Report on Resource Adequacy Plan For the State of Nagaland (2024-25 to 2031-32)

Government of India
Ministry of Power
Central Electricity Authority

Executive Summary

The electricity demand for the State of Nagaland is increasing with a CAGR of 4.15 % 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 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 daily peak demand of Nagaland occurs during night hours from the month of April to September. September onwards, the day and night peak electricity demand of Nagaland typically remains similar. The highest demand typically occurs during the months of July to September during the nighttime.

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 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. While carrying out the RA Studies, it was ensured that RPO is met.

With the existing and planned capacity, the hourly generation dispatch analysis has been carried out to assess the hourly demand-supply position till 2031-32 for Nagaland based on inputs available with CEA and NERLDC and to fulfil the RPO trajectory. It was found that the state's existing contracted capacity along with capacity addition plans for conventional as well as 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, long-term study for the State of Nagaland 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.

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 the state of Nagaland in the year 2031-32 is 424 MW, which comprises of 52 MW from Coal, 76 MW from Gas, 263 MW from Hydro, 26 MW from Solar, and 7 MW through Medium/Short- term contracts.

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 Nagaland based on the inputs available with CEA and NERLDC 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 Nagaland for catering to above highlighted uncertainties so that demand can be met reliably throughout the year.

2.0 Nagaland RA Study

2.1 Present Power Scenario in Nagaland

As of March, 2023, the total contracted capacity for Nagaland is 226 MW. Out of the total contracted capacity (CC), the share of non-fossil fuel-based CC is 43 %.

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	52	23
Gas	76	34
Hydro	97	43
Solar	1	0.4
Total	**226**	**100**

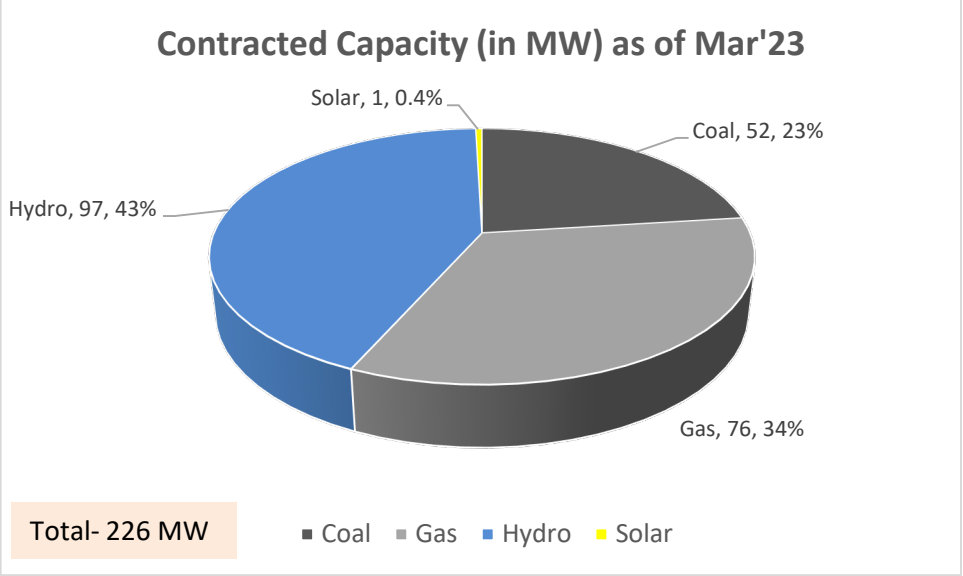


Figure 1 Fuel-wise Contracted Capacity (in MW) as on March 2023

2.2 Demand Analysis (2022-23)

Hourly demand pattern of 2022-23 was analyzed and it was observed that the peak demand season for Nagaland is during the months of July to September. The daily peak demand occurs during night hours from the month of April to September. September onwards, the day and night peak electricity demand of Nagaland typically remains similar.

