Report on
Resource adequacy plan
For the state of
Meghalaya
(2024-25 to 2031-32)

GOVERNMENT OF INDIA
MINISTRY OF POWER
CENTRAL ELECTRICITY AUTHORITY

Executive Summary

The electricity demand for the State of Meghalaya is increasing with a CAGR of 2.9 % from 2023-24 to 2031-32, as forecasted by 20th EPS. For satisfying resource adequacy i.e., meeting the electricity demand reliably and at affordable cost, the State needs to methodically plan its capacity expansion either by investing or by procuring power. Given the reduction in the 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 that the future generation capacity mix is cost-effective as well as environment friendly.

The electricity demand dynamics in Meghalaya are significantly influenced by sectoral allocations, with 39% dedicated to industrial usage, 34% for domestic consumption, 6% in commercial applications, and the remaining 21% for various other purposes. This sectoral distribution leads to distinctive patterns in the demand profile. Notably, the peak demand period spans from November to February. During these months, the electricity demand substantially exceeds that of the rest of the year. In contrast, the lowest demand is consistently observed in June. From June to September, the demand remains notably low compared to the other months, emphasizing the seasonality and varying requirements throughout the year.

Ministry of Power had notified 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, Central Electricity Authority is entrusted to prepare Long Term-National Resource Adequacy Plan (LT-NRAP). Further Distribution Utility need to carry out LT-DRAP (Long term Distribution Licensee Resource Adequacy Plan) to meet the utility peak and energy requirement reliably.

The Government of India has recently notified a new Renewable Purchase Obligation (RPO) trajectory till 2029-30, which ensures a certain amount of energy consumption to be met from renewable energy sources. While carrying out the RA Studies, it was ensured that RPO is met.

The resource adequacy studies to assess the hourly generation dispatch with the existing and planned capacity have been carried out upto 2031-32 for the State of Meghalaya based on data available with CEA and data received from NERLDC and NERPC due to the absence of inputs from the state of Meghalaya. It was found that the state's existing contracted capacity, along with capacity addition plans for conventional and renewable energy sources, may not be adequate to meet projected demand.

To find out the least cost option for generation capacity expansion for the period 2023-24 to 2031-32, a long-term study for the State of Meghalaya was carried with an objective of minimizing 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.

Reliability analysis was also carried out with varying demand, RE Generation and forced outage of coal-based capacities. Based on the study, the likely contracted capacity of Meghalaya is 1033 MW, comprising 243 MW from Coal, 130 MW from Gas, 566 MW from Hydro, and 14 MW from Biomass. Besides this, Meghalaya needs 80 MW from STOA contracts in order to meet its demand reliably.

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 studies has been carried out for Meghalaya based on data available with CEA and data received from NERLDC and NERPC and to fulfill the RPO trajectory. The study suggests the optimal resource mix till 2032 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 Meghalaya for catering to the above highlighted uncertainties so that demand can be met reliably throughout the year.

2.0 Meghalaya RA Study

2.1 Present Power Scenario in Meghalaya

As of March 2023, the total contracted capacity for Meghalaya is 679 MW. Out of the total contracted capacity (CC), the share of non-fossil fuel-based CC is 76 %.
The fuel-wise contracted capacity as of 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	35	5
Gas	130	19
Hydro	500	74
Bioenergy	14	2
Total	679	100

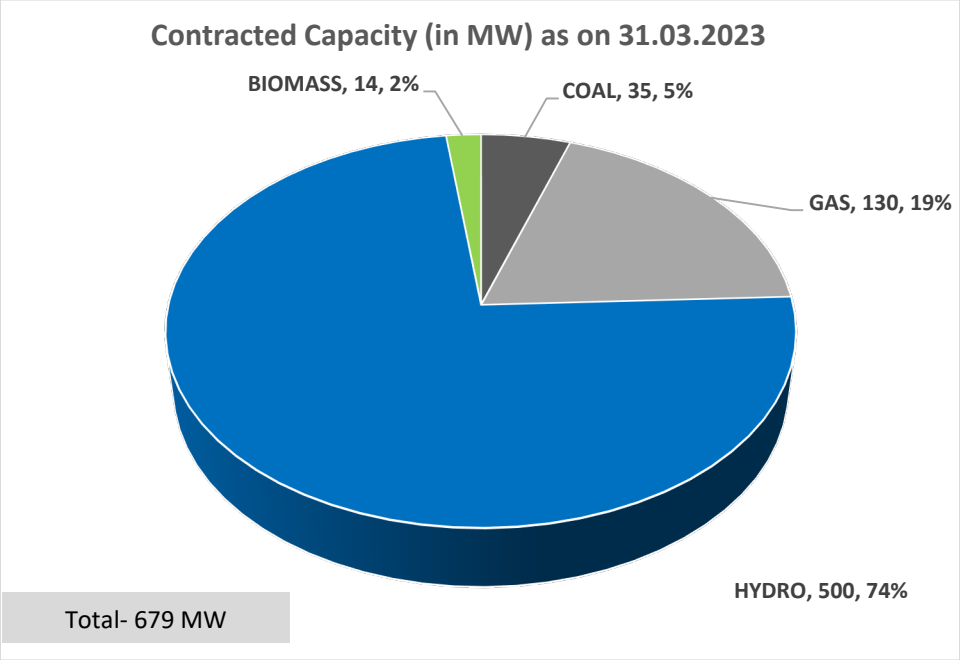


Figure 1 Fuel-wise Contracted Capacity (in MW) as on Mar 2023

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 Meghalaya is during the months of November, December, January, and February. The

hourly demand pattern generally remains similar for all the months. Meghalaya witnesses morning and evening peak demand. The Demand from April to October remains significantly low compared to other months, reflecting the effect of seasonality in demand.

