Report on
Resource Adequacy Plan for
Punjab

Government of India

Ministry of Power

Central Electricity Authority

Contents

Executive Summary

The electricity demand for the State of Punjab is increasing with a CAGR of 5.6 % from 2023-24 to 2029-30 as forecasted by 20th EPS. The projections of Punjab State Power Corporation Ltd. (PSPCL) also indicate that electricity demand may increase with a CAGR of 5.7 % 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 economy and seasonality contributes to the seasonal and diurnal variation of the electricity demand. The peak demand season for Punjab is during the monsoon months in June, July, August and September. The peak demand is witnessed during day hours in the monsoon months while there is not much difference in day and night peak demand during the other months. The Demand during the winter month of November and December is almost half of the demand observed during the month of June, July and August which reflects the effect of seasonality in demand.

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 Long-term Distribution Licensee Resource Adequacy Plan (LT-DRAP) 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. However, the RPO requirement for Punjab has been assessed in compliance with earlier RPO orders dated 22nd July, 2022 and 19th September, 2022 issued by the Ministry of Power.

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 2029-30 for Punjab based on inputs received from PSPCL. It was found that the state's likely contracted capacity along with the trajectory of the banking arrangement is not sufficient to meet capacity addition plans for conventional as well as renewable energy sources to meet projected demand.

To find out the least cost option for generation capacity expansion for the period 2023-24 to 2029-30, long-term study for the State of Punjab 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 Resource adequacy studies have projected likely optimal capacity mix for future years till 2030 which is able to meet anticipated demand reliably at every instance.

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 additional capacity expansion from renewable capacities have been considered other than required for meeting RPO requirements in the studies. No capacity addition other than the planned addition in nuclear capacity has been considered in the studies.

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 Punjab based on the inputs received from PSPCL and as per RPO trajectory. The study suggests the optimal resource mix till 2030 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 Punjab for catering to above highlighted uncertainties so that demand can be met reliably throughout the year.

2.0 Punjab RA Study

2.1 Present Power Scenario in Punjab

As of March 2023, the total contracted capacity for Punjab is 14613 MW. Out of the total contracted capacity (CC), the share of non-fossil fuel-based contracted capacity is 40.5%. 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	8233	56.4
Gas	137	0.9
Nuclear	197	1.3
Hydro	3447	23.6
Solar	1937	13.3
Wind	450	3.1
Bioenergy	212	1.5
Total	**14613**	**100**

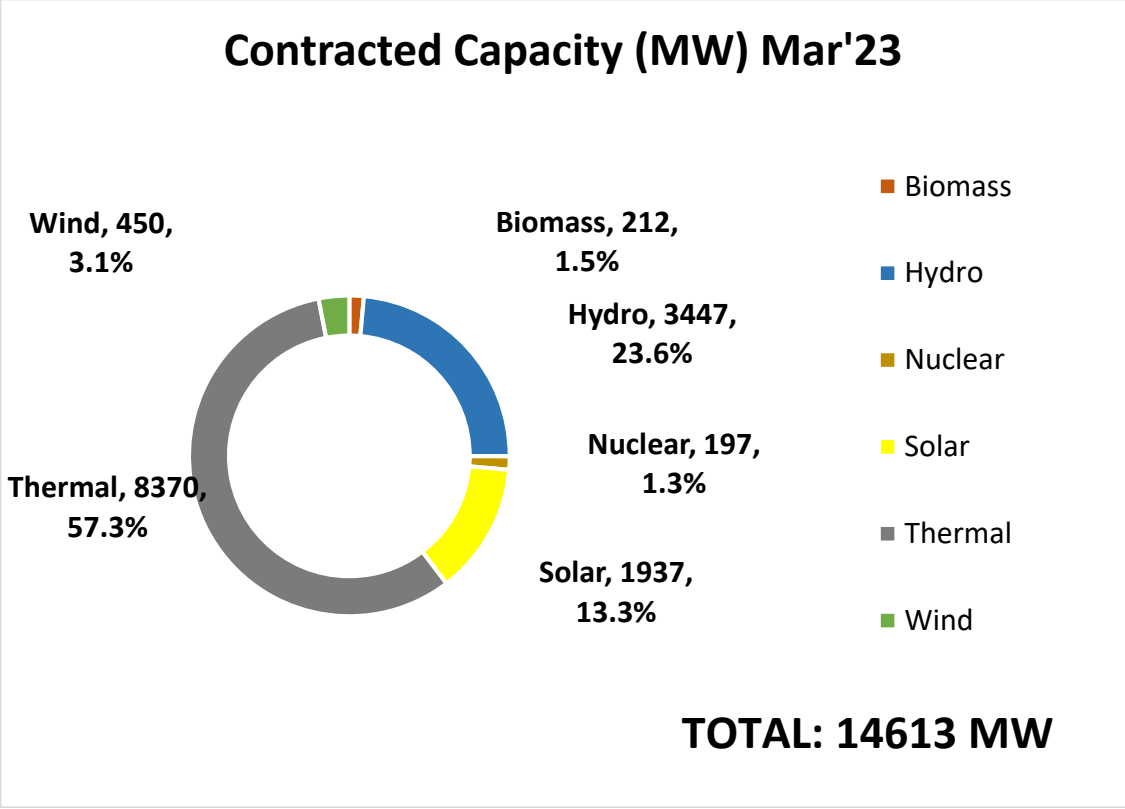

Figure 1 Fuel-wise Contracted Capacity (in MW) as on March 2023

2.2 Present Demand Analysis (2019-20)

Hourly demand pattern of 2019-20 was analyzed and it was observed that the peak demand season for Punjab is during the monsoon months in June, July, August and September. The hourly demand pattern during monsoon months is significantly different during the rest of the months. Punjab witnesses peak demand during day hours in the monsoon months while there is not much difference in day and night peak demand during the other months. The Demand during the winter month of November, December is almost half as observed during the month of June, July and August 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.