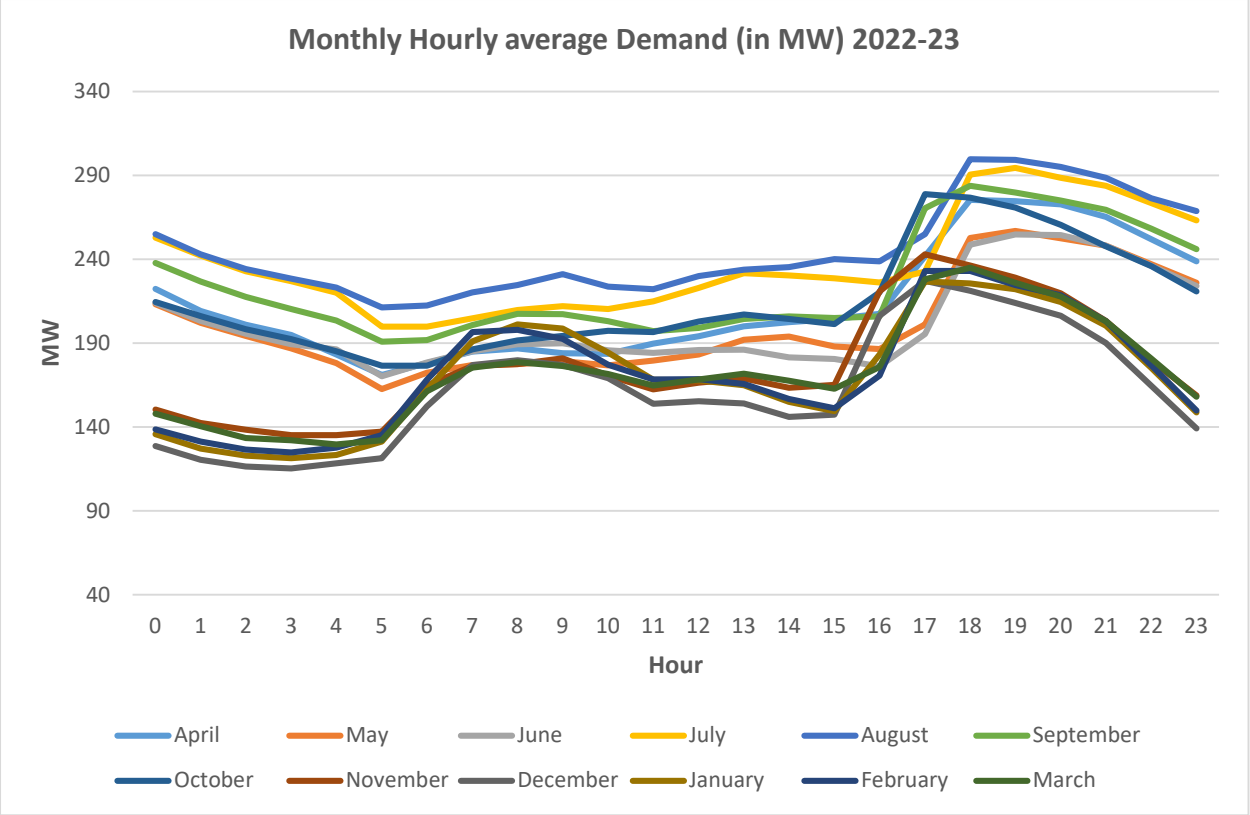


Figure 2 Average Hourly Demand Profile (MW)