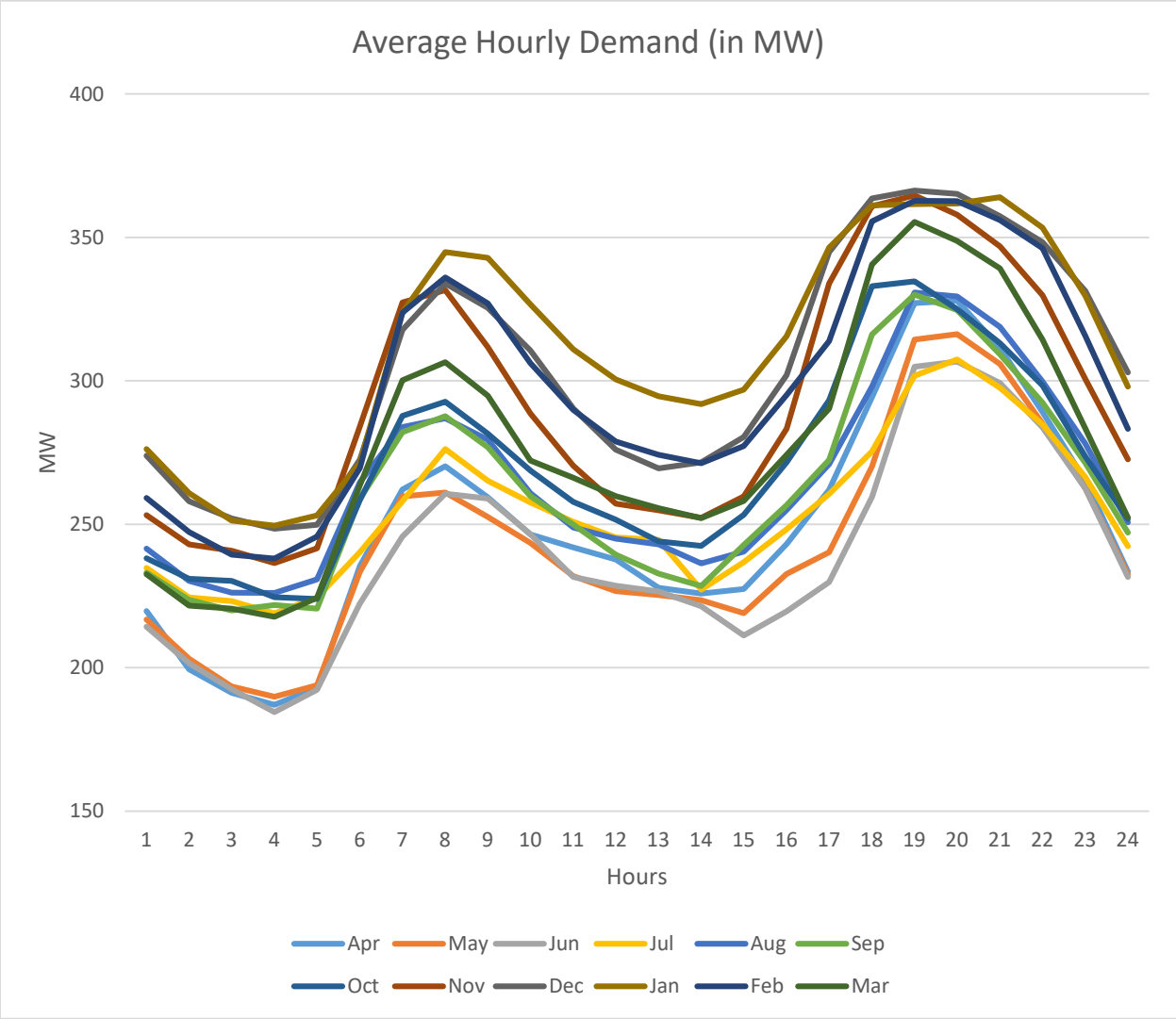


Figure 2 Average Hourly Demand Profile (MW)

