FINAL DRAFT REPORT ON RESOURCE ADEQUACY PLAN FOR THE STATE OF KARNATAKA

GOVERNMENT OF INDIA
MINISTRY OF POWER
CENTRAL ELECTRICITY AUTHORITY

Executive Summary

The electricity demand for the State of Karnataka is increasing with a CAGR of 3.93 % from 2023-24 to 2031-32 as forecasted by 20th EPS. The projections of KPTCL also indicate that electricity demand may increase with a CAGR of 4.34 % from 2023-24 to 2029-30. 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.

Agrarian nature of the state power demand and seasonality contributes to the seasonal and diurnal variation of the electricity demand. The electricity demand starts increasing from the month of January and is maximum during the month of March. The demand during the months of January, February and March is significantly higher compared to rest of the year. The lowest electricity demand generally occurs in the month of October. The peak electricity load is generally observed during day hours.

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 Discoms 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.

The resource adequacy studies to assess the hourly generation dispatch with the existing and planned capacity have been carried out to assess the hourly demand supply gap till 2031-32 for Karnataka based on inputs received from KPTCL. 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 Karnataka 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 Karnataka is 46,471 MW which comprises of 14750 MW from Coal, 2201 MW from Biomass, 4823

MW from Hydro, 9453 MW from Wind, 10993 MW from Solar, 698 MW from Nuclear, 2000 MW from Pumped Storage Plants and 1553 MW from Short term/Market based 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 Karnataka based on the inputs received from KPTCL 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 Karnataka for catering to above highlighted uncertainties so that demand can be met reliably throughout the year.

2.0 Karnataka RA Study

2.1 Present Power Scenario in Karnataka

As of March, 2023, the total contracted capacity for Karnataka is 29,878 MW. Out of the total contracted capacity (CC), the share of non-fossil fuel-based CC is 68 %.
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	9610	32.3
Nuclear	697	2.3
Hydro	4687	15.8
Solar	7627	25.6
Wind	5250	17.7
Bioenergy	1870	6.3
Total	29738	100

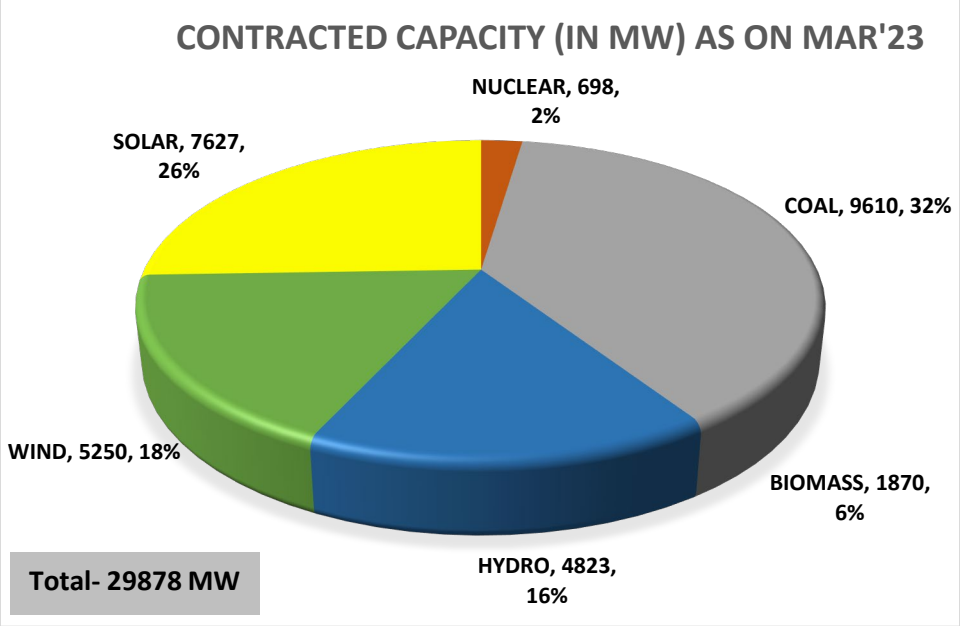


Figure 1 Fuel-wise Contracted Capacity (in MW) as on Mar 2023

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 Karnataka is during the months of January, February and March. The hourly demand pattern generally remains similar for all the months. Karnataka witnesses peak demand during day hours. The Demand during the months from June to October remains significantly low as compared to other months which reflects the effect of seasonality in demand.

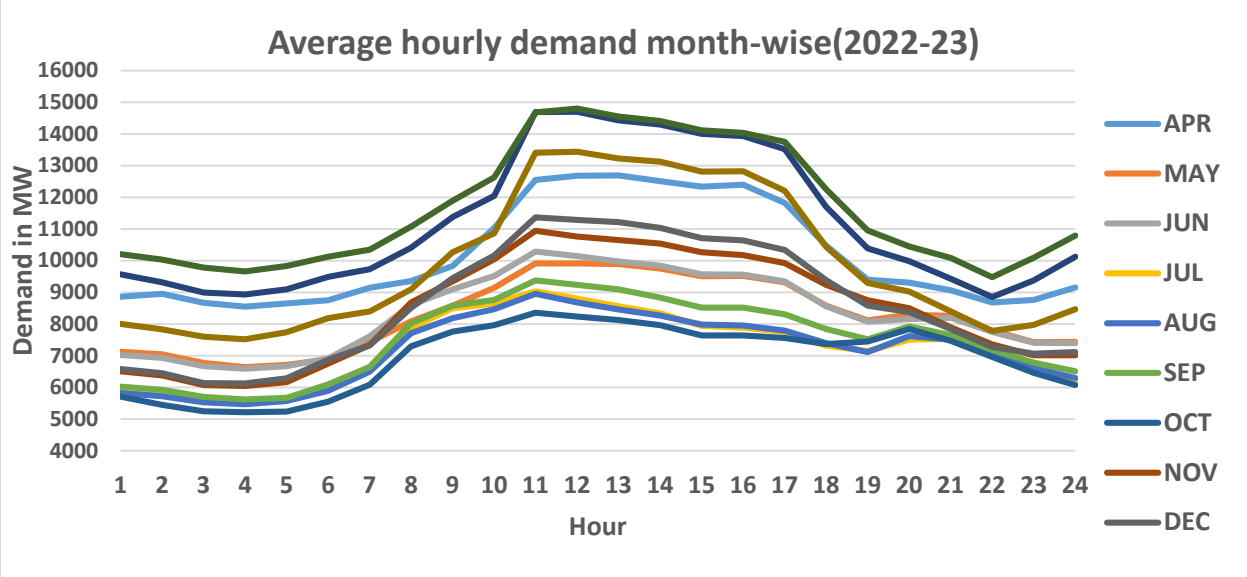


Figure 2 Average Hourly Demand Profile (MW)