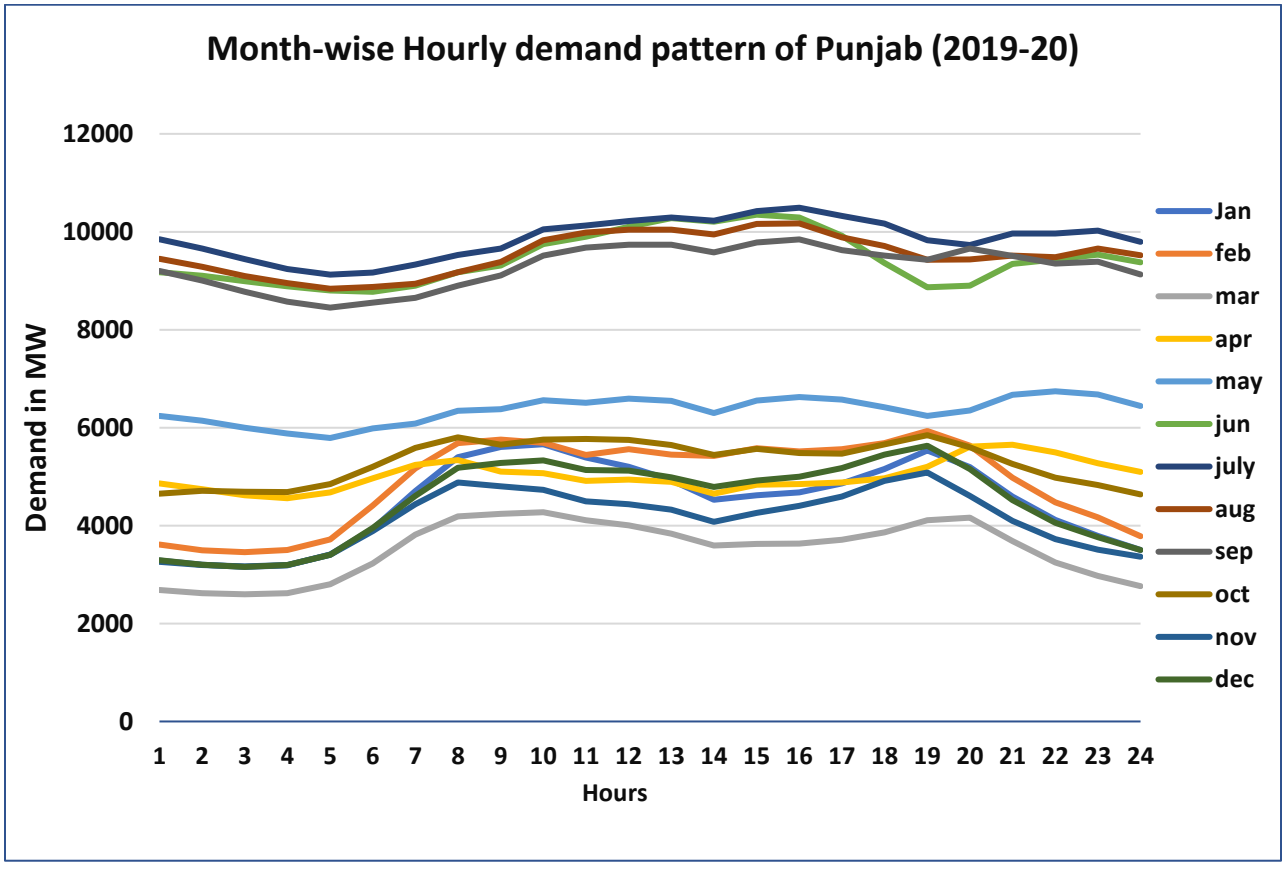

Figure 2 Average Hourly Monthly Demand Profile (MW)

It can be seen that during the months of July to September the electricity demand peaks by around 80% as compared to other months while the minimum demand is seen during the winter months of December to February.

Also, during the peak months, the demand incident on the grid is nearly constant during the day. However, during winter months, the afternoon demand is considerably higher than the

morning/evening hours. Punjab has prominent Day Peak in Monsoon Months from June till September while there is no significant variation in Day and night peak demand for rest of the year.

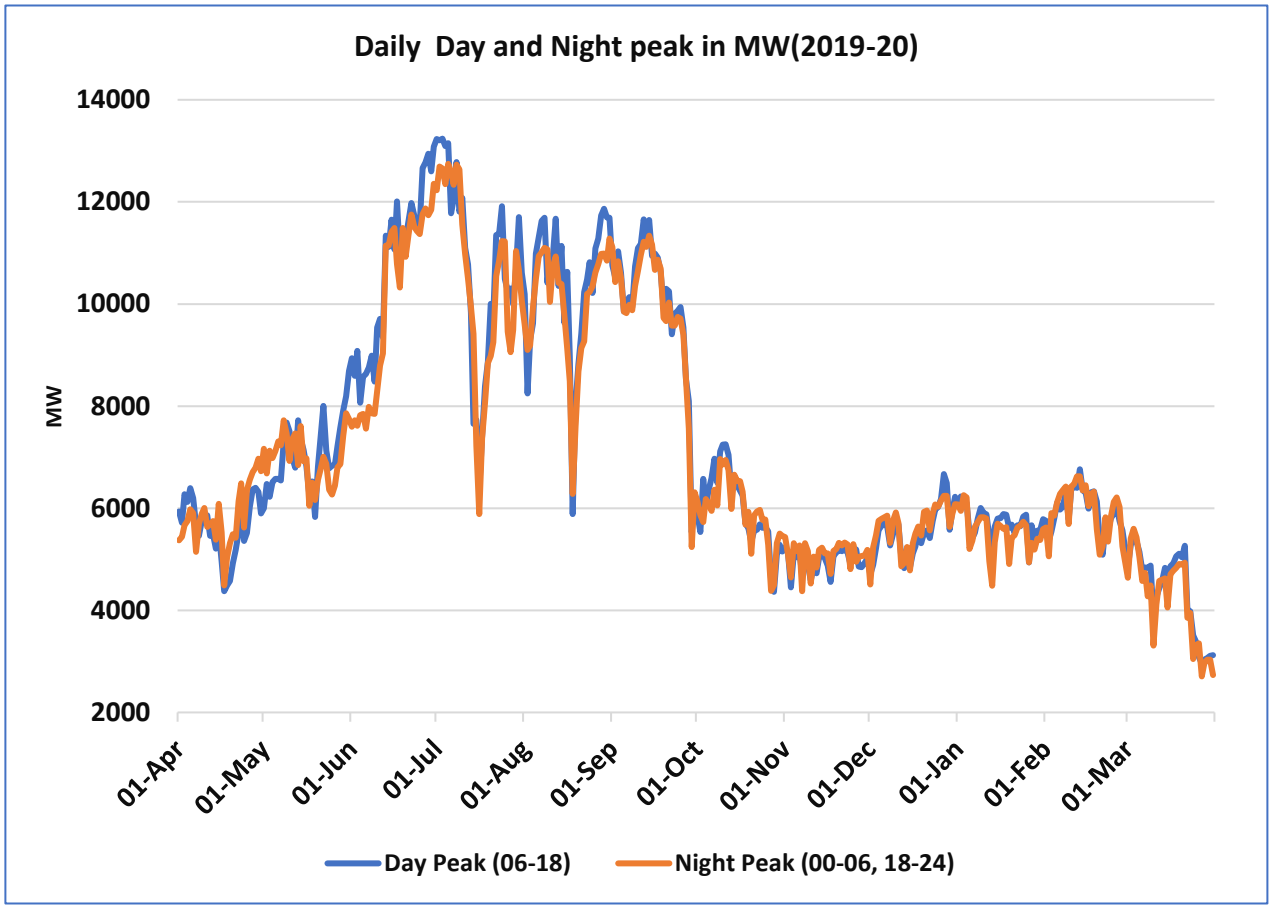

Figure 3 Day and Night Peak in MW of Punjab (2019-20)

The hourly demand pattern of 2019-20 was analyzed for finding out the number of occurrences of the peak and near peak demand. Such instances are critical for study purpose as it is necessary to ensure resource adequacy during such instances with an optimal mix of long-term, medium-term and short-term contracts.