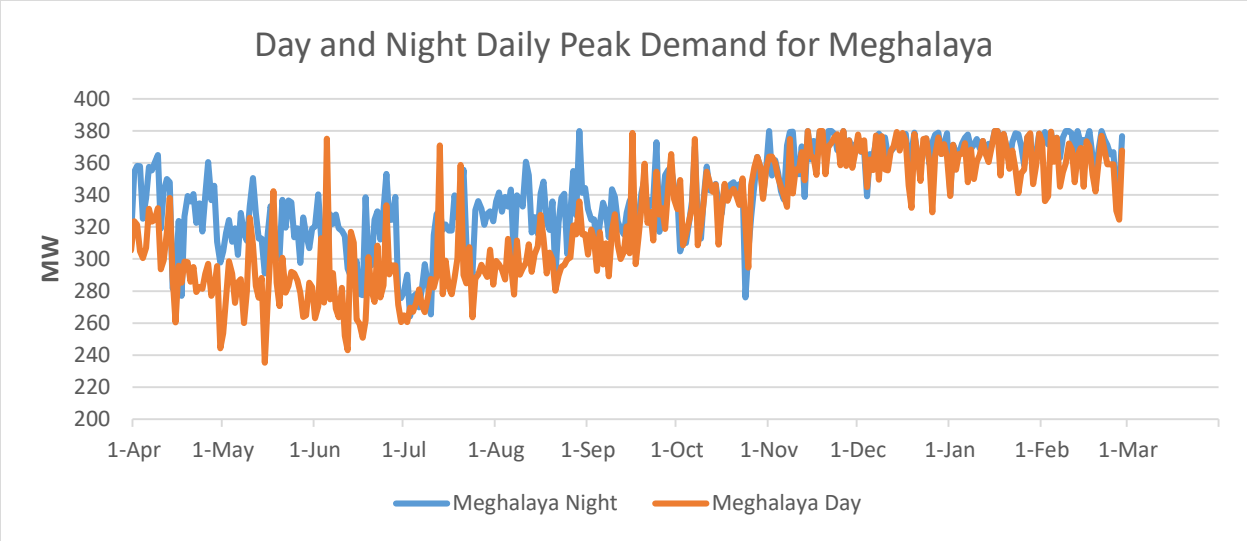


Figure 3 Day and Night Peak in MW of Meghalaya (2022-23)

3.0 Inputs/Assumptions for the Study

i) Peak and Energy Demand for Meghalaya has been taken as per 20th EPS Projections.

Table 2 Future Demand Projection by 20th EPS

	2023-24	**2024-25**	**2025-26**	**2026-27**	**2027-28**	**2028-29**	**2029-30**	**2030-31**	**2031-32**
Energy Projections (MU)	2437	2527	2618	2711	2805	2898	2993	3067	3134
Year on Year Growth	-	3.7%	3.6%	3.6%	3.5%	3.3%	3.3%	2.5%	2.2%
Peak Demand Projections (MW)	441	457	474	492	510	528	546	561	575
Year on Year Growth	-	3.6%	3.7%	3.8%	3.7%	3.5%	3.4%	2.7%	2.5%

ii) The future hourly demand profile for 2031-32 has been projected using the hourly demand profile for 2022-23 as the base profile.

iii) The actual hourly solar and wind generation profiles and CUFs, as available with CEA, have been considered for the Study as no data was submitted by Meghalaya.

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

v) Existing & Planned Capacity: No planned capacity has been considered due to absence of any inputs from Meghalaya, and only hydro capacity of 65.5 MW has been considered during the period 2023-24 and 2024-25 based on the data available with CEA.

vi) RPO trajectory: In order to meet its Renewable Purchase Obligation (RPO), as per RPO trajectory notified by the Ministry vide order dated 22nd July, 2022, Meghalaya's requirement to add/contract additional renewable capacity (MW) has been assessed as below.

Table 3 Total Energy required to meet RPO (MU) as per MoP order dated 22.07.2022

	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30
Wind	39	62	88	116	147	179	208
Hydro	16	27	39	49	60	73	84
Other RPO	605	666	737	810	882	947	1005

Table 4 Generation eligible for RPO (MU) as per existing and planned capacity addition*

	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30
Wind	0	0	0	0	0	0	0
Hydro	147	318	318	318	318	318	318
Other RPO	1590	1590	1590	1590	1590	1590	1590

Table 5 Surplus/Shortfall (-) in RPO Generation considering Fungibility for Wind RPO (MU)

	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30
Wind	0	0	0	0	0	0	0
Hydro	92	229	191	153	111	66	26
Other RPO	985	924	853	780	708	643	585

Additional capacity to be contracted by Meghalaya to meet RPO is given below:

Table 6 As per RPO trajectory, Meghalaya needs to add/contract following additional capacity (MW).

	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	Total
Wind	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Large + Small Hydro	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Solar + Other RE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**

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.

In addition to the above two metrics, the Planning Reserve Margin (PRM) is a predominant metric used to ensure adequacy of generation resources in the system. PRM in a power system is expressed as certain percentage of peak load forecast of the system.

4.1 Demand variation:

The reliability study in the current case has been carried out by varying the projected hourly demand for the future years by varying ±5% by introducing a random variable (with normal distribution) for demand as per the observed behaviour over the years.

4.2 RE variation

In the long-term capacity expansion planning studies, a particular profile for Solar and Wind Plants is considered based on the observed solar and wind generation data to determine the optimal capacity mix. However, due to the intermittent nature of these sources, the generation from these non-dispatchable sources may vary across years. In the absence of any data from the state of Meghalaya, solar generation and wind generation have been varied by ±10%, to incorporate the variation in these generation sources and plan for requisite measures to mitigate such behaviour.

4.3 Forced Outage of Thermal Generators

The forced outage rate of thermal generators of Meghalaya was observed for previous years, and it was observed that the average forced outage rate is typically at 10% with ±5% variation. The same has been incorporated into the model.

Based on the variation, reliability studies are carried out to ascertain the robustness of the system. The LOLP & EENS of the system are within the 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 2031-32 is about 784 MU. The yearly likely unserved energy with the planned capacities is given below.