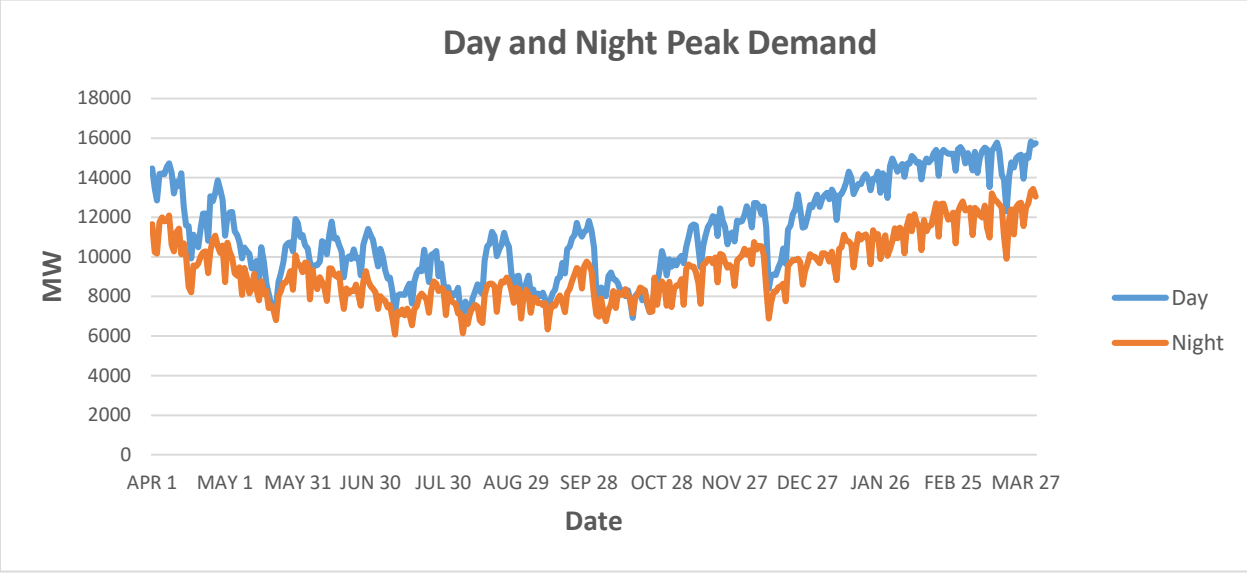


Figure 3 Day and Night Peak in MW of Karnataka (2022-23)

3.0 Inputs/Assumptions for the Study

i) Peak and Energy Demand for the state of Karnataka has been taken as per KPTCL Projections. The Demand estimation furnished by KPTCL was higher than projected by 20th EPS and actual demand recorded in 2022-23. Therefore, the Studies have been carried out using KPTCL projections. The demand projections provided by KPTCL were until the year 2029-30 only. The demand projections for 2030-31 and 2031-32 were calculated using the CAGR of demand projections provided by KPTCL

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)	77876	80922	84132	88232	91852	95486	99758	102973	105970
Year on Year Growth	-	3.91 %	3.97%	4.87%	4.10%	3.96%	4.47%	3.22%	2.91%
Peak Demand Projections (MW)	15636	16277	16947	17810	18578	19352	20254	20954	21613
Year on Year Growth	-	4.10%	4.12%	5.09%	4.31%	4.17%	4.66 %	3.45%	3.14%

Table 3 Future Demand Projection by KPTCL

	2023-24	**2024-25**	**2025-26**	**2026-27**	**2027-28**	**2028-29**	**2029-30**	**2030-31**	**2031-32**
Energy Projections (MU)	85985	89496	93194	97095	101233	105943	110941	115755	120778
Year on Year Growth	-	4.08 %	4.13%	4.19%	4.26%	4.65%	4.72%	4.34%	4.34%
Peak Demand Projections (MW)	15770	16580	17439	18353	19135	20025	20970	21990	23058
Year on Year Growth	-	5.10%	5.18%	5.24%	4.26%	4.65%	4.71%	4.85%	4.85%

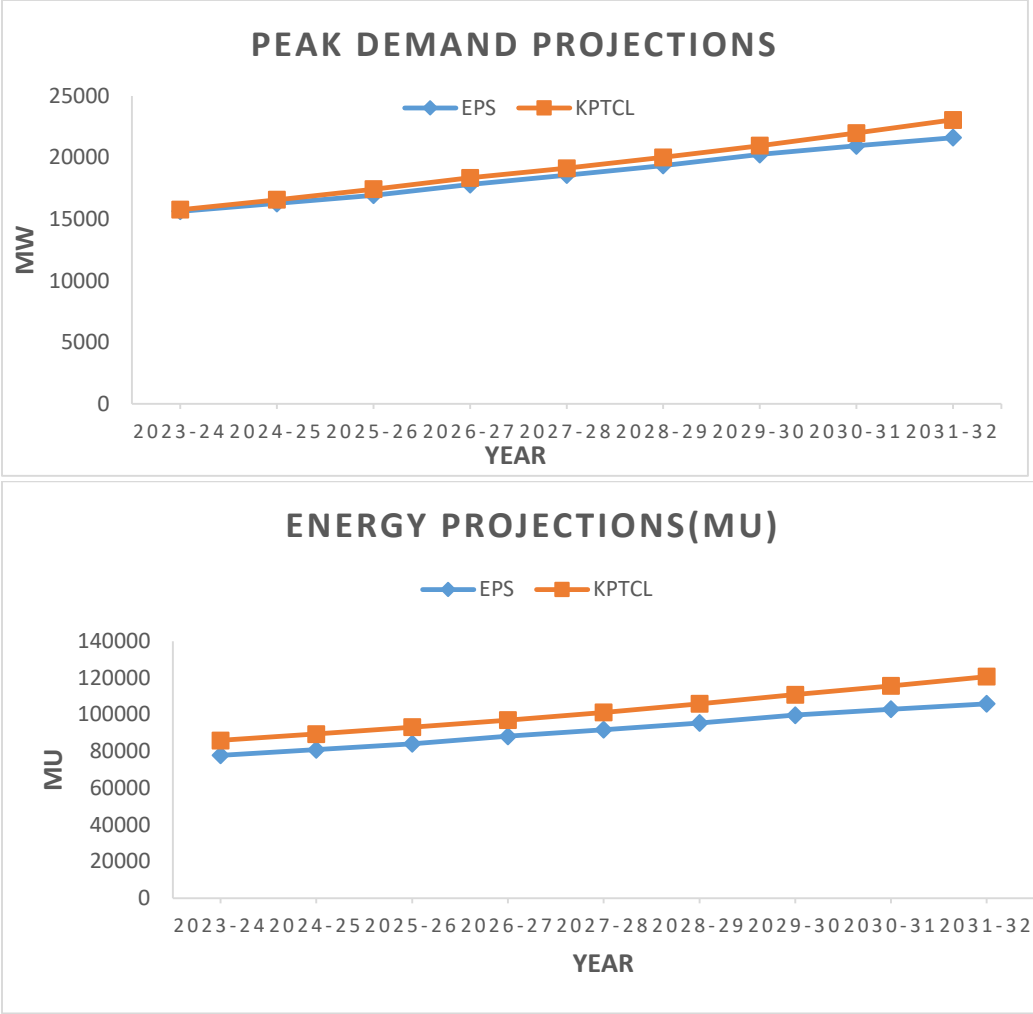


Figure 4 Comparison of Energy Requirement and peak Demand Projections of EPS vs KPTCL