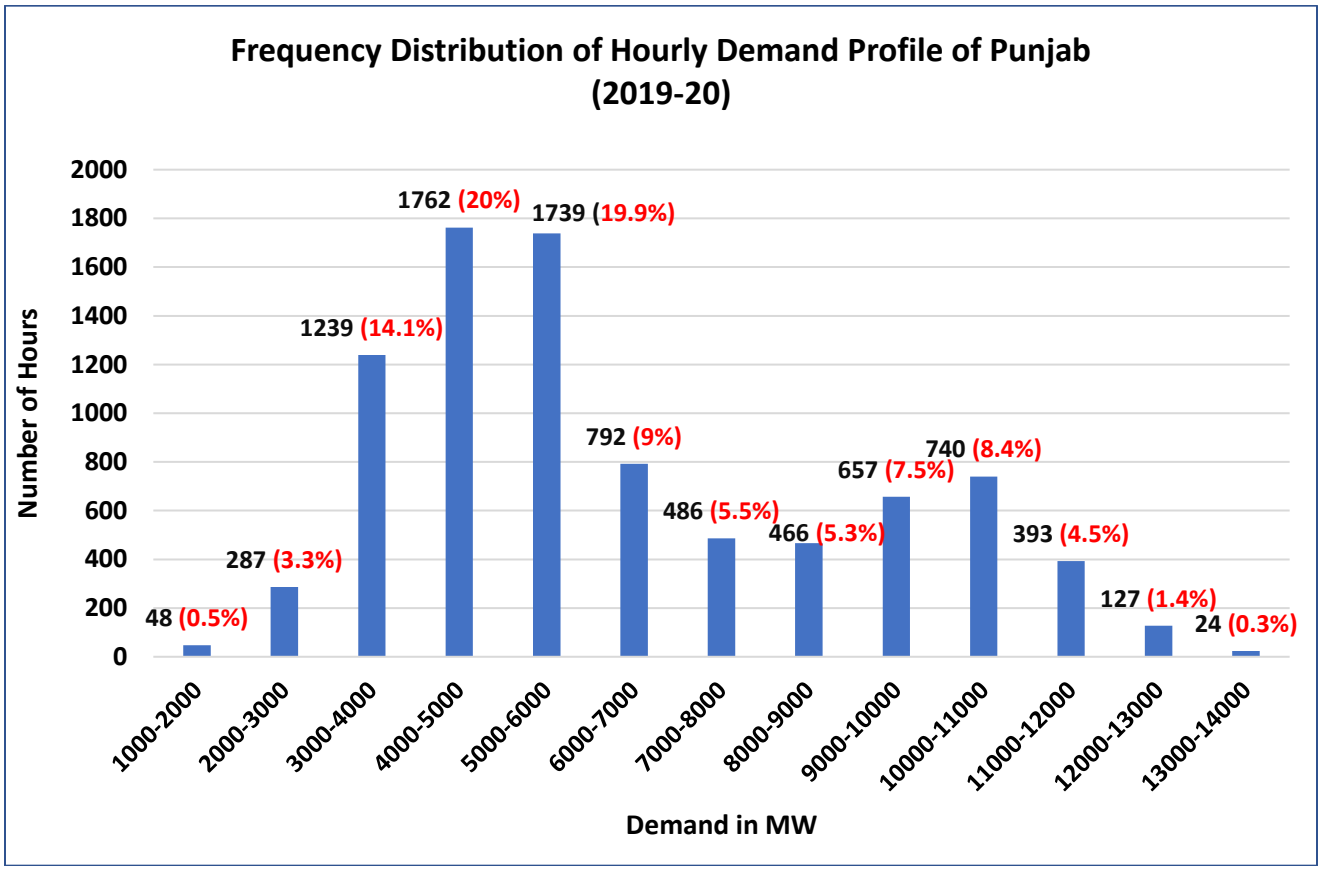

Figure 4: Frequency Distribution of Hourly Demand Profile of Punjab

3.0 Inputs/Assumptions for the Study

i) Peak and Energy Demand for the state of Punjab has been taken as per 20th EPS (Electric Power Survey) report and includes demand from Open Access. The energy Demand estimation by PSPCL was lower than projected by 20th EPS and actual demand recorded in 2022-23 while State Peak demand projections is more than the 20th EPS projections. The suppression of future demand estimate may lead to underestimation in capacity requirement in RA studies. Hence 20th EPS estimates were found to be reasonable demand inputs for the study period.

Table 2 Future Demand Projection by 20th EPS

Energy Requirement (MU) and Peak Demand (MW) Projections as per 20th EPS								
	2022-23	**2023-24**	**2024-25**	**2025-26**	**2026-27**	**2027-28**	**2028-29**	**2029-30**
Energy Projections (MU)	66464	69686	73493	77571	81959	86536	91359	97237
Year on Year Growth		4.85%	5.46%	5.55%	5.66%	5.58%	5.57%	6.43%
Peak Demand Projections (MW)	14327	14859	15502	16189	16925	17684	18478	19466
Year on Year Growth		3.71%	4.33%	4.43%	4.55%	4.48%	4.49%	5.35%

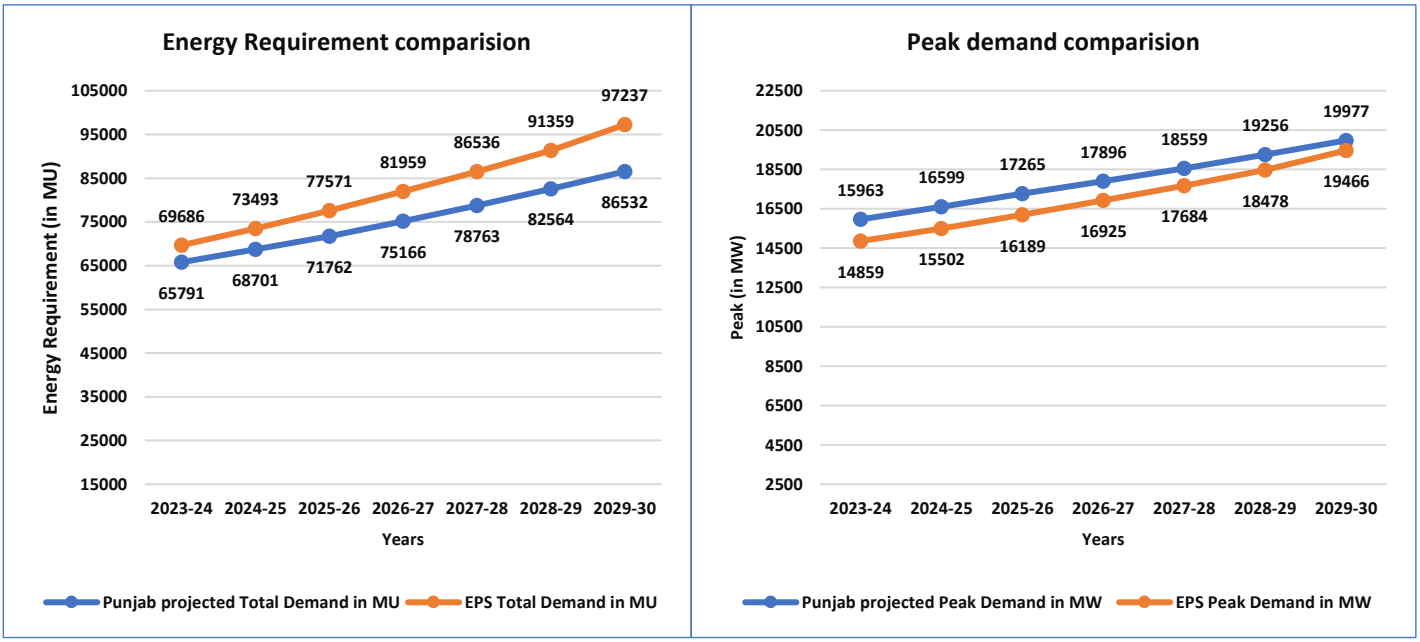

Figure 5 Comparison of Energy Requirement and peak Demand Projections of EPS vs Punjab

ii) The hourly power demand data of the state for the last three years viz. 2017-18 to 2022-23 (except Covid affected years 2020-21 and 2021-22) was analyzed for assessing the occurrence of daily, monthly and seasonal peaks as well as the variation in the shape of the demand curve throughout the year. It was found that the hourly demand pattern for the years 2017-18 and 2018-19 are most representative of the current demand pattern for the state. Therefore, future hourly demand profile for the year 2029-30 has been projected while considering the demand of the state for the year 2017-18 and 2018-19 as the base profile.