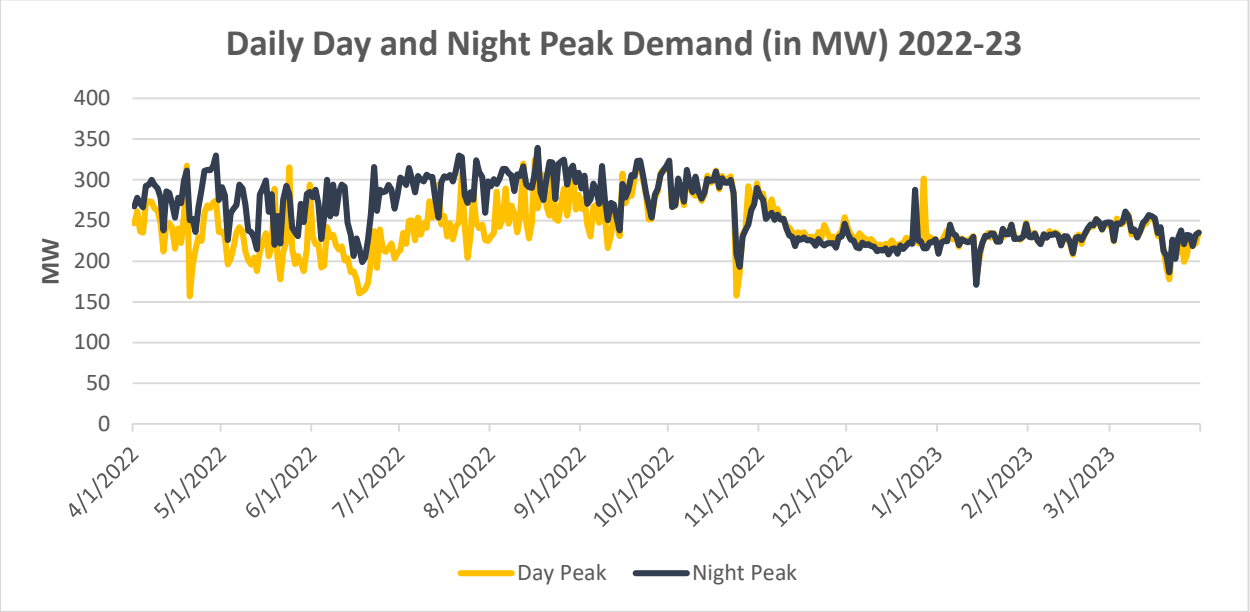


Figure 3 Day and Night Peak in MW of Nagaland (2022-23)

3.0 Inputs/Assumptions for the Study

i) Peak and Energy Demand for RA Studies of the state of Nagaland 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)	953	997	1041	1088	1134	1182	1228	1272	1299
Year on Year Growth		4.62%	4.41%	4.51%	4.23%	4.23%	3.89%	3.58%	2.12%
Peak Demand Projections (MW)	171	179	187	195	204	213	221	230	235
Year on Year Growth		4.68%	4.47%	4.28%	4.62%	4.41%	3.76%	4.07%	2.17%

ii) Future demand profile for the year 2031-32 has been projected using the demand profile for the year 2022-23 as the base profile.

iii) The actual hourly solar generation profiles and CUFs of Southern Region have been considered for the Study.

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

v) Existing & Planned Capacity: The existing and planned capacity has been taken as per information available with CEA and NERLDC.

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, Nagaland'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	15	25	35	47	59	73	85
Hydro	6	11	15	20	24	30	35
Other RPO	236	263	293	325	356	386	412

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	138	138	138	138	357	357	357
Other RPO	305	305	305	305	305	305	305

Table 5 Surplus/Shortfall (-) in RPO Generation considering Fungibility for Hydro RPO and Other 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	0	0	0	0	0	0	0
Other RPO	0	0	0	0	0	0	0

As per the RPO trajectory, Nagaland does not need to add/contract any additional capacity (MW) to meet its RPO, as the existing and planned contracts are sufficient to meet the RPO trajectory up to 2029-30.

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 the adequacy of generation resources in the system. PRM in a power system is expressed as a certain percentage of the peak load forecast of the system.

4.1 Demand variation:

The variation in demand is primarily due to temperature, weather parameters or any random outages of transmission lines and generation units, etc. This variation has been captured in the reliability study by varying the projected hourly demand for the future years by varying ±5% by introducing a random variable (with normal distribution) for demand as per the 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 5% 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 forced outage rate of thermal generators were observed for previous years and it was observed that average forced outage rate 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 quantum of total unserved energy in the year 2031-32 is about 8.44 MU. The yearly likely unserved energy with the planned capacities is given below.