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

iii) The actual hourly solar and wind generation profiles and CUFs provided by KPTCL 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: As per the information received from KPTCL 4204 MW of Wind-based capacity is planned till 2027-28, 3366 MW of Solar-based capacity is planned till 20256-26, 330 MW of Biogen-based capacity is planned till 2025-26. Also, an additional 2000 MW of PSP capacity is planned till 2030-31.

vi) The banking details provided by KPTCL have not been considered while doing RA Studies.

vii) 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, Karnataka's

requirement to add/contract additional renewable capacity (MW) has been assessed as below.

Table 4 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	1375.76	2201.602	3131.318	4165.376	5294.486	6526.089	7699.305
Hydro	567.501	966.5568	1379.271	1747.71	2176.51	2659.169	3128.536
Other RPO	21332.88	23600.1	26252.75	28992.57	31817.53	34632.77	37242.89

Table 5 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	6989.65	9634.68	12266.62	14809.19	15121.41	14854.71	14504.85
Hydro	71	71	122	122	122	122	2312
Other RPO	32735.87	38685.64	40143.5	40703.57	41310.23	41830.93	42479.79

Table 6 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	5117.39	6537.52	7878.03	9018.1	7772.41	5791.45	5989.01
Hydro	0	0	0	0	0	0	0
Other RPO	11403	15085.5	13890.8	11711	9492.7	7198.16	5236.9

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

Table 7 As per RPO trajectory, Karnataka 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 variation in demand pattern of Karnataka for last 2 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.

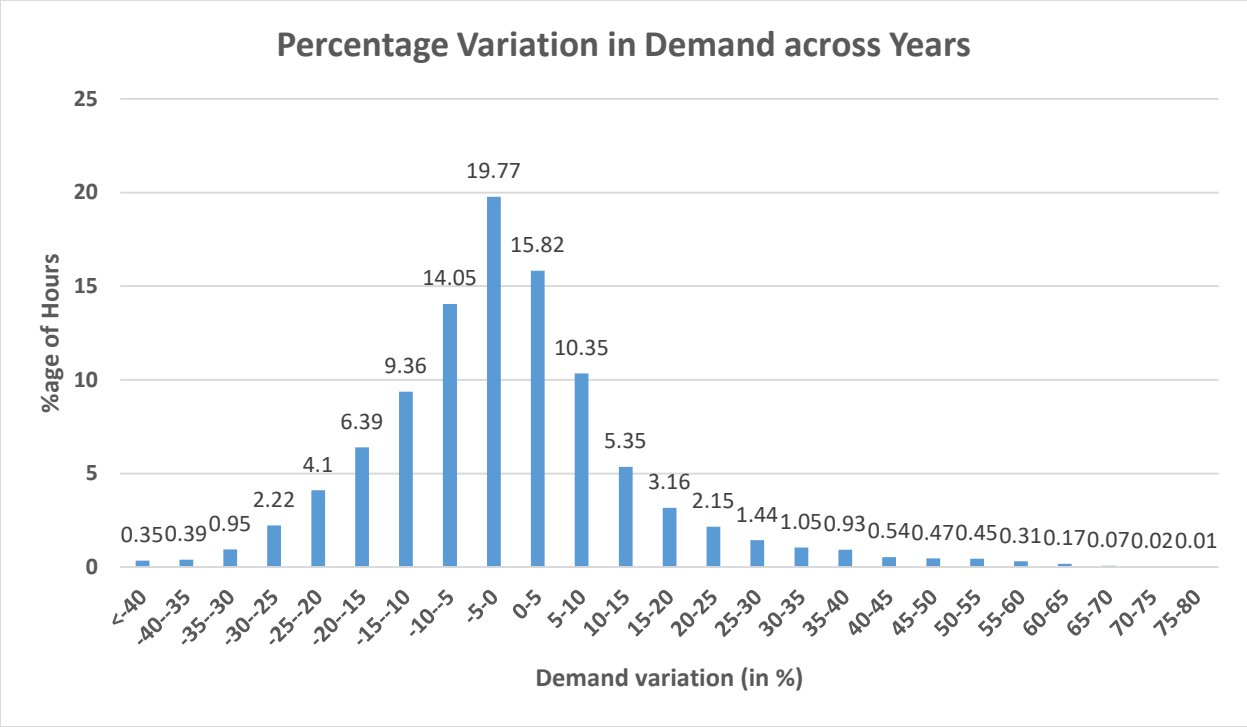


Figure 5 Hourly Percentage Variation in Demand across years

It can be observed that the hourly demand typically varies ±20% and ±10% from corresponding hour in previous years (Normalized figure) for 84% and 60% of instances respectively. 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 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 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 forced outage rate of thermal generators of KPTCL 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 total unserved energy in the year 2031-32 is about 6574 MU. The yearly likely unserved energy with the planned capacities is given below.