iii) The solar and Wind generation for the state of Punjab is mostly from tie ups from developers outside the state. Therefore, for the studies solar generation profile of Northern region (as considered for National Electricity Plan (NEP), 2023 studies), has been considered for the studies. Similarly, for Wind capacity, wind generation profile of Northern region has been considered.

iv) The average annual CUF of solar capacity was estimated to be around 18.5 % and that of wind capacity as 24.33 % based on the historic data. However, the annual CUF of the upcoming solar capacity is considered to be on the higher side due to technology improvements (24 %).

v) The hydro energy availability varies significantly across the years as it depends on the monsoon rains in a particular year. The historical monthly energy generation for the Hydro plants has been considered for the studies. The model optimizes available hydro generation in such a way that maximum benefit of hydro can be exploited

during peak hours along with ensuring minimum outflow even during off-peak hours.

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

vii) Projected source-wise capacity addition till 2029-30:

As per the information received from PSPCL, Punjab, the year-wise likely increase in contracted and/or planned capacity (MW) for the State of Punjab is shown in table below:

Table 3

Resource	Planned Capacities (in MW)						
	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30
Thermal	0	0	0	0	800	800	800
Solar	0	0	0	0	0	0	0
Wind	0	0	0	0	0	0	0
Hydro	144	288	0	0	0	0	0
Biomass	0	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0	0
Total	144	288	0	0	800	800	800

viii) The details of the year-wise planned capacity addition are attached at Annexure.

ix) 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). However, the studies have been based on RPO trajectory notified by the Ministry vide order dated 22nd July, 2022. In order to meet its Renewable Purchase Obligation (RPO) Punjab needs to add/contract additional renewable capacity (MW) as assessed 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	1115	1808	2606	3516	4526	5628	6748
Hydro	460	794	1148	1475	1861	2293	2742
Other RPO	17289	19380	21852	24473	27198	29865	32642

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	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydro	505	1438	1438	1438	1438	1438	1438
Other RPO	15447	15447	15447	15447	15447	15447	15447

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	-1070	-1163	-2316	-3516	-4526	-5628	-6748
Hydro	0	0	0	-37	-422	-855	-1304
Other RPO	-1842	-3933	-6405	-9026	-11751	-14418	-17196

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

Table 7 As per RPO trajectory, the year wise additional capacity (MW) required by Punjab to add/contract is as follows:

	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30
Wind	502.76	43.82	541.55	563.62	474.37	517.64	526.40
Hydro	0.00	0.00	0.00	11.45	118.86	133.47	138.52
Other RPO	1051	1193	1411	1496	1556	1522	1586
TOTAL	1553.76	1236.82	1952.55	2071.07	2149.23	2173.11	2250.92

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 analyzing 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. The range of variation considered for generating the samples of different system parameters are depicted in the table below:

Table 8

SI No.	**System Parameter**	**Range of Variation (in %)**
1.	Forced outage of conventional generators	10±5
2.	RE generation	±10
3.	Demand	±5

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.

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 2029-30 is about 560.9 MU. The yearly likely unserved energy with the planned capacities is given below.

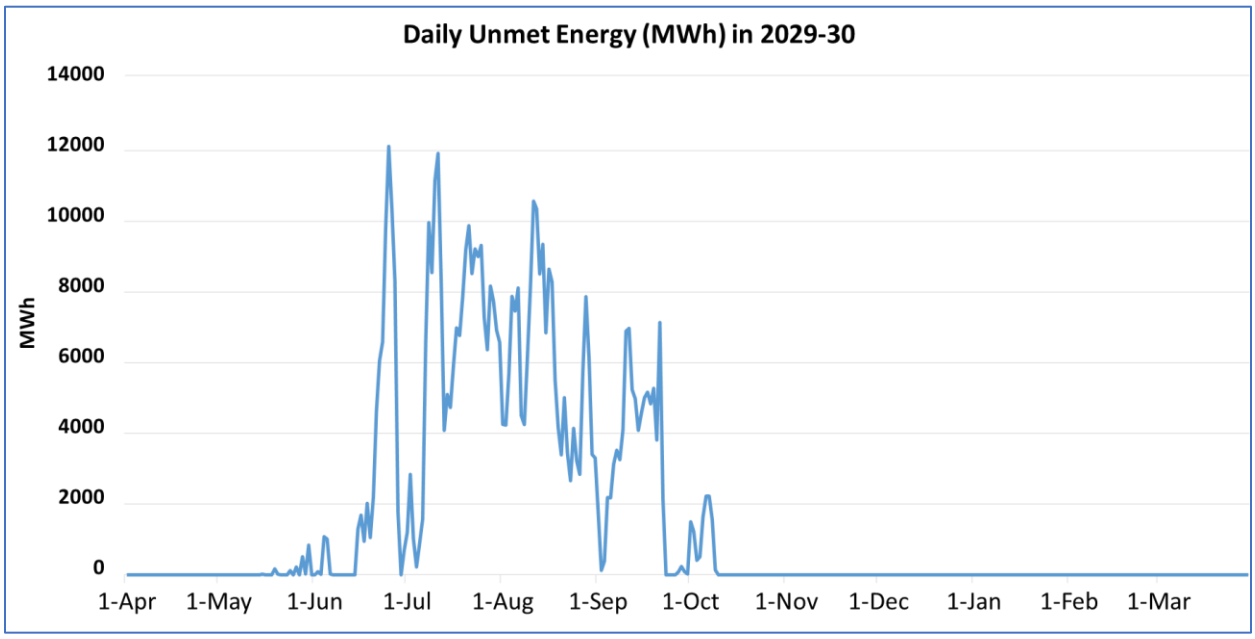

Figure 6 Yearly likely unserved energy with the planned capacities for Punjab (in MU)

It can be seen from the above pattern that quantum of unserved energy shall be maximum during the months of July and August. The monthly unmet energy in million units (MU) is tabulated below:

Table 9

Sl. No.	Months	Monthly Unmet Energy (MU)
1.	May	1.93
2.	June	71.86
3.	July	204.07
4.	August	184.28
5.	September	87.29
6.	October	11.44

The unserved energy coincides with peak demand months when the contracted capacity (present, planned and additional RE for RPO) is unable to meet the demand. The quantum of unserved energy that is likely to be maximum in the months of July and August is suggested to be met through short term power contracts.