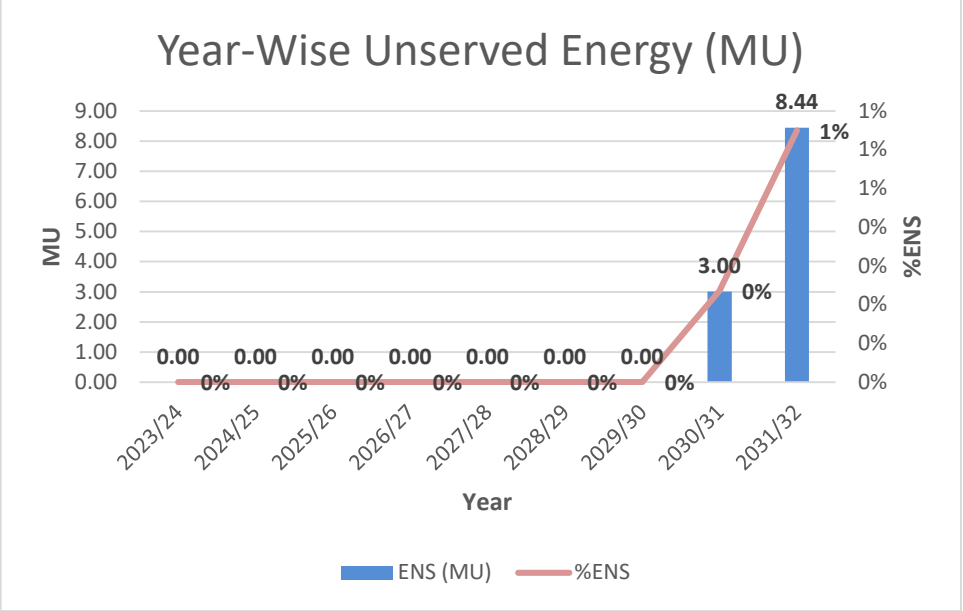


Figure 4 Yearly likely unserved energy with the planned capacities for Nagaland (in MU)

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 high demand months when the contracted capacity (present and planned) is unable to meet the demand.