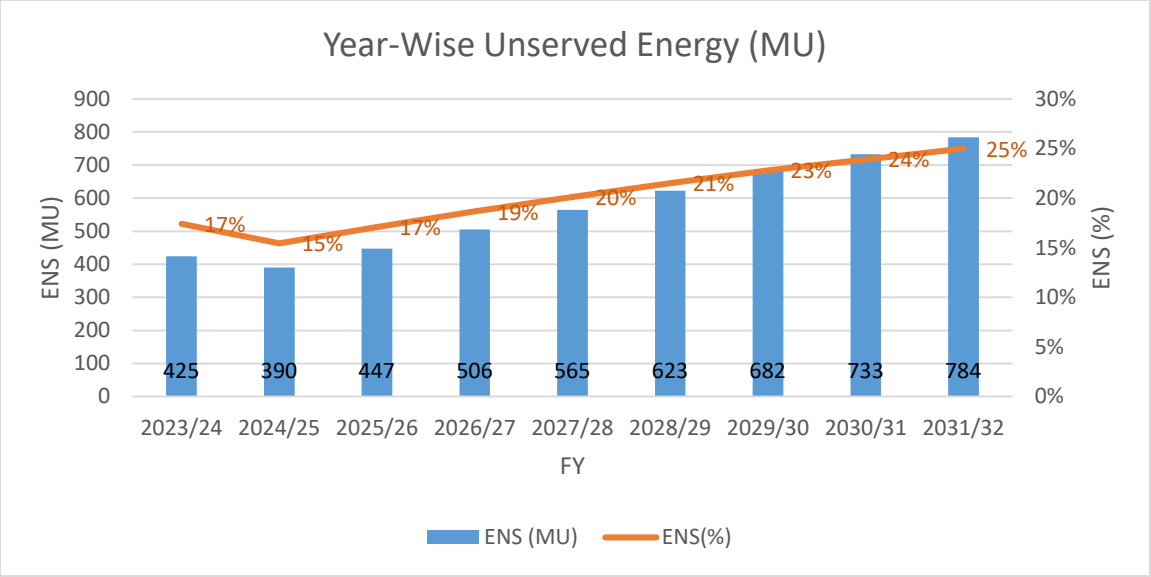


Figure 4 Yearly likely unserved energy with the planned capacities for Meghalaya (in MU)

The study has also analyzed the Daily and monthly pattern of unserved energy in the year 2031-32, it can be seen that the unserved energy coincides with peak demand months when the contracted capacity (present and planned) is unable to meet the demand.

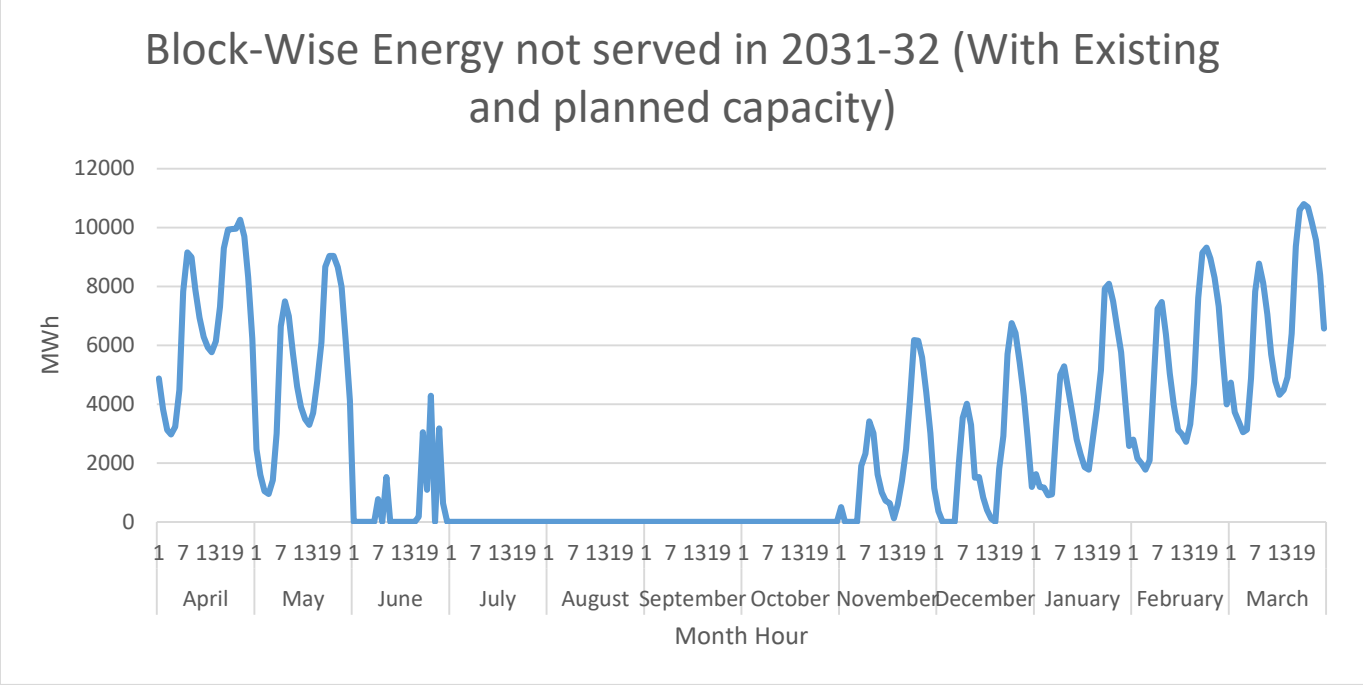


Figure 5 Daily Unserved Energy Pattern MU (2031-32)

5.2 Capacity Mix Projection

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

i) There is a requirement for coal from 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 Meghalaya are given below:

Table 7 Year-wise capacity projections (in MW)

	COAL	GAS	BIOMASS	HYDRO	WIND	SOLAR	STORAGE (6 Hours)	STOA
2023/24	35	130	14	517	0	0	0	152
2024/25	35	130	14	566	0	0	0	152
2025/26	35	130	14	566	0	0	0	165
2026/27	168	130	14	566	0	0	0	70
2027/28	182	130	14	566	0	0	0	74
2028/29	195	130	14	566	0	0	0	77
2029/30	211	130	14	566	0	0	0	78
2030/31	223	130	14	566	0	0	0	80
2031/32	243	130	14	566	0	0	0	80