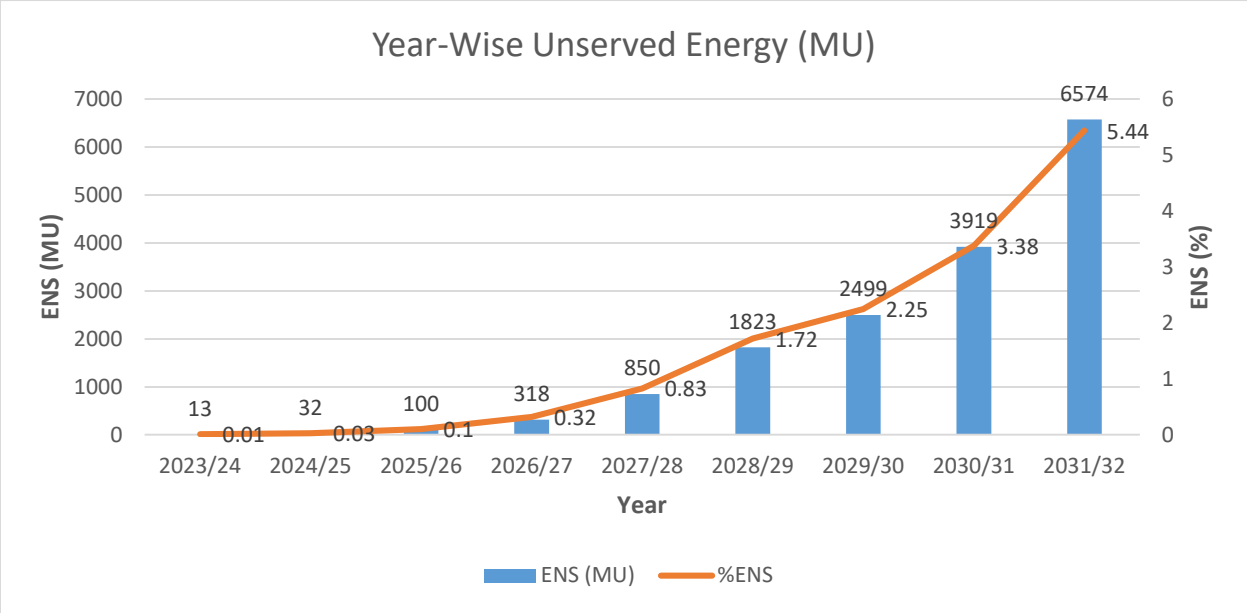


Figure 6 Yearly likely unserved energy with the planned capacities for Karnataka (in MU)

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.

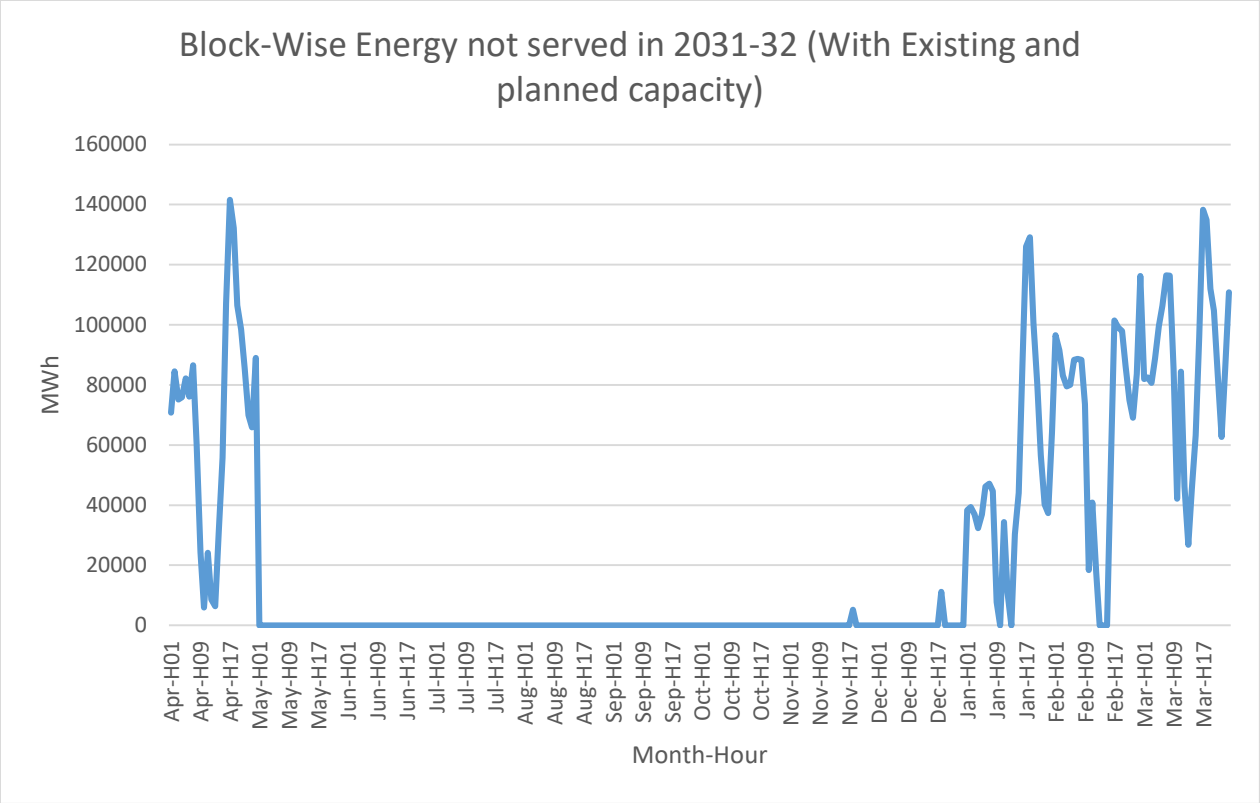


Figure 7 Daily Unserved Energy Pattern MU (2031-32)

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 Coal-based capacity 2027/28 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 Karnataka are given below:

Table 8 Year-wise capacity projections (in MW)

	NUCLEAR	COAL	BIO-MASS	HYDRO	WIND	SOLAR	STORAGE (PSP)	STOA/ MTOA
2023-24	698	9610	1942	4823	6250	8133	0	1457
2024-25	698	9610	2083	4823	7250	10627	0	1693
2025-26	698	9610	2201	4823	8250	10993	0	1958
2026/27	698	9610	2201	4823	9224	10993	0	2799
2027/28	698	11832	2201	4823	9453	10993	0	1823
2028/29	698	12518	2201	4823	9453	10993	0	2211
2029/30	698	12953	2201	4823	9453	10993	1000	1826
2030-31	698	13545	2201	4823	9453	10993	2000	1393
2031-32	698	14750	2201	4823	9453	10993	2000	1553