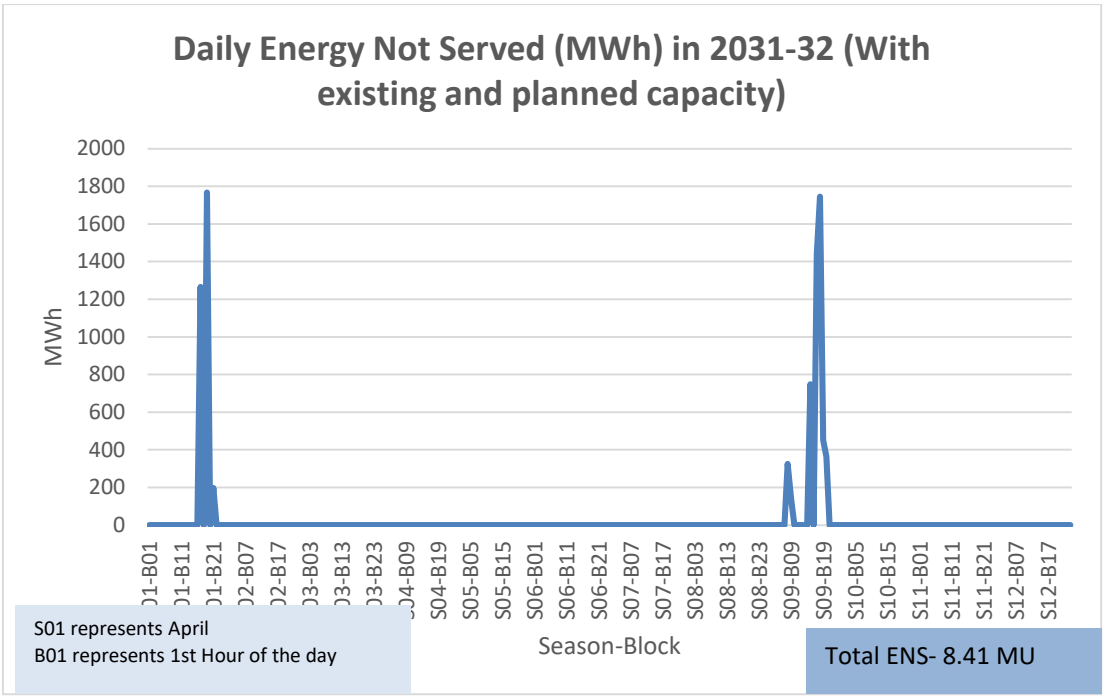


Figure 5 Yearly likely unserved energy with the existing and planned capacities for Nagaland (in MWh)

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) 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 Nagaland are given below:

Table 6 Year-wise capacity projections (in MW)

	COAL	GAS	HYDRO	SOLAR	STOA/MTOA
2023-24	52	76	129	26	0
2024-25	52	76	173	26	0
2025-26	52	76	173	26	0
2026/27	52	76	173	26	0
2027/28	52	76	263	26	0
2028/29	52	76	263	26	0
2029/30	52	76	263	26	0
2030/31	52	76	263	26	4
2031/32	52	76	263	26	7

