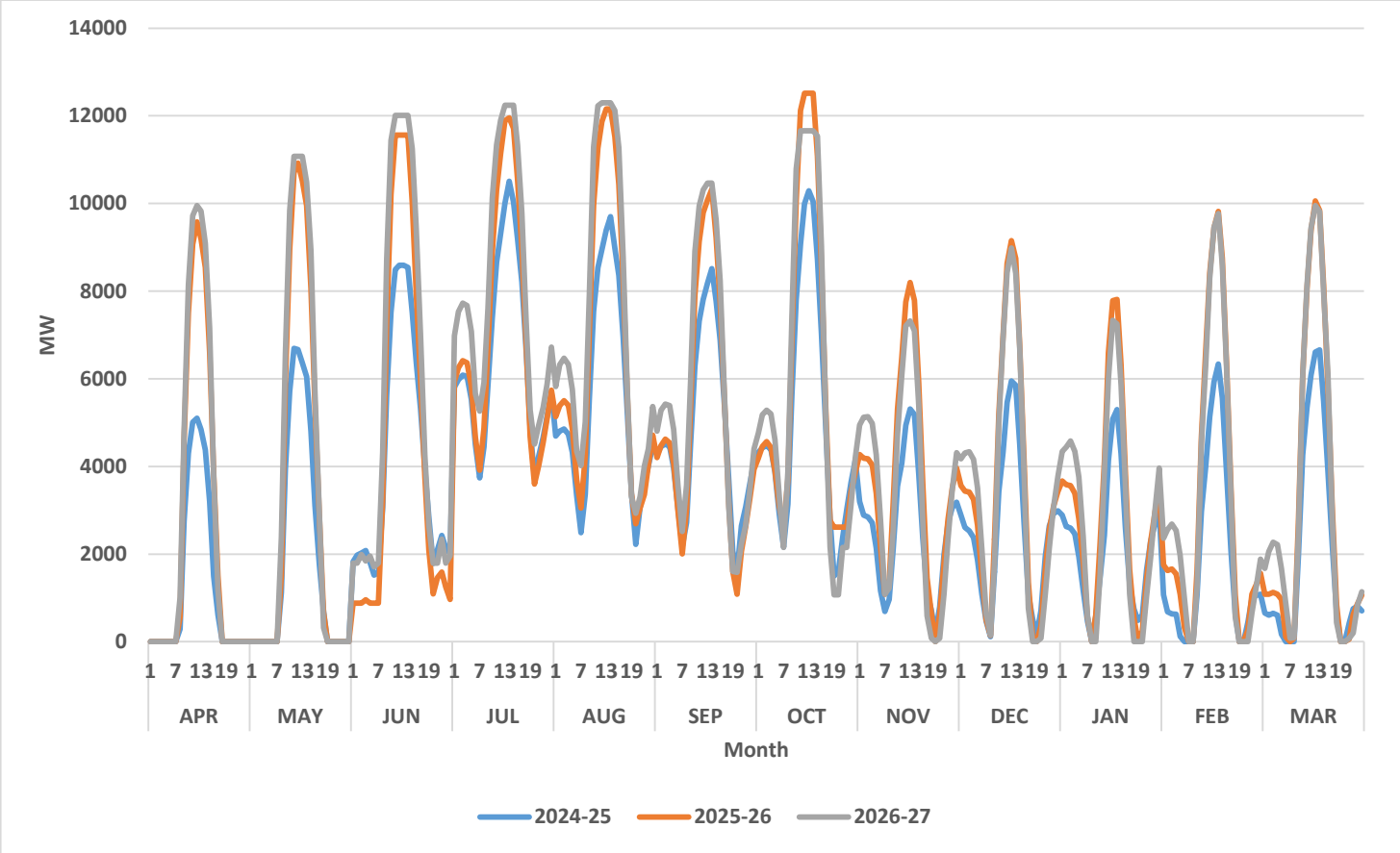


Figure 13 Surplus Coal Capacity Year-wise (MW)

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 Maharashtra (MSEDCL).
- 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