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

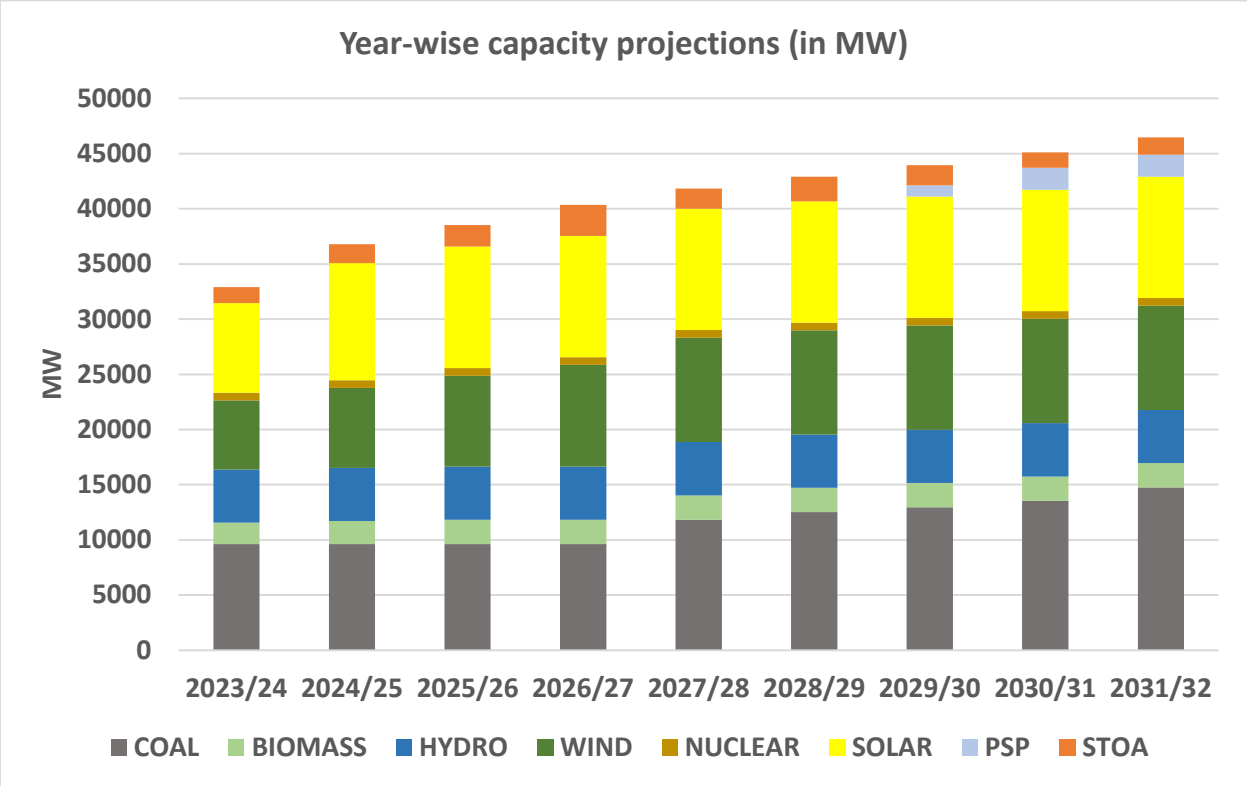


Figure 8 Projected Capacity Mix Year-wise (MW) for Karnataka

As per the Resource Adequacy studies, the total projected Capacity for the year 2031-32 is 46,471 MW which consists of 14750 MW from Coal, 698 MW from Nuclear, 4823 MW from Hydro, 9453 MW from Wind, 10993 MW from Solar, 2000 MW from Storage, 2201 MW from Biomass, and 1553 MW from STOA. 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 Karnataka has been assessed as 5%. In addition, the projected/contracted capacity fulfils the stipulated Renewable Purchase Obligation.