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

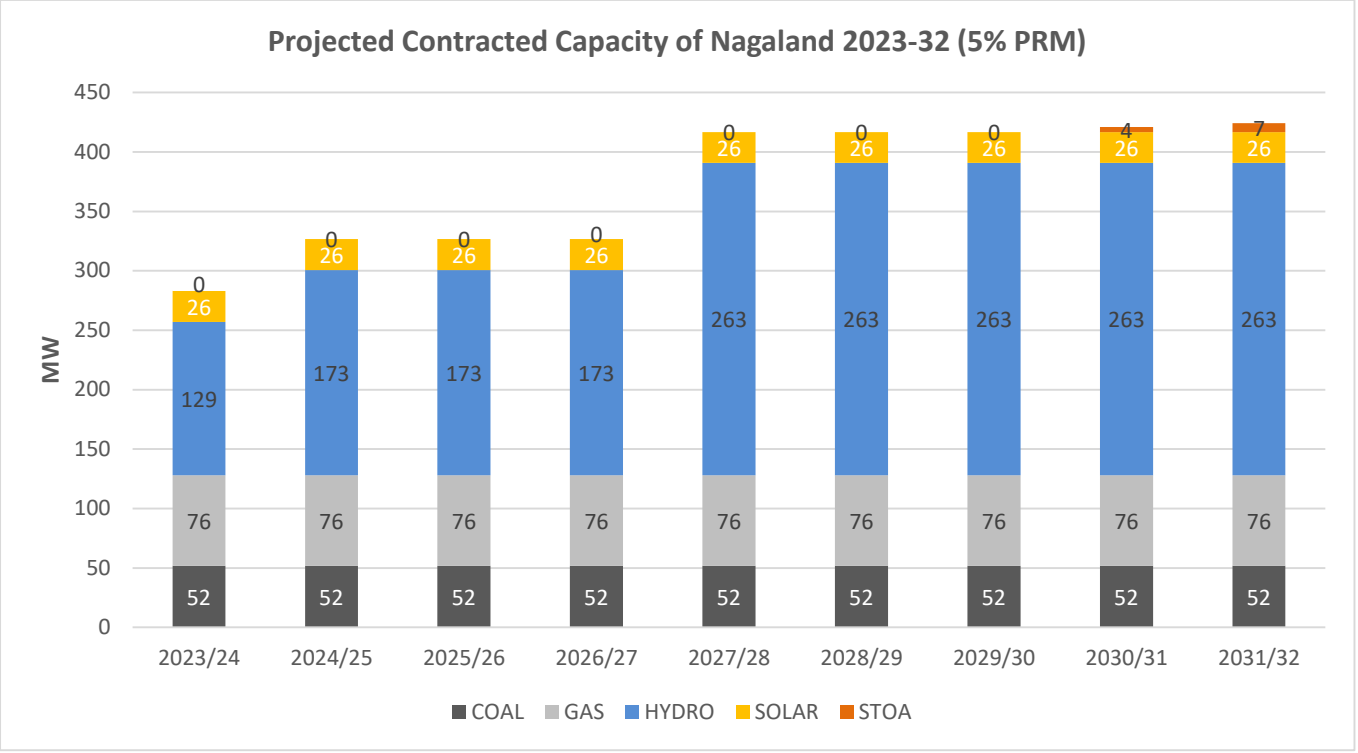


Figure 6 Projected Capacity Mix Year-wise (MW) for Nagaland

As per the Resource Adequacy studies, the total projected Capacity for the year 2031-32 is 424 MW which consists of 263 MW from Hydro, 76 MW from Gas, 52 MW from Coal, 26 MW from Solar, and 7 MW through medium/short term contracts. 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 Nagaland has been assessed as 5%. In addition, the projected/contracted capacity fulfils the stipulated Renewable Purchase Obligation.