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 no requirement of storage for Punjab till 2031/32.
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 Punjab are given below:

Table 10 Year-wise capacity projections (in MW)

Year-wise projected contracted capacity of Punjab (in MW)									
YEAR	COAL	GAS	NUCLEAR	HYDRO	WIND	SOLAR	BIOMASS	STOA/ MTOA	TOTAL Contracted Cap
2023/24	8233	137	197	3591	953	2988	212	4882	21193
2024/25	8233	137	197	3879	997	4182	212	5180	23017
2025/26	8233	137	197	3879	1538	5593	212	5564	25353
2026/27	11197	137	197	3890	2102	7089	212	5300	30124
2027/28	11197	137	197	4009	2576	8644	212	5300	32272
2028/29	12797	137	197	4142	3094	10167	212	5300	36046
2029/30	13597	137	197	4281	3620	11752	212	5300	39096

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

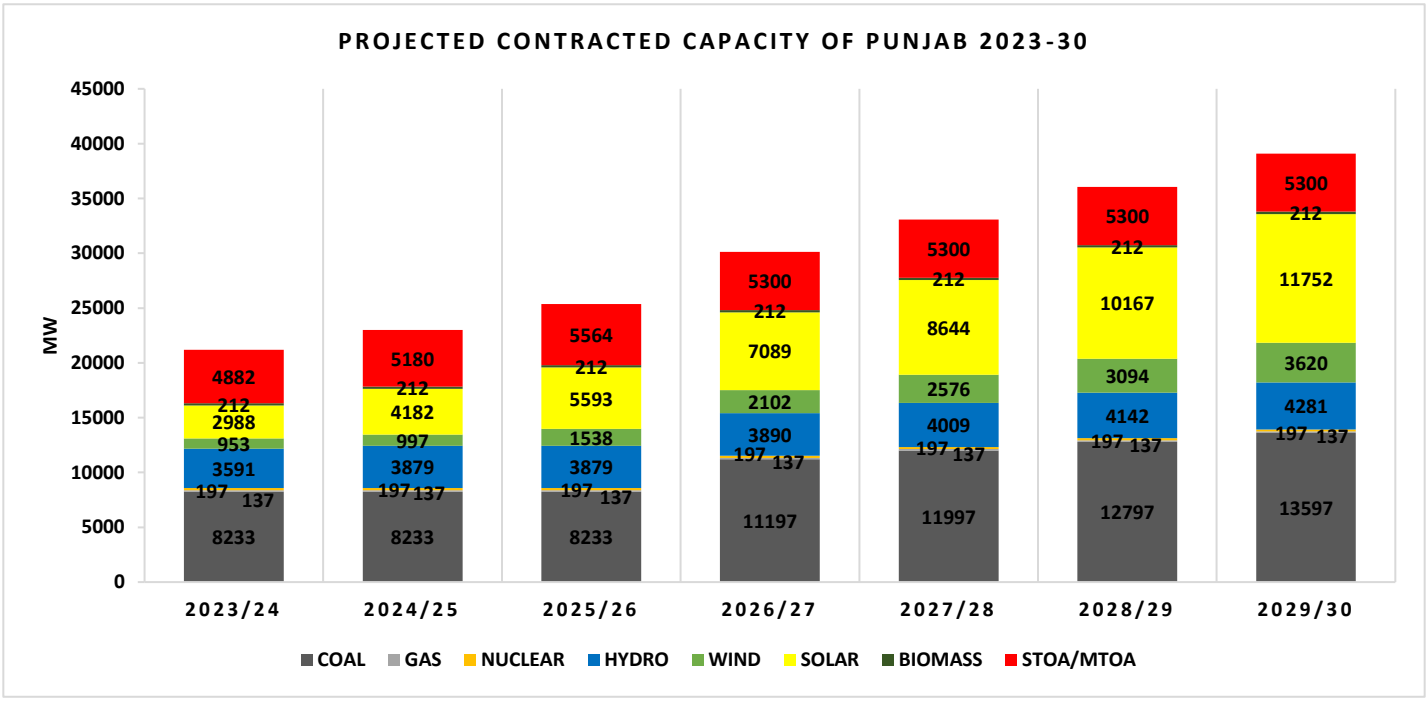

Figure 7 Projected Capacity Mix Year-wise (MW) for Punjab

As per the Resource Adequacy studies, the projected contracted capacity for the year 2029-30 for the Punjab state is 39096 MW which consists of 13597 MW from Coal, 137 MW from Gas, 197 MW from Nuclear, 4,281 MW from Hydro, 3,620 MW from Wind, 11752 MW from Solar and 5300 MW from STOA/MTOA. The dependence on STOA/ MTOA is primarily during the high demand season and it may not be economical to have long term contracts dedicated for meeting the surge in demand witnessed during the monsoon months. Bilateral/ Banking arrangements may be suitable for meeting the quantum of contracts mentioned as STOA/MTOA. This quantum and mix of contracted capacity shall be able to meet the projected demand with prescribed reliability criteria.

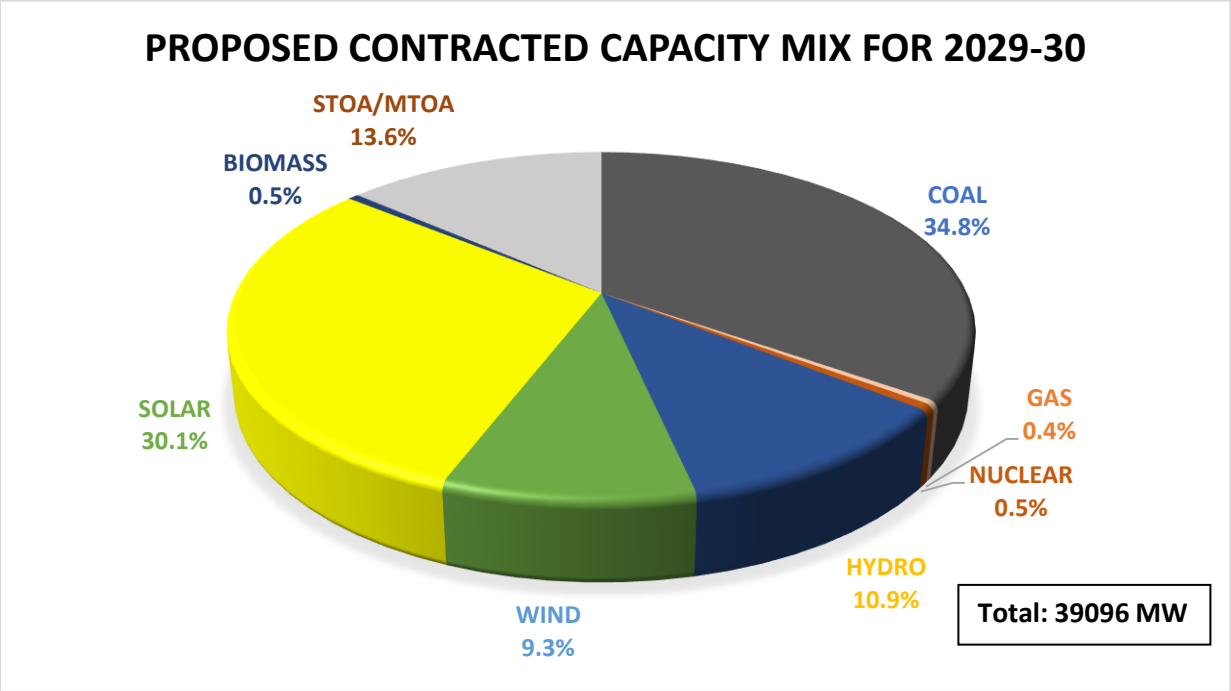

Figure 8 Contracted Capacity Mix in 2029-30 with 21% PRM

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 Punjab has been assessed as 21%. In addition, the projected/contracted capacity fulfils the stipulated Renewable Purchase Obligation.

The share of non-fossil fuel based Contracted capacity excluding STOA/MTOA is expected to increase from 48% in 2023-24 to about 60% by 2030 with higher contribution from non-fossil fuel-based capacities in alignment with RPO trajectory.