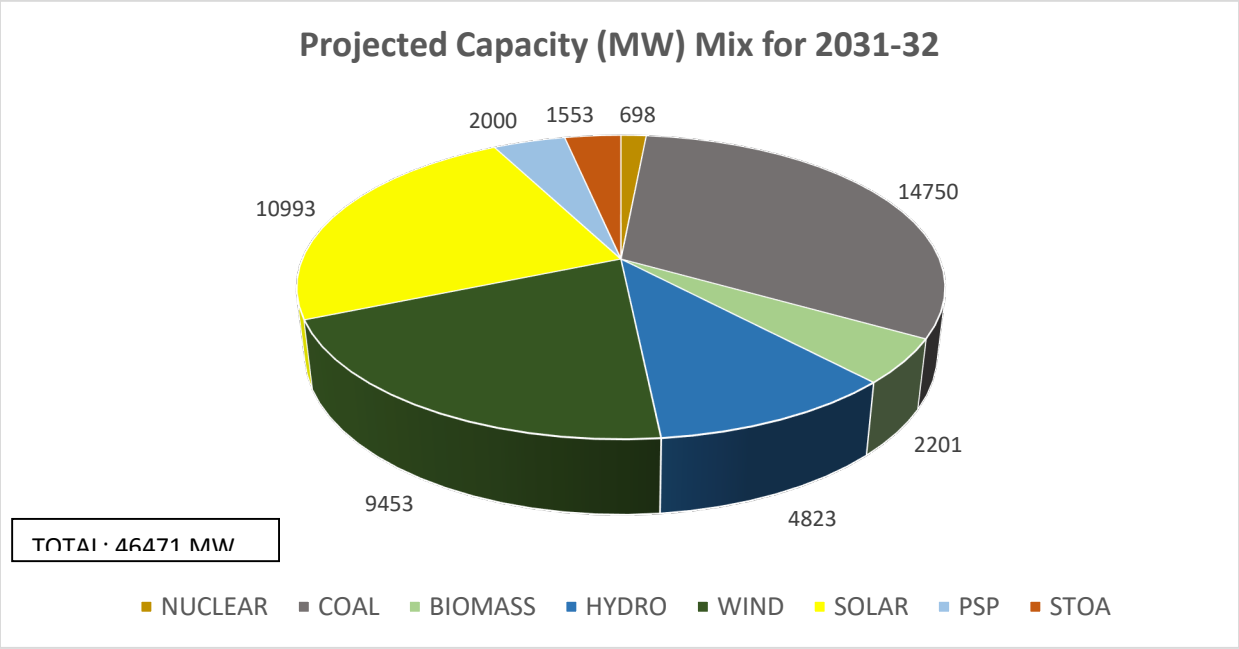
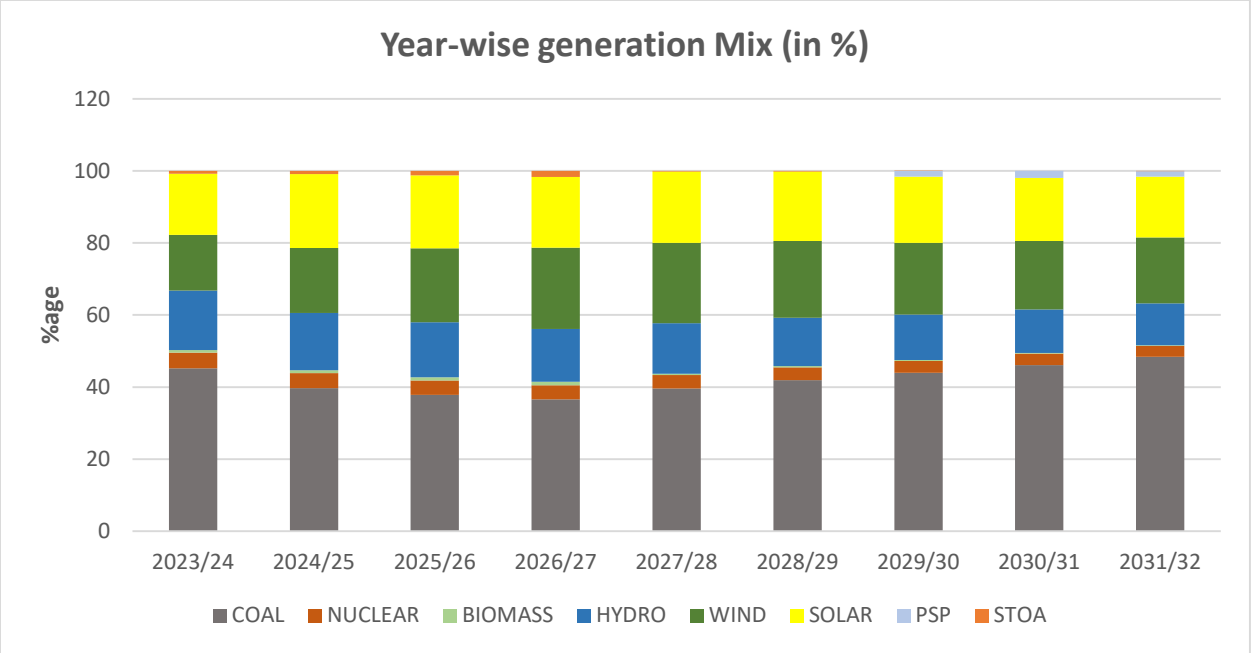
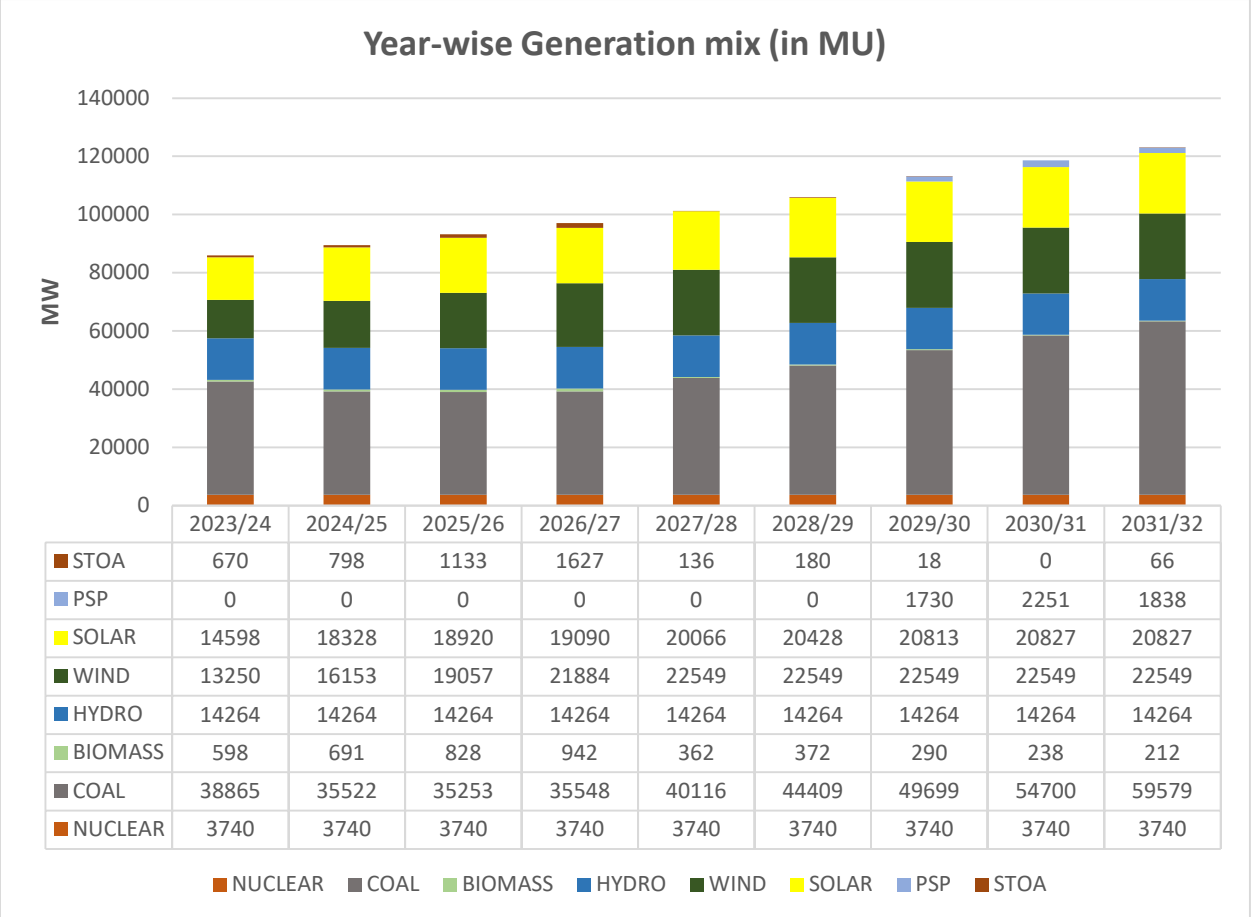


Figure 9 Contracted Capacity Mix in 2031-32 with 5% PRM

The share of non-fossil fuel-based capacity in the total contracted capacity is projected to increase to around 68.3% in 2032 from 67.8 % in 2022-23 with higher contribution from non-fossil fuel-based capacities in alignment with RPO trajectory. The contribution of STOA or dependence on market in the generation mix for meeting the peak demand requirement is in the range of 0.4-1.5% in different years till 2032.





	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32
STOA	670	798	1133	1627	136	180	18	0	66
PSP	0	0	0	0	0	0	1730	2251	1838
SOLAR	14598	18328	18920	19090	20066	20428	20813	20827	20827
WIND	13250	16153	19057	21884	22549	22549	22549	22549	22549
HYDRO	14264	14264	14264	14264	14264	14264	14264	14264	14264
BIOMASS	598	691	828	942	362	372	290	238	212
COAL	38865	35522	35253	35548	40116	44409	49699	54700	59579
NUCLEAR	3740	3740	3740	3740	3740	3740	3740	3740	3740

Figure 10 Year-wise projected generation mix (in GWh)

5.3 Day-wise Surplus Capacity Karnataka (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 October 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. Karnataka has likely surplus capacity available during the months from May to October (tentatively in the range of 450-5500 MW for different years as shown below) which can be shared with other states.