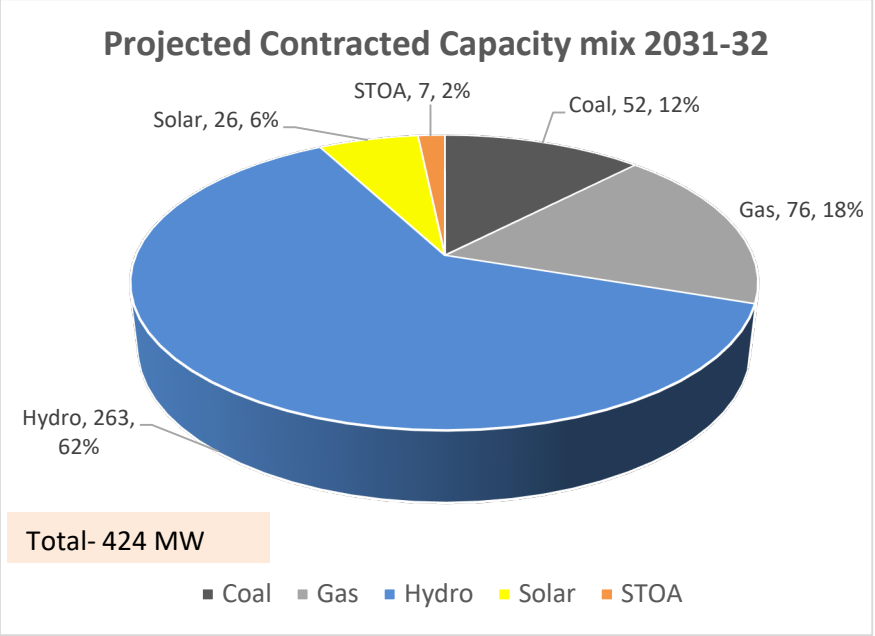


Figure 7 Contracted Capacity Mix in 2031-32 with 5% PRM

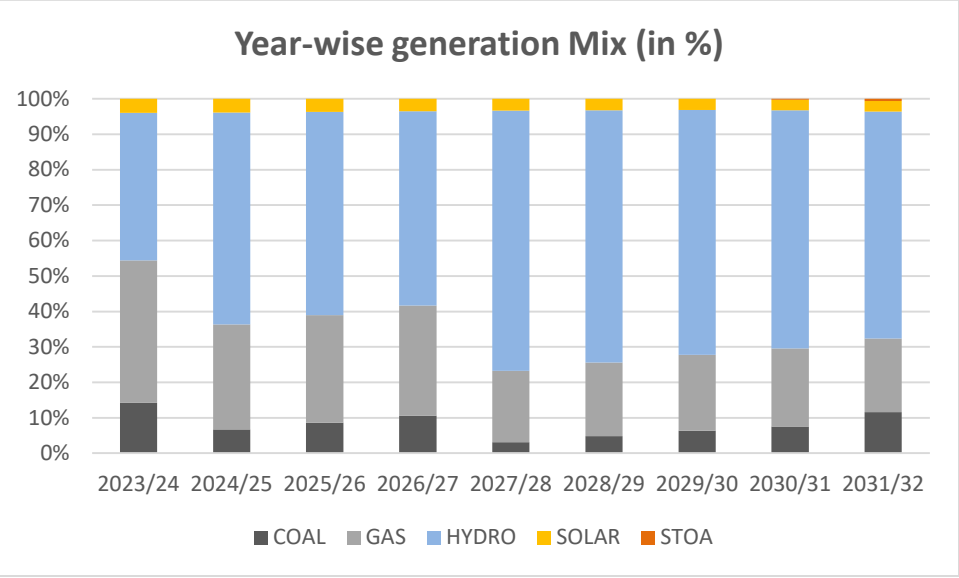
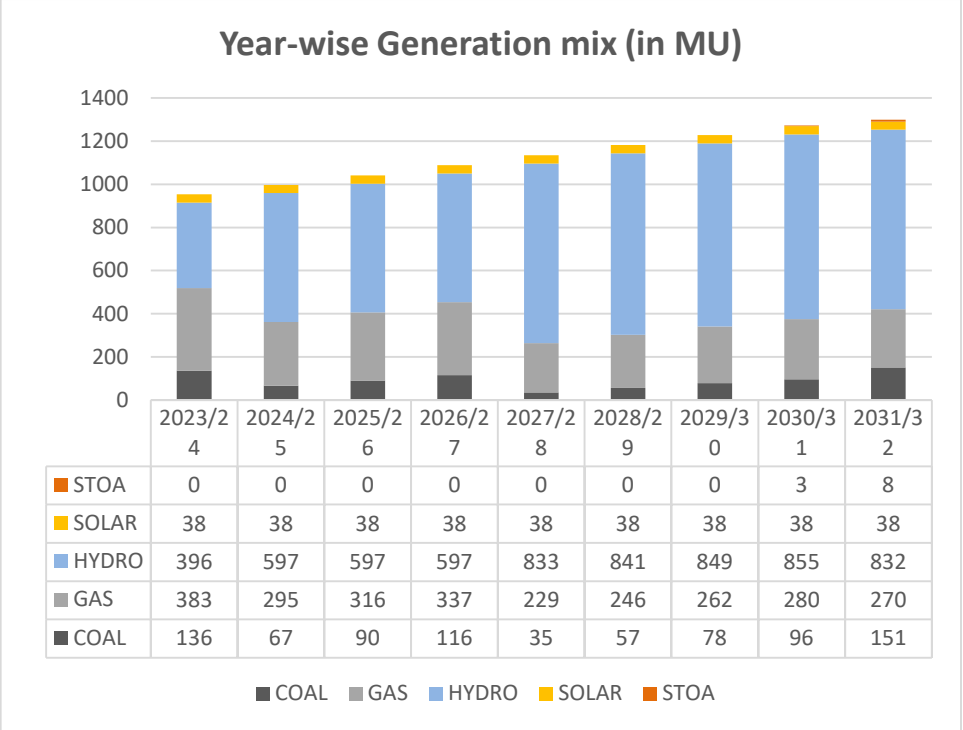


Figure 8 Year-wise projected generation mix (in %age)



	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32
STOA	0	0	0	0	0	0	0	3	8
SOLAR	38	38	38	38	38	38	38	38	38
HYDRO	396	597	597	597	833	841	849	855	832
GAS	383	295	316	337	229	246	262	280	270
COAL	136	67	90	116	35	57	78	96	151

Figure 9 Year-wise projected generation mix (in GWh)

5.3 Coal Capacity Performance

The gas capacity PLF is expected to remain in the range of 8%-35% for the years till 2032 indicating higher absorption of renewable energy.