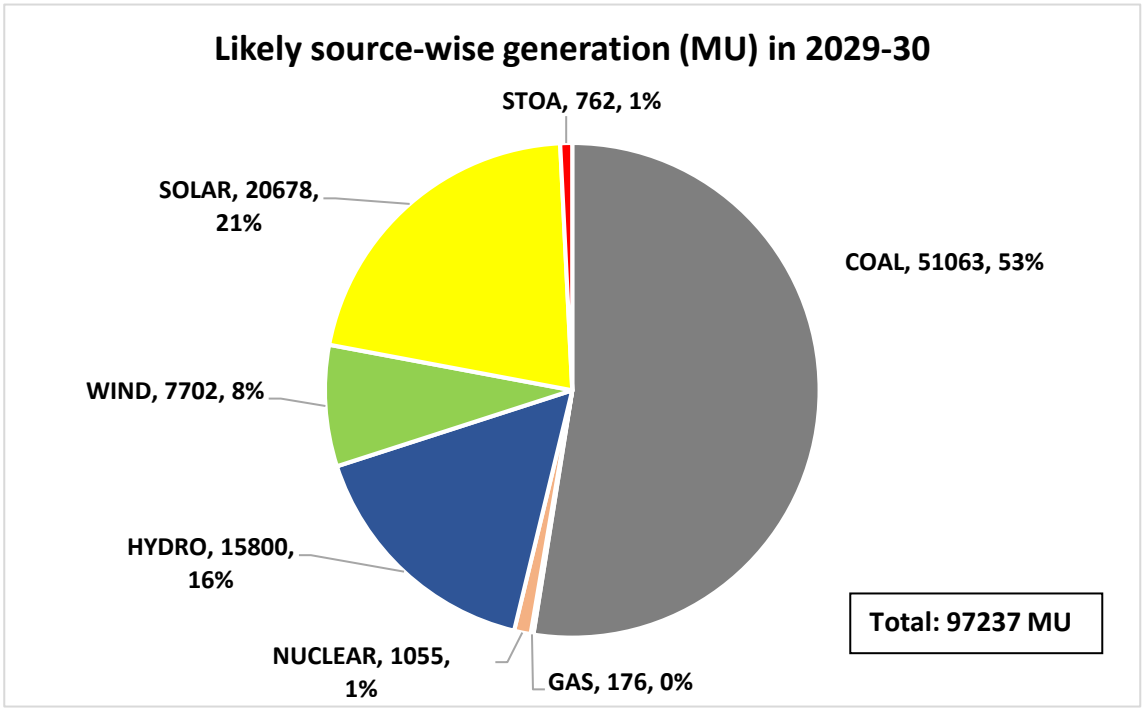

Figure 9 Year-wise projected net generation mix (in GWh)

5.3 Day-wise Surplus Capacity Punjab (MW)

The pattern of surplus capacities 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.

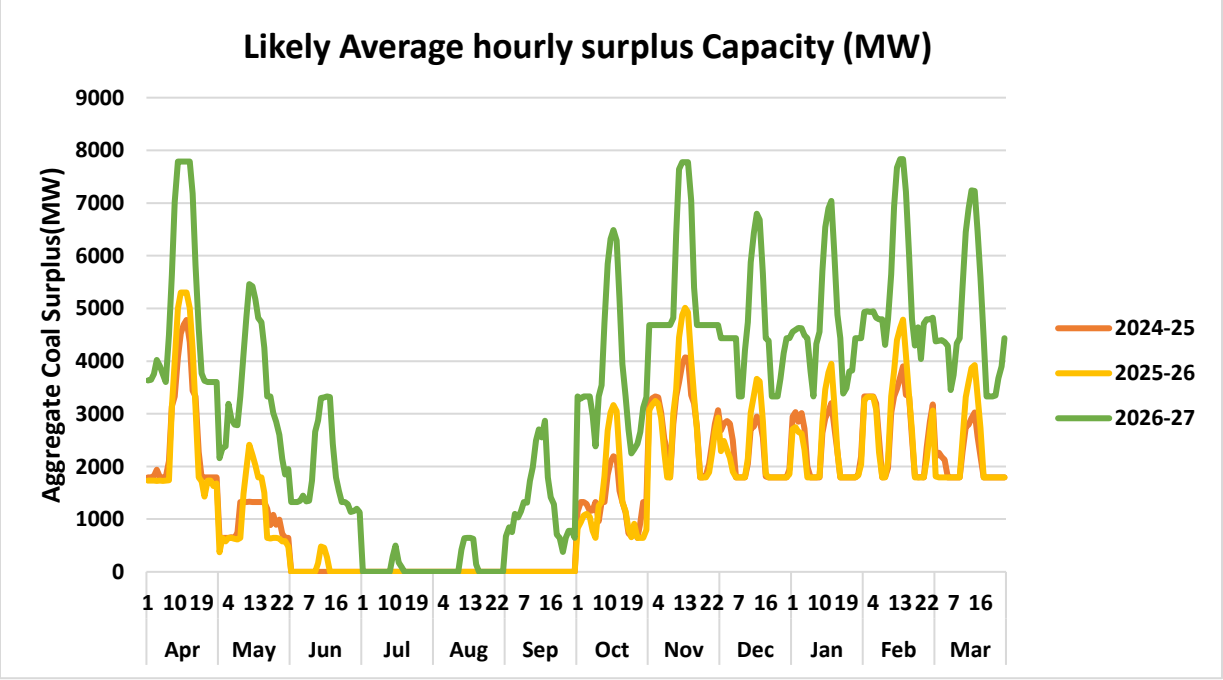

Figure 10 Surplus Capacity Year-wise (MW)

5.4 Capacity contract requirement for future

It has been found out in the studies that Punjab 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 11 Year wise Capacity Addition for Punjab (in MW)

	COAL		HYDRO		WIND	SOLAR	TOTAL		MTOA/STOA
	Planned contract	**Additional contract**	**Planned contract**	**Additional contract**	**Additional contract**	**Additional contract**	**Planned contract**	**Additional contract**	**Additional Contract**
2023/24	0	0	144	0	503	1051	144	1554	4882
2024/25	0	0	288	0	44	1194	288	1238	5180
2025/26	0	0	0	0	541	1411	0	1952	5564
2026/27	0	2964	0	11	564	1496	0	5035	5300
2027/28	800	0	0	119	474	1555	800	2148	5300
2028/29	800	0	0	133	518	1523	800	2174	5300
2029/30	800	0	0	139	526	1586	800	2251	5300
TOTAL	**2400**	**2964**	**432**	**402**	**3170**	**9816**	**2832**	**16352**	

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 (Stressed) scenario:

- Peak and Energy Demand- 5% increase compared to the EPS demand

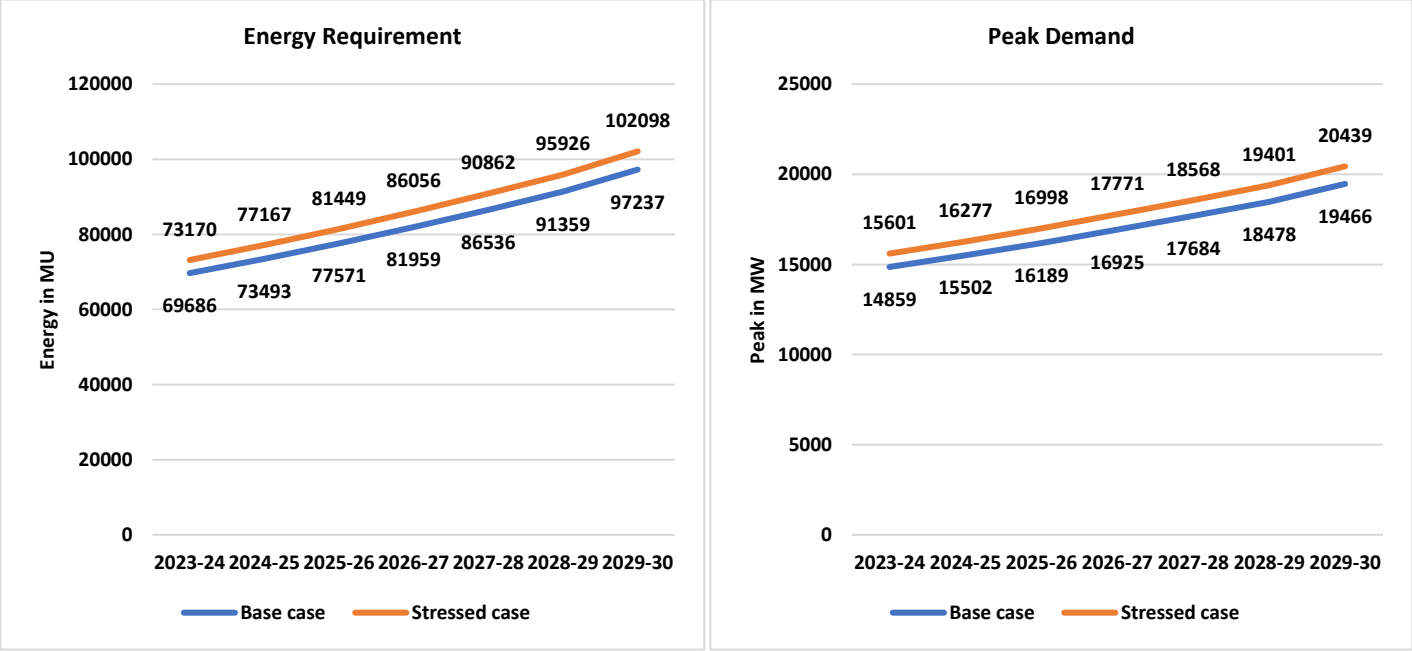

Figure 11

- Capacity Addition being delayed from their anticipated year as follows:

Table 12 Time Delay in commissioning of contracted capacity

Contracted Capacity Type	Years Delayed
Hydro	2
Nuclear	2
Renewable Energy Capacity	1
Coal	1

6.1 Year-wise RPO Requirement in Alternate Resilient Scenario:

Table 13 Year-wise capacity requirement (in MW) for RPO compliance in Alternate Resilient Scenario

Additional RE Capacity(MW) required to be added/contracted for meeting RPO in case of increased demand								
	2023-24	**2024-25**	**2025-26**	**2026-27**	**2027-28**	**2028-29**	**2029-30**	**Total**
Wind	100	342	394	449	498	544	553	**2879**
Large + Small Hydro	137	108	0	0	125	140	145	**656**
Solar + Other RE	2198	1253	1481	1571	1633	1598	1664	**11399**
Total	**2435**	**1703**	**1875**	**2020**	**2256**	**2282**	**2363**	**14934**

6.2 Capacity Mix Projections

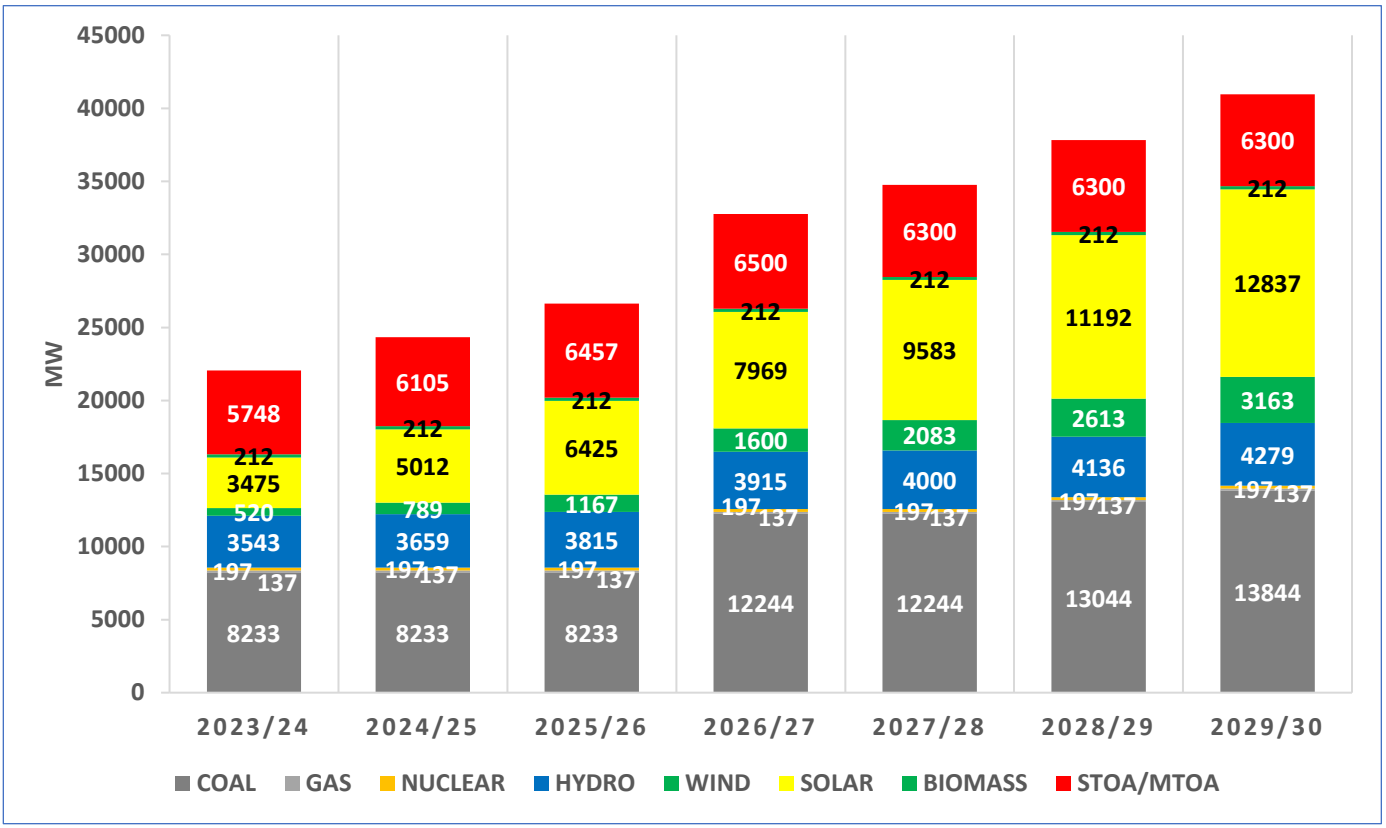

Figure 12: Year-wise capacity projections (in MW) for Most Resilient Scenario

In this scenario, 4,011 MW of additional Coal based required from 2026-27 onwards (beyond under construction/ planned) in stressed scenario. The requirement of STOA/MTOA/Banking arrangement/Market based contracts to meet the power deficit in peak hours during July/August in stressed scenario increases up to 6500 MW in 2026/27 and 6300 MW in 2029/30.