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

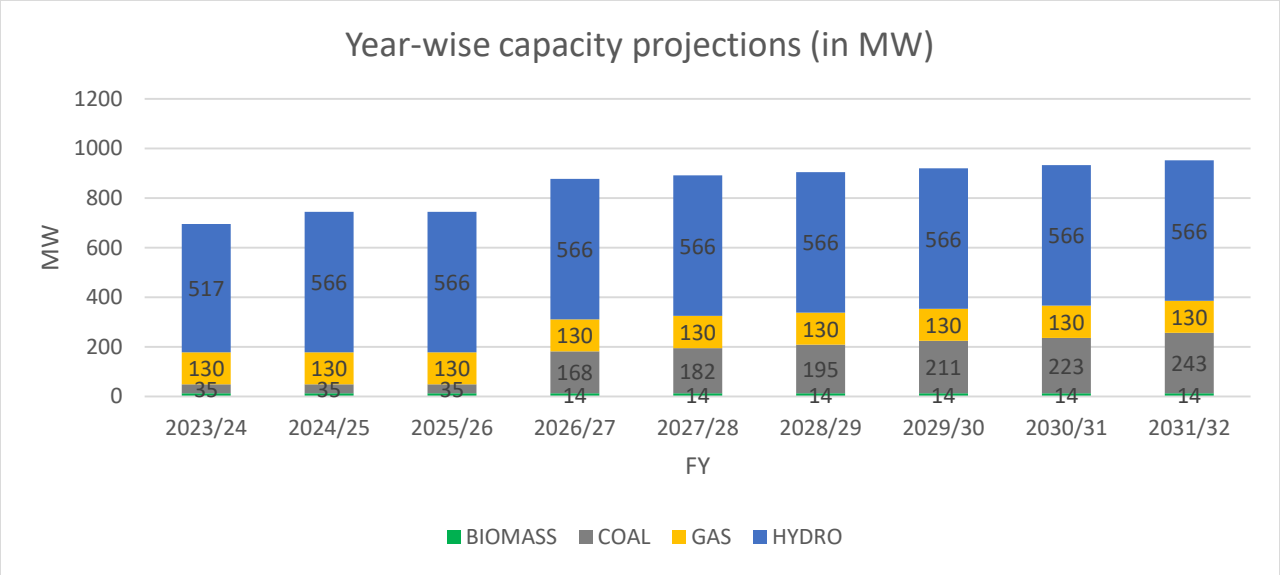


Figure 6 Projected Capacity Mix Year-wise (MW) for Meghalaya

As per the Resource Adequacy studies, the total projected Capacity for the year 2031-32 is 953 MW, which comprises 243 MW from Coal, 14 MW from Biomass, 566 MW from Hydro. This CC 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 Meghalaya has been assessed as 19.1%. In addition, the projected/contracted capacity fulfils the stipulated Renewable Purchase Obligation.