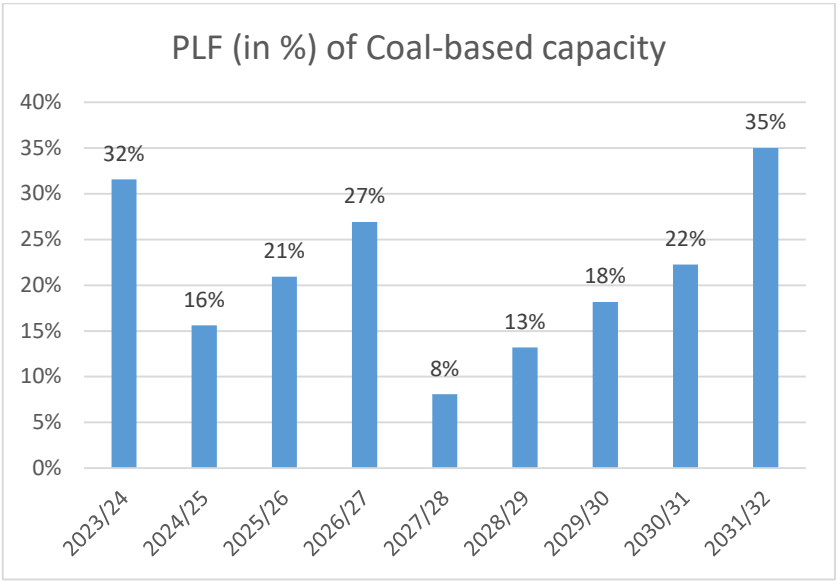


Figure 10 Year-wise coal capacity PLF for Nagaland (in %)

6.0 Capacity contract requirement for future

It has been found in the studies that Nagaland needs to contract the following capacities (planned and additional) per year till 2032 to meet its demand reliably, along with the fulfilment of its RPO as notified by MoP.

Table 7 Year-wise Capacity Addition for Nagaland (in MW)

FY	Hydro	Solar	STOA	TOTAL	
	Planned	Planned	Additional	Planned	Additional
2023-24	32.4	25	0	**57.4**	**0**
2024-25	17	0	0	**17**	**0**
2025-26	15	0	0	**15**	**0**
2026-27	0	0	0	**0**	**0**
2027-28	90	0	0	**90**	**0**
2028-29	0	0	0	**0**	**0**
2029-30	0	0	0	**0**	**0**
2030-31	0	0	4	**0**	**4**
2031-32	0	0	7	**0**	**7**

7.0 Conclusion

I. In absence of demand data from the State, the study has considered demand projections of 20th EPS for assessing the resource adequacy of Nagaland.

II. The current capacity mix in Nagaland has 57% of contracted capacity from fossil fuel sources. The peak demand season is typically from August to September with peak demand occurring during night time.

III. The study has been done based on the hourly load pattern of the year 2022-23.

IV. Nagaland is likely to witness energy deficit ranging from 3 MUs in 2030-31 to 8.4 MUs in 2031-32 with the existing and planned capacity addition. Nagaland is surplus in fulfilment of its Renewable Purchase Obligations (RPO) and does not need any additional RE capacity to fulfil its Renewable Purchase Obligations. The projected capacity and generation mix fulfil the RPO obligations by 2030 as specified by the Ministry of Power.

V. The STOA/MTOA 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.

VI. The coal-based capacity PLF is expected to remain in the range of 8%- 35% for the years till 2032 ensuring higher absorption of higher renewable energy.

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Assumption ion for Resource Adequacy Studies for the state of Nagaland

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 available with CEA and NERLDC
4. Future Capacity addition: based on RPO trajectory
5. Cost parameters: based on values taken in NEP.

RE CUF considered

Hydro Existing/ Planned PLF	Bioenergy PLF	Solar Existing/ Planned CUF	Wind Planned/ Existing CUF	PSP/ Small Hydro CUF
37%/45 %	18%	16% / 18%	33% / 22%	25% /15%

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.