Table 14 Year-wise capacity requirement (in MW) in Alternate Resilient Scenario

	COAL		HYDRO		WIND	SOLAR	TOTAL		MTOA/STOA
	Planned contract	Additional contract	Planned contract	Additional contract	Additional contract	Additional contract	Planned contract	Additional contract	Additional Contract
2023/24	0	0	0	96	70	1051	0	1217	5748
2024/25	0	0	0	117	269	1537	0	1580	6105
2025/26	0	0	144	12	378	1413	144	1801	6457
2026/27	0	4011	236	0	432	1544	236	5939	6500
2027/28	0	0	52	33	483	1614	52	2071	6300
2028/29	800	0	0	136	530	1609	800	2189	6300
2029/30	800	0	0	144	550	1645	800	2280	6300
TOTAL	**1600**	**4011**	**432**	**538**	**2712**	**10413**	**2032**	**17077**	

Projected Contracted Capacity (Base Case vs Projected Stress Case for year 2029-30)

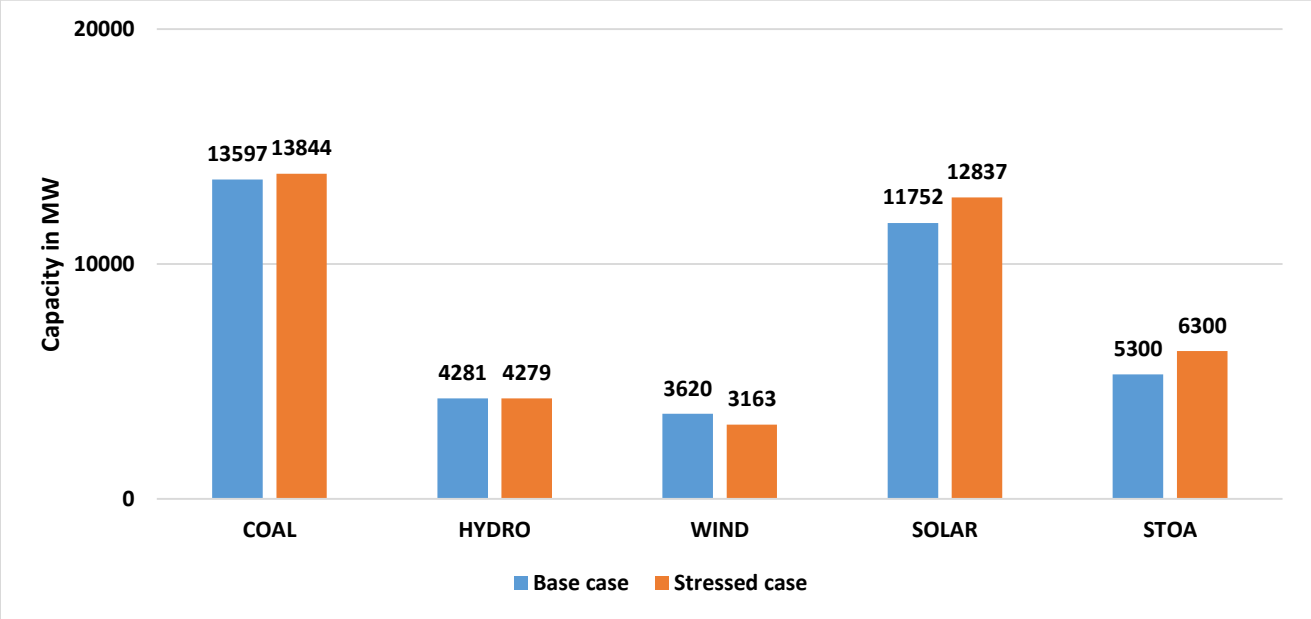

Figure 13

In the stress case, the projected contracted capacity in coal is increased to 13844 MW as against to 13597 MW in 2029-30 and a significant increase is also observed in STOA/MTOA market contracts from 5300 MW to 6300 MW.

7.0 Conclusion

1) The study has considered two scenarios for assessing the resource adequacy of Punjab based on the demand projections by Electric Power Survey. The demand projections by PSPCL are slightly lower compared to the demand projections by 20th Electric Power Survey (EPS).

2) The current capacity mix in Punjab has about 57% of IC from fossil fuel sources. The peak demand season is monsoon months from June to September. The study is based on the hourly load pattern of the year 2019-20.

3) Punjab is likely to witness energy deficit of about 561 MU in 2029-30 with the existing and planned capacity addition. Punjab 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 and ESO obligations by 2030 as specified by Ministry of Power. It requires to contract Solar and wind capacities from 2023/24 and hydro from 2026/27 till 2029/30.

4) Punjab is likely to have unserved energy in coming years and need to contract fossil and non- fossil capacities for meeting energy requirements other than the planned capacities. Punjab requires additional coal-based capacities to be procured other than the capacity already planned to the quantum of around 2960 MW. The quantum of capacities required to be contracted is about 9816 MW from solar, 3170 MW from Wind, 402 MW from Hydro in addition to the already planned capacities. Punjab does not require to contract storage capacities like PSP/ BESS for the purpose of energy shifting to night hours as the energy demand in night hours is low compared to day hours.

5) The dependence on STOA/ MTOA is primarily during the high demand season to the quantum of about 5300 MW in 2029-30. It may not be economical to have long term contracts dedicated for meeting the surge in demand witnessed during the monsoon months. Bilateral/ Banking arrangements may be suitable for meeting the quantum of contracts mentioned as STOA/MTOA. The energy requirement to be met from STOA is about 1% of the total energy requirement but is critical in winter months of peak demand to fulfil the end consumer demand. STOA value reflects the peak value (MW) requirement in the capacity mix.

6) The Alternate Resilient Scenario carried out for Punjab for possibility of higher demand than projected by 20th Electric Power Survey has revealed that the coal requirement increases by around 1000 MW from 2026/27 compared to the base case scenario. The requirement of storage and dependency on STOA also increases compared to the base case scenario.

7) It is likely that Punjab may have surplus capacity available during the winter months from November to March (tentatively in the range of 2000 MW) which can be shared with other states resulting in reduction in fixed cost of capacities.

Annexure

Future Contracted/Approved Capacity (MW) of Central and State Sector

Plant Name	Type	Expected COD/ Remark	PSPCL share (in MW)
Parbati-II	Hydro	2023-24	80
Subhansri	Hydro	2023-24	64
Vishnugarh Pipalkoti	Hydro	2024-25	30
Shahpur Kandi	Hydro	2024-25	206
Tapovan Vishnugarh	Hydro	2024-25	52
Super-critical Power plant Ropar Unit-1	Thermal	2027-28	800
Super-critical Power plant Ropar Unit-2	Thermal	2028-29	800
Super-critical Power plant Ropar Unit-3	Thermal	2029-30	800

Assumptions for Resource Adequacy Studies for the state of Punjab

1. Electricity Demand & peak requirement: As per 20th Electric Power Survey
2. Demand Profile: Based on hourly demand profile of 2022-23 (2020-21 & 2021-22 were neglected due to Covid affected)
3. Existing & Planned Capacity: As per the information received from PSPCL
4. Future Capacity addition: based on RPO trajectory
5. Cost parameters: based on information received from PSPCL

RE CUF considered

Existing Hydro PLF	Planned Hydro PLF	Bioenergy PLF	Existing Solar CUF	Planned Solar CUF Average	Existing Wind CUF	Planned Wind CUF(Average)	Small Hydro CUF
27.0%	48%	25.0%	19.3%	22.0%	19.5%	24%	17.2%

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	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	-	-	-	-	-
Biomas s	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	-	-	-	-	-
	Candidate	-	-	80 %	-	-	-	-	-
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.