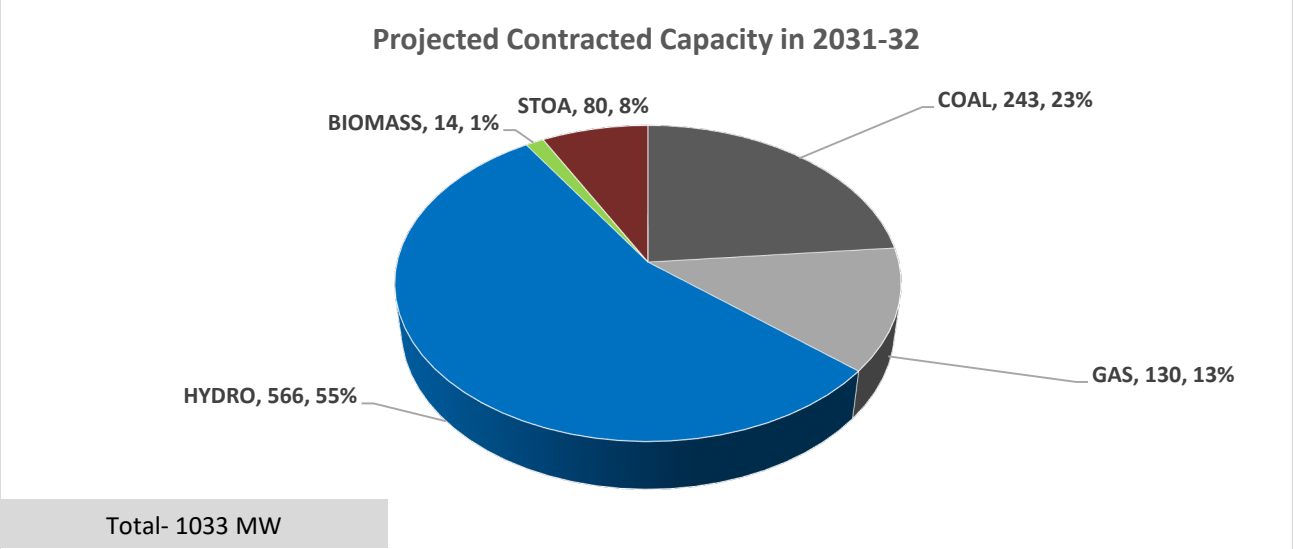
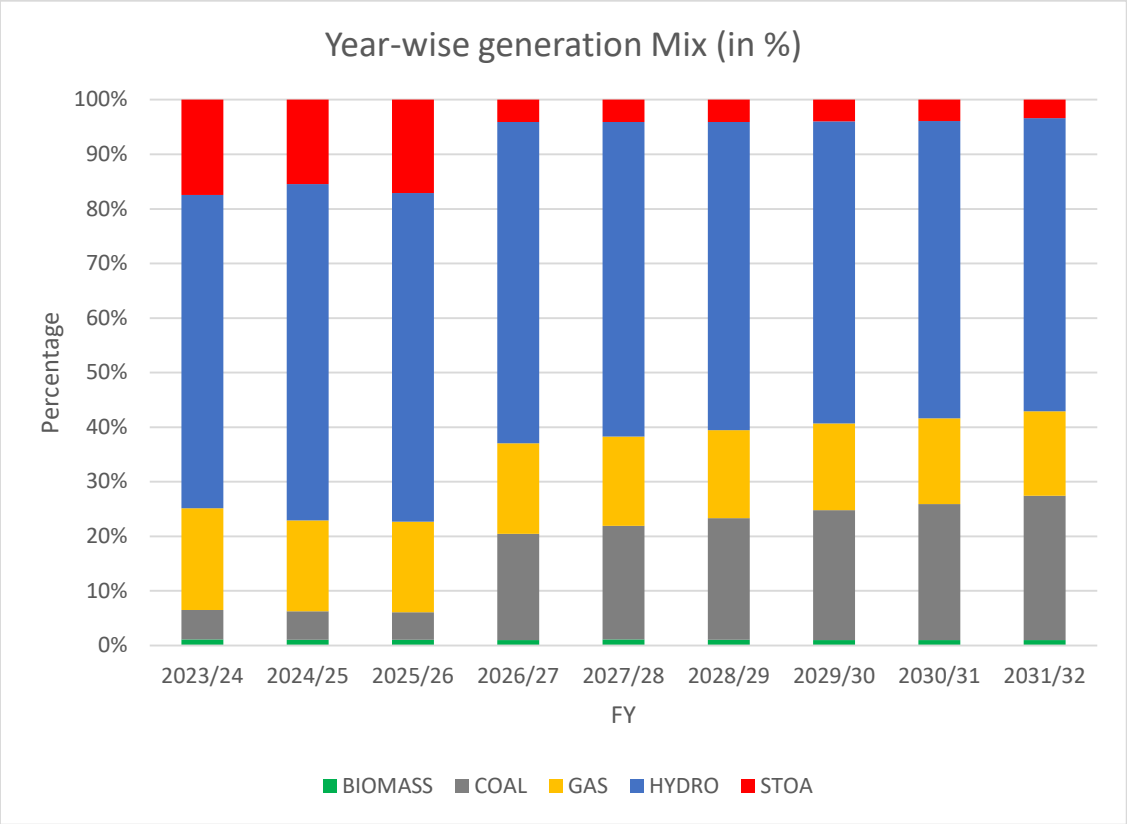


Figure 7 Contracted Capacity Mix in 2029-30 with 19.1% PRM

The share of non-fossil fuel-based capacity in the total contracted capacity is projected to decrease to around 61% in 2032 from 77 % in 2022-23 with due to increase in requirement of coal based capacity to meet its demand. The contribution of STOA or dependence on market in the generation mix for meeting the peak demand requirement is in the range of 15.1-31.9% in different years till 2032.