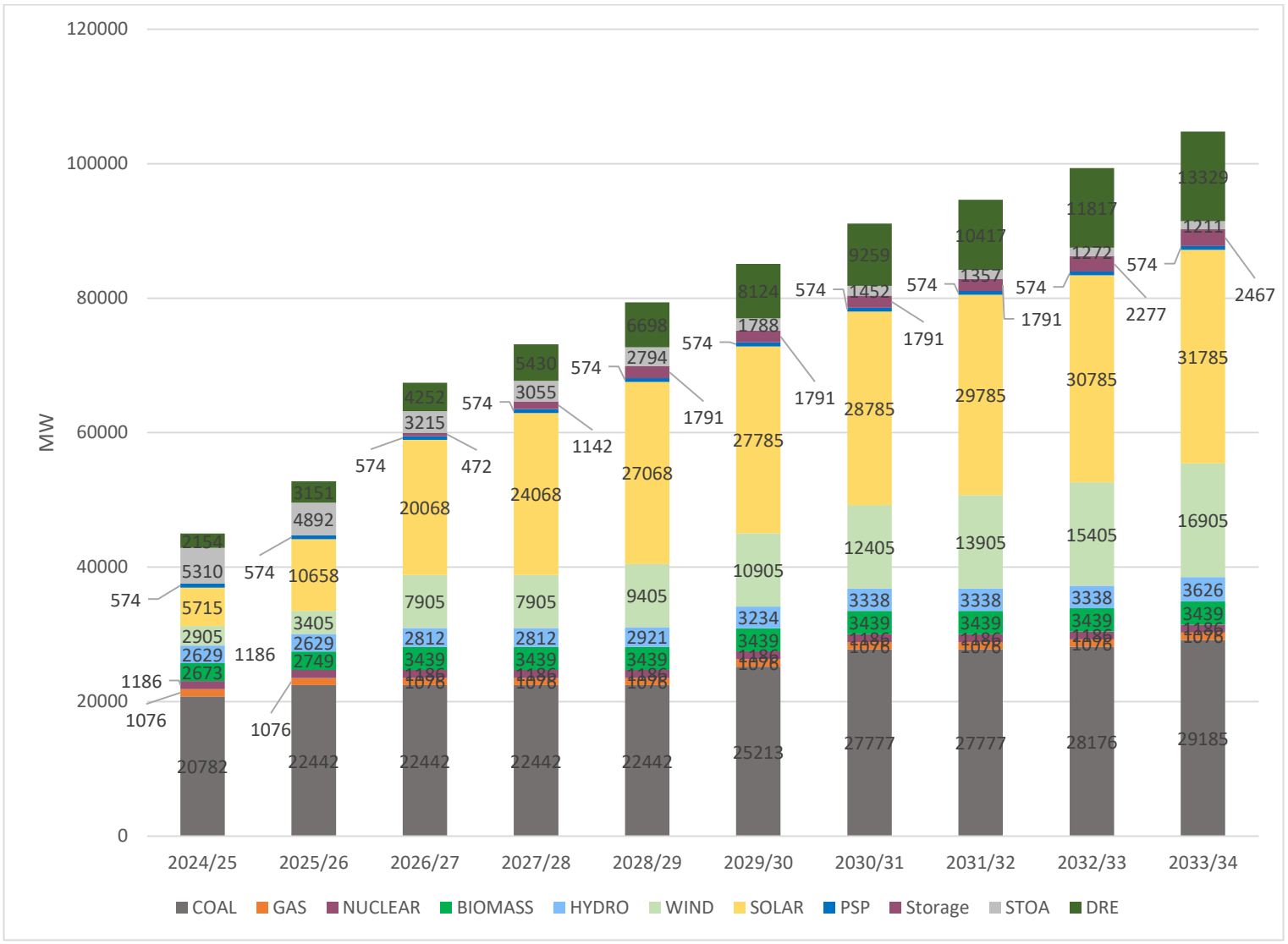


Figure 14: Year-wise capacity projections (in MW) for Alternate Resilient Scenario

In this scenario, Coal requirement is increased by around 1623 MW, Storage requirement increases by around 373 MW, Solar requirement increases by around 1500 MW, Wind requirement increases by around 1000 MW compared to the base case in terminal year 2033-34.