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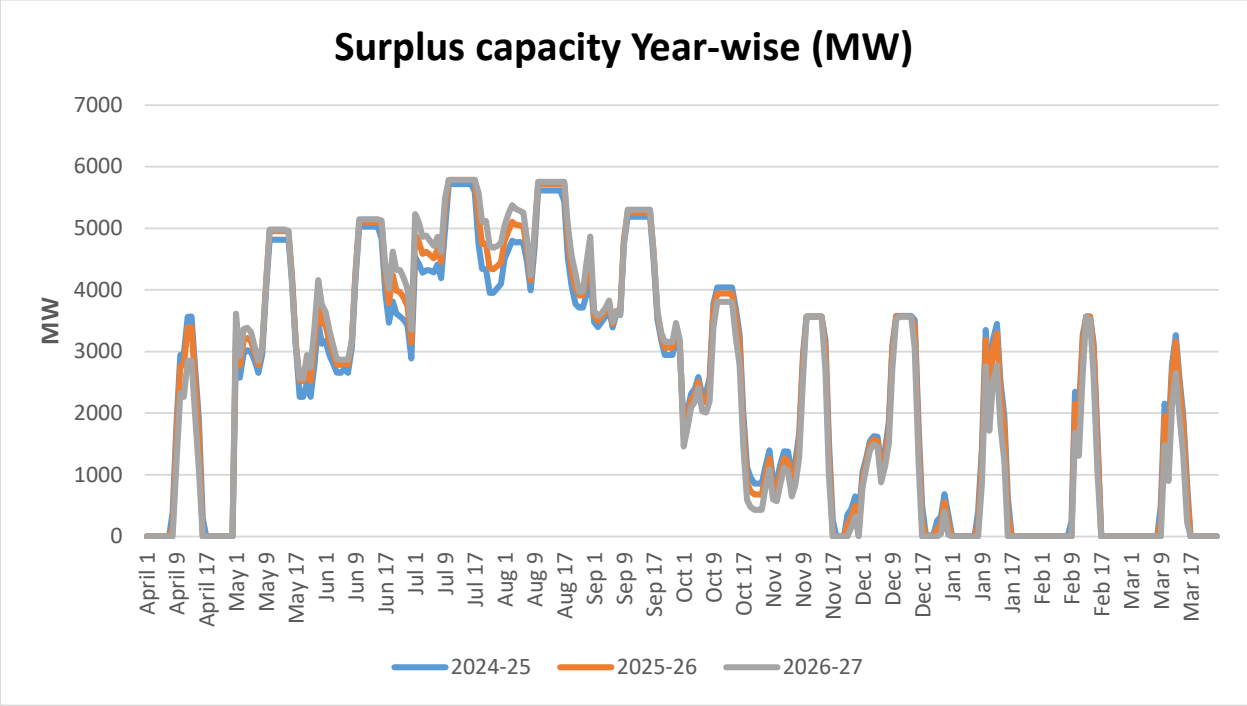

Figure 11 Surplus Coal Capacity Year-wise (MW)

5.4 Coal Capacity Performance

The coal capacity PLF is expected to remain in the range of 40%- 49% for the years till 2032 indicating higher absorption of higher renewable energy. The low PLF of coal-based capacity can also be attributed to the fact that peak demand of Karnataka occurs during day time when abundant solar generation is available.

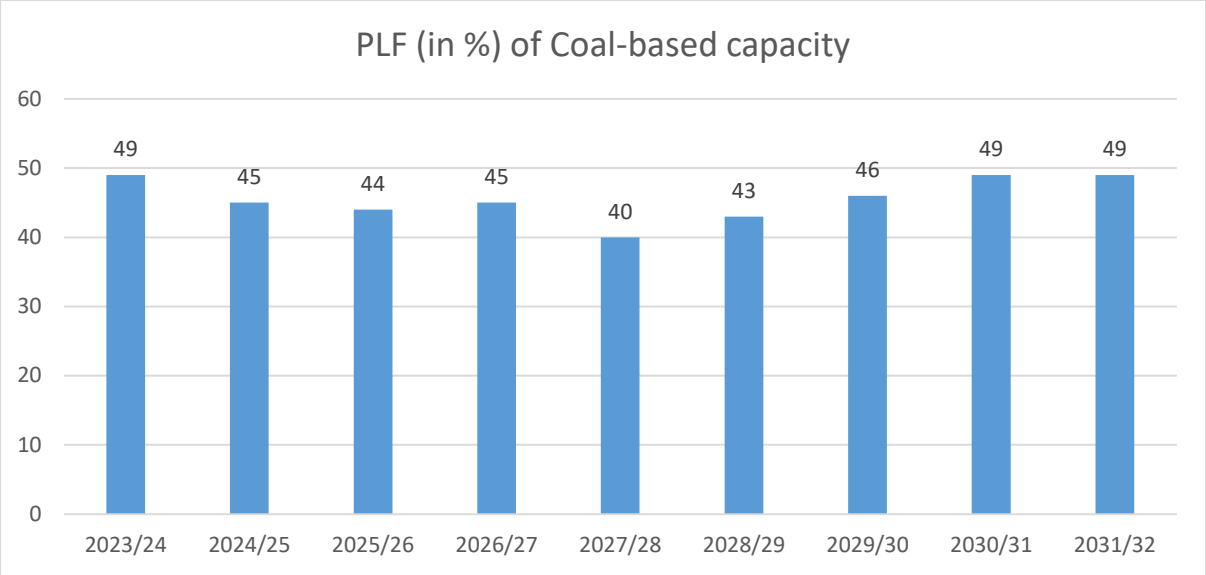

Figure 12 Year-wise coal capacity PLF for Karnataka (in %)

6.0 Capacity contract requirement for future

It has been found out in the studies that Karnataka 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 9 Year wise Capacity Addition for Karnataka (in MW)

	COAL	*PSP*	*WIND*	*SOLAR*	*BIOMASS*	*STOA/MTOA*	*TOTAL*	
	Additional	*Planned*	*Planned*	*Planned*	*Planned*	*Additional*	*Planned*	*Additional*
2023/24	*0*	*0*	*1000*	*506*	*72*	*1457*	*1578*	*1457*
2024/25	*0*	*0*	*1000*	*2494*	*141*	*1693*	*3635*	*1693*
2025/26	*0*	*0*	*1000*	*366*	*117*	*1958*	*1483*	*1958*
2026/27	*0*	*0*	*974*	*0*	*0*	*2799*	*974*	*2799*
2027/28	*2222*	*0*	*230*	*0*	*0*	*1823*	*230*	*4045*
2028/29	*686*	*0*	*0*	*0*	*0*	*2211*	*0*	*2897*
2029/30	*435*	*1000**	*0*	*0*	*0*	*1826*	*1000*	*2261*
2030/31	*593*	*1000**	*0*	*0*	*0*	*1393*	*1000*	*1986*
2031/32	*1205*	*0*	*0*	*0*	*0*	*1553*	*0*	*2758*

***Sharavathy PSP Project**

7.0 Alternate Resilient Scenario Analysis

In view of the recent surge in Power demand during the year 2023-24 and capacity addition being delayed vis-a –vis the envisaged timelines, it was realized that 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 stress scenario:

- Peak Demand- 5% increase compared to the KPTCL demand projections.
- Capacity Addition being delayed from their anticipated year as follows:

Table 13 Time Delay in commissioning of contracted capacity

Contracted Capacity Type	Years Delayed
Hydro/PSP	2
Renewable Energy Capacity	1

7.1 Capacity Mix Projections

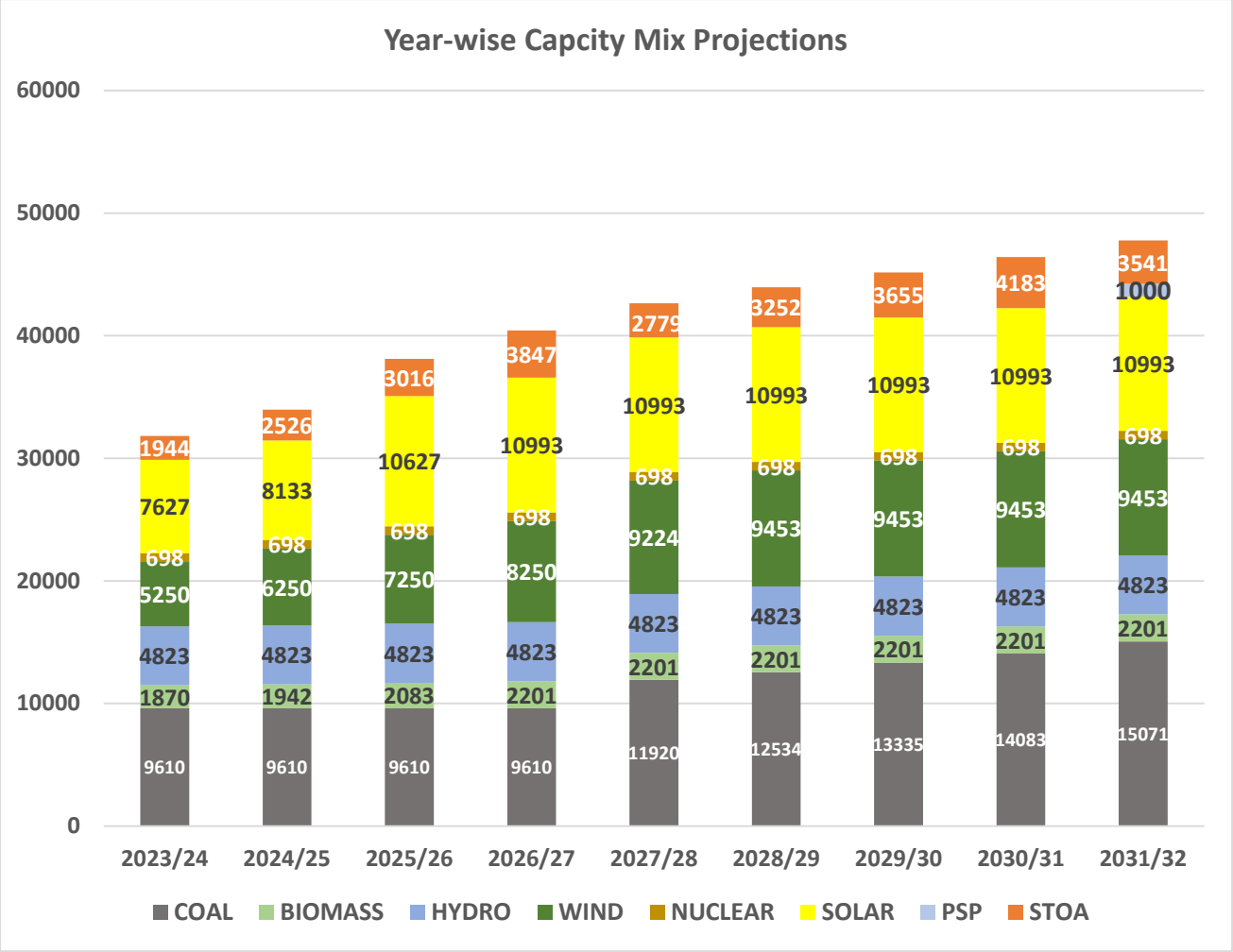

Figure 13: Year-wise capacity projections (in MW) for Most Resilient Scenario

In this scenario, the coal requirement in the year 2031-32 increases by around 320 MW in case of stress case scenario compared to the base case.

Also, the requirement of Short term market based contracts for meeting the peak demand in stress case scenario increases by around 1980 MW.

8.0 Conclusion

The study has considered demand projections of KPTCL for assessing the resource adequacy of Karnataka. The demand projections by KPTCL are higher compared to the demand projections by 20th Electric Power Survey (EPS).

The current capacity mix in Karnataka has 32% of contracted capacity from fossil fuel sources. The peak demand season is typically from January to March with peak demand occurring during day time. The Demand during the months from June to October remains significantly low as compared to other months which reflects the effect of seasonality in demand. 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 in such periods.

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

Karnataka is likely to witness energy deficit ranging from 13 MUs to 6574 MUs in different years from 2023-24 to 2031-32 with the existing and planned capacity addition. Karnataka is surplus in fulfilment of its Renewable Purchase Obligations (RPO) and further need not contract any renewable capacities. The projected capacity and generation mix fulfils the RPO obligations by 2030 as specified by Ministry of Power.

Karnataka is likely to have unserved energy in coming years and need to contract fossil-based capacities for meeting energy requirements other than the planned capacities. Karnataka requires additional coal-based capacities to be procured other than the capacity already planned. The quantum of coal-based capacities required to be contracted is about 2222 MW in the year 2027-28 which increases to around 5140 MW in the year 2031-32.

The energy requirement to be met from STOA is about 1% of the total energy requirement 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.

The coal capacity PLF is expected to remain in the range of 40%- 49% for the years till 2032 ensuring higher absorption of higher renewable energy.

The Alternate Resilient Scenario carried out for Karnataka for possibility of higher demand than projected by KPTCL has revealed that the coal requirement increases by around 320 MW in 2031-32 compared to the base case scenario. The dependency on STOA also increases compared to the base case scenario.

It is likely that Karnataka may have surplus capacity available during the months from May to October (tentatively in the range of 450 -5500 MW) which can be shared with other states.

Assumption for Resource Adequacy Studies for the state of Karnataka

1. Electricity Demand & peak requirement: As per KPTCL projections
2. Demand Profile: Based on hourly demand profile of 2022-23.
3. Existing & Planned Capacity: As per the information received from KPTCL
4. Future Capacity addition: based on RPO trajectory
5. Cost parameters: based on information received from KPTCL and NEP

RE CUF considered

Hydro Planned/ Existing PLF	Bioenergy PLF	Solar Existing/ Planned CUF	Wind Planned/ Existing CUF	PSP/ Small Hydro CUF
37%	20%	20.50 % / 24.0%	33% / 22.20	25.0% /15.0%

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.