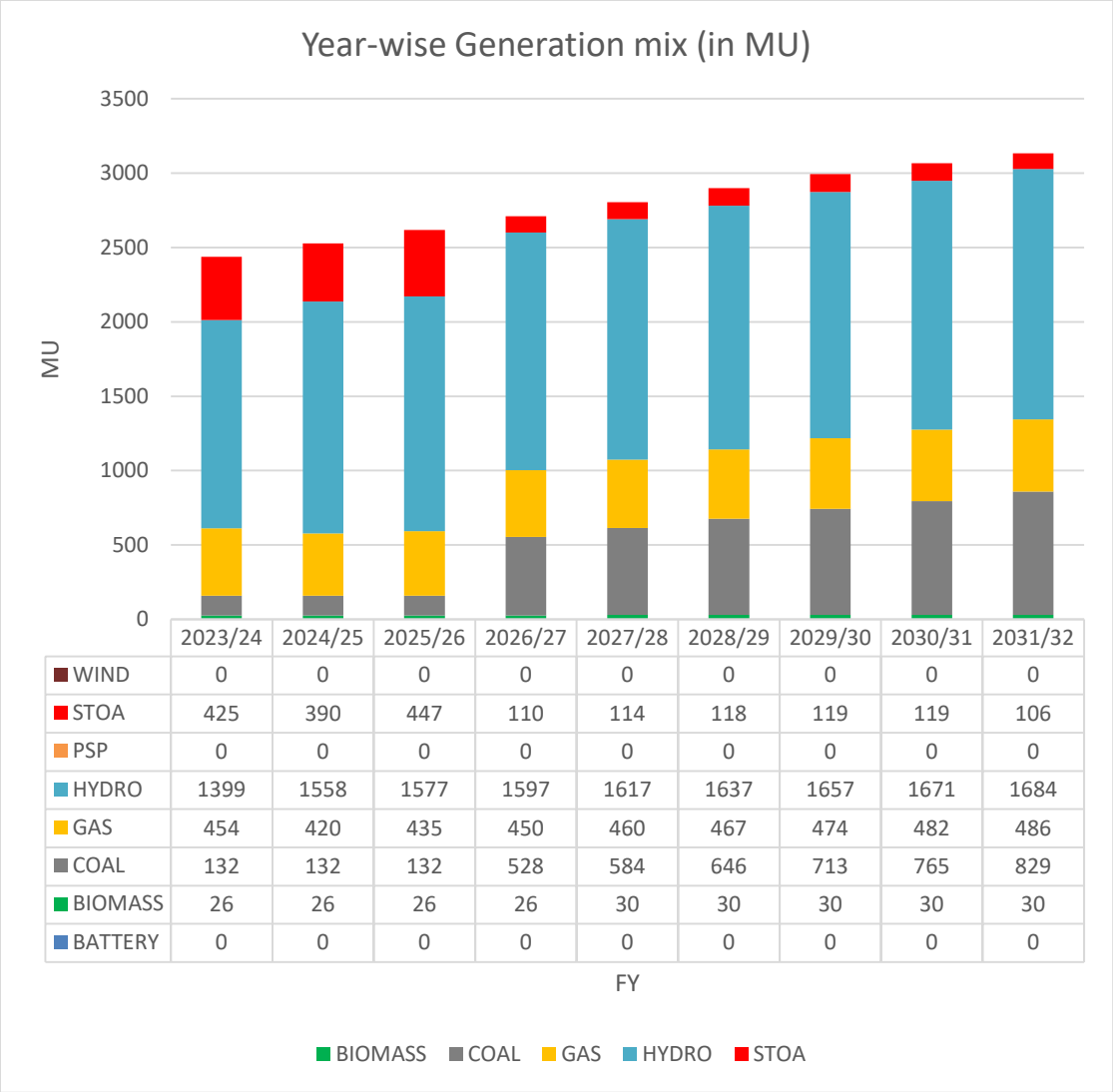


Figure 8 Year-wise projected generation mix (in MU)

5.3 Day-wise Surplus Capacity Meghalaya (MW)

The pattern of surplus capacities has been observed as below. Available Surplus capacity can be due to seasonal variation of demand wherein the demand in the months from May to December is significantly lower as compared to other months of the year. This capacity can be shared with other states, thereby reducing the fixed cost burden on the utilities resulting in reduction in the cost for consumer. Meghalaya has likely surplus capacity available during the months from June to October (tentatively in the range of 26-140 MW for different years as shown below) which can be shared with other states.

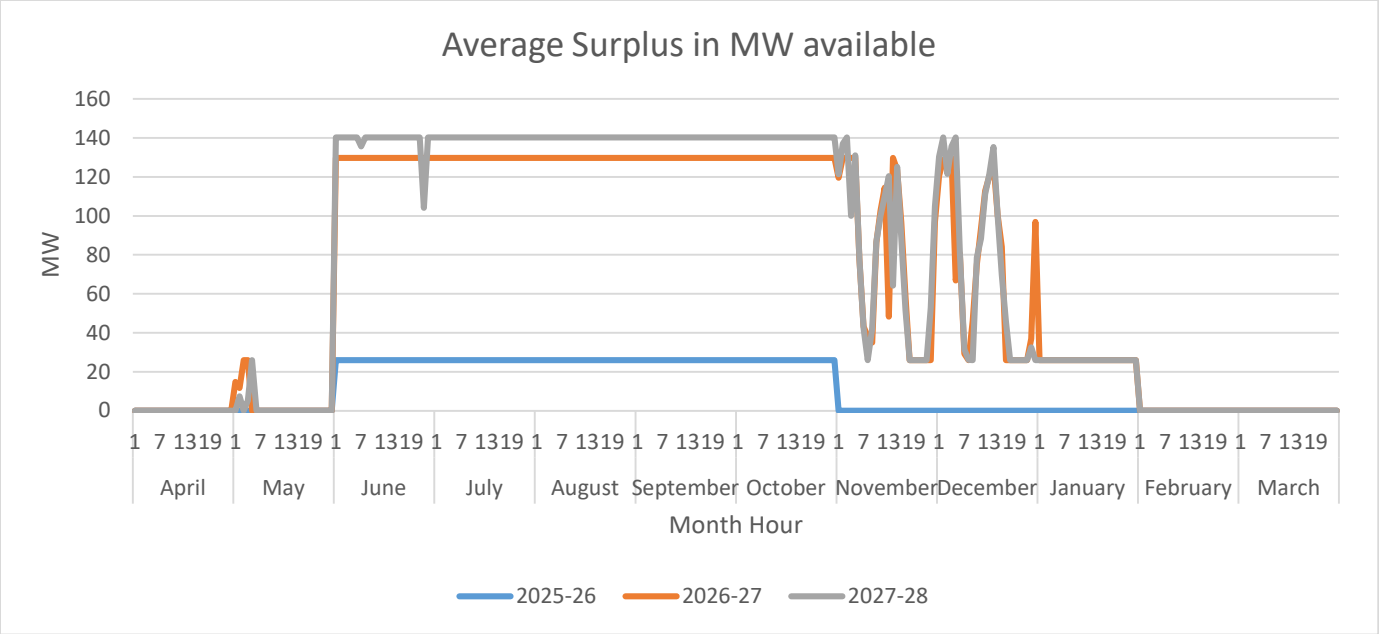


Figure 9 Surplus Coal Capacity Year-wise (MW)

5.4 Coal Capacity Performance

The coal capacity PLF is expected to reduce from 43% in 2023-24 to the range of 37%- 39% for the years till 2032.