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 1600 -2100 MW starting from year 2029-30 and STOA requirement may further increase by 100 -1830 MW starting from year 2025-26 .

7.0 Conclusion

The study has considered two scenarios Base case and Alternate resilient scenario for assessing the resource adequacy of Maharashtra (MSEDCL) based on the demand projections provided by Maharashtra (MSEDCL). The following conclusions can be drawn based on the studies: -

- The demand projections by MSEDCL are comparable to the demand projections by 20th Electric Power Survey (EPS).
- The current capacity mix in Maharashtra (MSEDCL) has 62% of IC from fossil fuel sources. The peak demand season is winter months from November to May. The study is based on the hourly load pattern of the year 2022-23.
- Maharashtra (MSEDCL) is likely to witness energy deficit ranging from 977 MUs to 10397 MUs in different years from 2024-25 to 2033-34 with the existing and planned capacity addition. Maharashtra (MSEDCL) 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.
- Maharashtra (MSEDCL) is likely to have unserved energy in coming years and need to contract non-fossil capacities for meeting energy requirements other than the planned capacities. The additional quantum of capacities required (other than already plan) to be contracted is about 2329 MW from Coal,5500 MW from solar, 12000 MW from Wind, 2094 MW of storage (4 Hours),12694 MW from DRE till 2033-34.
- The storage requirement can be either met from BESS and PSP depending on the availability of the capacity and associated contracts.
- 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 85%- 72% for the years till 2033-34 ensuring higher absorption of higher renewable energy.

- The Alternate Resilient Scenario carried out for Maharashtra (MSEDCL) has revealed that the Coal requirement is increased by around 1623 MW, Storage requirement increases by around 373 MW, Solar requirement increases by around 1500 MW, Wind requirement increases by around 1000 MW compared to the base case in terminal year 2033-34.
- It is likely that Maharashtra (MSEDCL) may have surplus capacity available during the months from June to October (tentatively in the range of 1500-12500 MW for 2024-25) which can be shared with other states.

Annexure-I

Future Contracted/Approved Capacity (MW) of Central and State Sector (Thermal, Hydro, Nuclear)

SR. NO	POWER PLANT	MSEDCL'S SHARE (MW)	TYPE OF GENERATION	EXPECTED COD/ REMARK
1	NTPC LARA C'GAD STAGE 02, UNIT 1&2	228	THERMAL	FY 2028-29
2	BHUSAWAL UNIT 6	660	THERMAL	FY 2024-25
3	KOARDI UNIT-11 & 12	1320	THERMAL	FY 2029-30
4	SIPAT PROJECT, STAGE – III	264	THERMAL	FY 2029-30
5	MBPL	480	THERMAL	FY 2029-30
6	MEDIUM TERM (UNDER SHAKTI B(V))- MOP FOR 5 YEARS	1000	THERMAL	APR-2024 TO MAR-2029
7	LONG TERM (UNDER SHAKTI B(V)) – MOP	1500	THERMAL	APR-2029 ONWARDS
8	KAPS UNIT 4	223.1	THERMAL	FY 2024-25
9	SUBANSARI HYDRO ELECTRIC PROJECT	183	HYDRO	FY 2024-25
10	PAKALDUL HEP	100	HYDRO	FY 2027-28
11	RATLE HYDROELECTRIC PROJECT	213	HYDRO	FY 2027-28
12	KWAR HEP	54	HYDRO	FY 2028-29
13	DUGAR HE PROJECT	50	HYDRO	FY 2028-29
14	KIRU HE PROJECT	109	HYDRO	FY 2026-27
15	DIBANG MULTIPURPOSE PROJECT	288	HYDRO	FY 2031-32
16	SAWALKOT HE PROJECT	323	HYDRO	JULY-2032
	TOTAL	**6995.1**		

Assumption for Resource Adequacy Studies for the state of Maharashtra (MSEDCL)

1. Electricity Demand & peak requirement: As per demand projections provided by Maharashtra (MSEDCL).
2. Demand Profile: Based on hourly demand profile of 2022-23
3. Existing & Planned Capacity: As per the information received from MSEDCL
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.