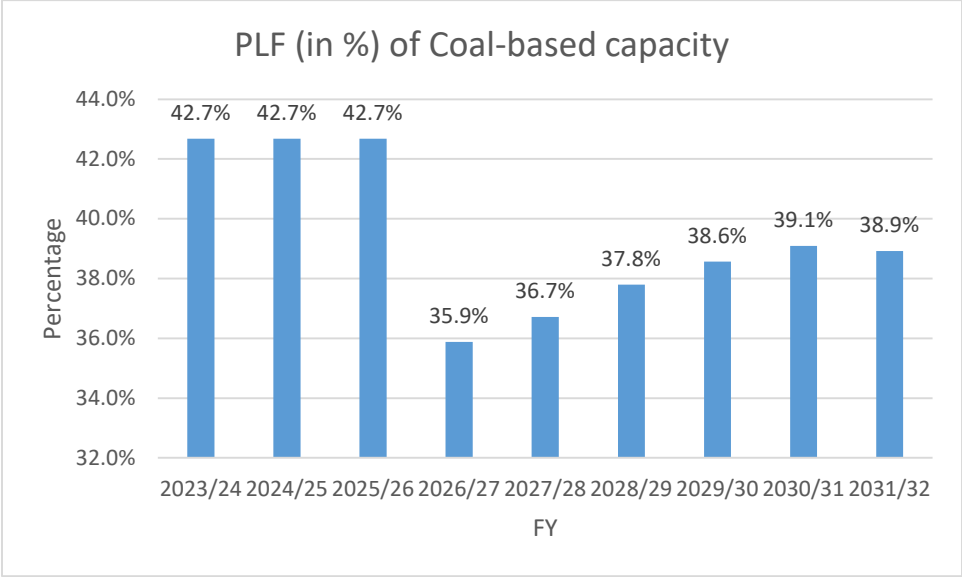


Figure 10 Year-wise coal capacity PLF for Meghalaya (in %)

6.0 Capacity contract requirement for future

It has been found out in the studies that Meghalaya 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 8 Year wise Capacity Addition for Meghalaya (in MW)

Year	COAL		HYDRO		STOA/MTOA	TOTAL	
	Planned	Additional	Planned	Additional	(NET)	Planned	Additional
2023/24	0	0	17	0	152	17	152
2024/25	0	0	49	0	152	49	152
2025/26	0	0	0	0	165	0	165
2026/27	0	133	0	0	70	0	203
2027/28	0	14	0	0	74	0	87
2028/29	0	13	0	0	77	0	90
2029/30	0	16	0	0	78	0	94
2030/31	0	12	0	0	80	0	92
2031/32	0	20	0	0	80	0	800

7.0 Conclusion

1. The study has considered demand projections of 20th EPS for assessing the resource adequacy of Meghalaya.
2. The current capacity mix in Meghalaya has 24% of contracted capacity from fossil fuel sources. The peak demand season is typically from November to February with peak demand occurring during evening time. The Demand during the months from April to October remains significantly low as compared to other months, which reflects the effect of seasonality in demand. Optimal utilisation of resources through short-term contracts like banking or STOA, as currently practised for managing the seasonal variation in demand, is one of the effective ways to ensure resource adequacy in such periods.
3. The study has been done based on the hourly load pattern of the year 2022-23.
4. Meghalaya is likely to witness an energy deficit ranging from 390 MUs to 784 MUs in different years from 2023-24 to 2031-32 with the existing and planned capacity addition. Meghalaya is surplus in fulfilment of its Renewable Purchase Obligations (RPO) and does not need to contract any renewable capacities. The projected capacity and generation mix fulfil the RPO obligations by 2030 as specified by the Ministry of Power.
5. Meghalaya is likely to have unserved energy in coming years and needs to contract coal-based capacities for meeting energy requirements other than the planned capacities, in order to meet the large quantum of unserved energy. The quantum of coal-based capacities required to be contracted is about 208 MW by the year 2031-32.
6. The energy requirement to be met from STOA is less than 5% of the total energy requirement from 2026-27 onwards but is critical in months of peak demand to fulfil the end consumer demand. STOA value reflects the peak value (MW) requirement in the capacity mix. However, in energy terms, the requirement from STOA is quite less.
7. The coal capacity PLF is expected to reduce from 43% in 2023-24 to the range of 37%-39% for the years till 2032.
8. It is likely that Meghalaya may have surplus capacity available during the months from June to October (tentatively in the range of 26-140 MW for different years, as shown below), which can be shared with other states.

Assumption for Resource Adequacy Studies for the state of Meghalaya

1. Electricity Demand & peak requirement: As per 20th EPS projections
2. Demand Profile: Based on the hourly demand profile of 2022-23.
3. Existing & Planned Capacity: As per the information regarding hydro plants available with CEA
4. Future Capacity addition: based on RPO trajectory
5. Cost parameters: based on NEP

RE CUF considered

Hydro Planned/ Existing PLF	Solar Existing/ Planned CUF	Wind Planned/ Existing CUF	Small Hydro CUF
40%/40%	40%/20%	24%/24%	17%

RPO Trajectory

	RPO Target Trajectory (%)							
	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30
Wind RPO	0.81	1.60	2.46	3.36	4.29	5.23	6.16	6.94
Hydro RPO	0.35	0.66	1.08	1.48	1.80	2.15	2.51	2.82
Other RPO	23.44	24.81	26.37	28.17	29.86	31.43	32.69	33.57

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	20	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	-	-	-	-

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
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 for the candidate capacities:

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
Solar	4.1	1 % of Capex	0.5	25
Pumped Storage	6 Cr	4 % of Capex	7	40
Battery Energy Storage (4-Hour)	5.62 Cr to 4.72 Cr	1 % of Capex	0.5	14
Battery Energy Storage (5-Hour)	6.62 Cr to 5.51 Cr	1 % of Capex	0.5	14
Battery Energy Storage (6-Hour)	7.61 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 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.