सत्यमेव जयते

Report on Resource Adequacy Plan for the utility NDMC, Delhi

(2024-25 to 2033-34)

Government of India
Ministry of Power
Central Electricity Authority

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Executive Summary

India's power sector has seen a huge transition during the last few years, driven primarily by climate change and energy security concerns. In August 2022, India updated its NDC according to which target to reduce emissions intensity of its GDP has been enhanced to 45 percent by 2030 from 2005 level, and the target on cumulative electric power installed capacity from non-fossil fuel-based energy resources has been enhanced to 50% by 2030. Consecutively, there has been substantial addition of renewable energy (RE) and transmission capacities.

As per Rule 16 of the Electricity (Amendment) Rules 2022, 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) to meet the utility peak and energy requirement reliably.

As per the Resource Adequacy Guidelines, each Distribution licensee shall undertake a Resource Adequacy Plan (RAP) for a 10-year horizon (Long-term Distribution Licensee Resource Adequacy Plan (LT-DRAP)) to meet their own peak and electrical energy requirement. The plan shall be vetted/validated by Central Electricity Authority for leveraging the benefit of national level optimization for the Distribution licensees. The LT-DRAP shall be carried out by the distribution licensees on an annual rolling basis considering the contracted capacity as a part of the system and shall optimize for additional capacity required.

The Government of India has notified new Renewable Purchase Obligation (RPO) trajectory till 2029-30 vide gazette notification dated 20th October, 2023 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 electricity energy requirement and peak demand for NDMC, Delhi is increasing with a CAGR of 2% and 3.18% respectively from 2023-24 to 2031-32 as forecasted in 20th EPS. The projections of NDMC indicate that electricity energy requirement and peak demand may increase with a CAGR of 5.94% and 5.96% respectively from 2023-24 to 2033-34. For satisfying resource adequacy i.e., meeting the electricity demand reliably and at affordable cost, the utility 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 that the future generation capacity mix is cost effective as well as environment friendly.

The energy consumption of the utility is majorly constituted from commercial consumers i.e., 73% and the consumption pattern is observed to undergo seasonal and diurnal variation. The electricity demand starts increasing from the month of April and is maximum during the month of June and July. The demand during the months of May to September is significantly higher

compared to rest of the year. The lowest electricity demand generally occurs during winter months. The peak electricity load is generally observed during day hours.

To find out the least cost option for generation capacity expansion for the period 2024-25 to 2033-34, long-term study for the utility, was carried out 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.

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.

Reliability analysis was also carried out with varying demand, RE Generation and forced outage of coal-based capacities. Based on the study, 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.

As per the Resource Adequacy studies, the total projected Capacity for the year 2033-34 is 821 MW (along with 25 MW of Storage from Battery and 90 MW from Distributed Renewable Energy (DRE)) which consist of 99 MW of coal, 200 MW of Gas, 2.44 MW of Biomass, 150 MW of Hydro, 200 MW of Solar and 170 MW of Hybrid. Additionally, 400 MW from short term/medium term/market based tie ups may be required. This estimated Installed Capacity (IC) is likely to meet the projected demand with prescribed reliability criteria

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/ short-term basis.

Further, Ministry of Power vide gazette notification dated 20th October, 2023 had notified the source wise minimum share of consumption of non-fossil sources (renewable energy) by designated consumers. Based on the trajectory specified, RPO quantum in million units (MUs) from hydro, wind, other (solar, biomass etc.) and distributed renewable energy (DRE) 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 NDMC in fulfilment of the designated RPO trajectory, on the basis of the inputs received from the utility. The study suggests the optimal resource mix till 2033-34 taking into account the 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 NDMC, catering to above highlighted uncertainties so that demand can be met reliably throughout the year.

2.0 NDMC RA Study

2.1 Present Power Scenario in NDMC

As of March, 2024, the total contracted capacity of NDMC is 644 MW. Out of the total contracted capacity (CC), the share of non-fossil fuel based contracts capacity is 9%.

The fuel-wise contracted capacity as of 31st March, 2024 is given in Table and Figure below:

Table 1 Fuel-wise Contracted Capacity as on 31st March, 2024

Source	Contracted Capacity (MW)	Percentage (%)
Coal	387	60%
Gas	200	31%
Green Power	55	9%
Biomass	2	0%
Total	**644**	100%

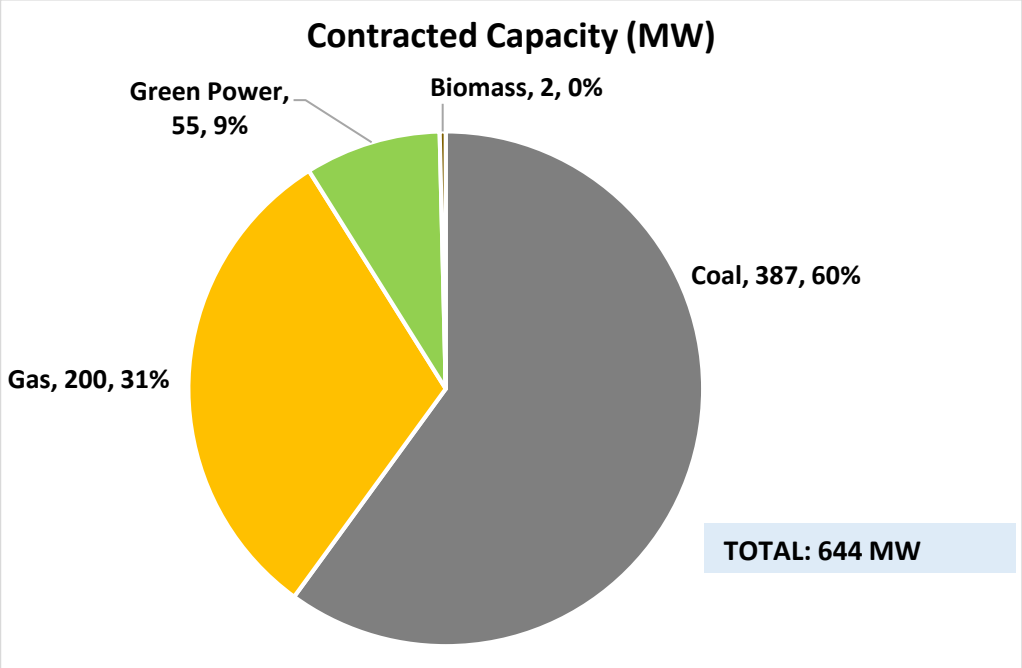


Figure 1 Fuel-wise Contracted Capacity (in MW) as on Mar 2024

2.2 Present Demand Analysis (2022-23)

Hourly demand pattern of 2022-23 was analyzed and it was observed that the peak demand of NDMC typically occurs during day time in June month and it is observed that the demand is comparatively higher during summer months (i.e, in April to September) than the rest of the year.

Monthly average demand of NDMC for the year 2022-23 was derived from the hourly demand data of that year in which two (2) distinct plots are observed for the months Apr-Sep and Oct-Mar, as shown in the figure below. The average hourly demand for the months of Apr-Sep is found to be in the range of 108 to 280 MW and for the months of Oct-Mar is found to be in the range of 72 to 188 MW. This clearly indicates that the range of average demand is higher for Apr-Sep months than that of Oct-Mar months.

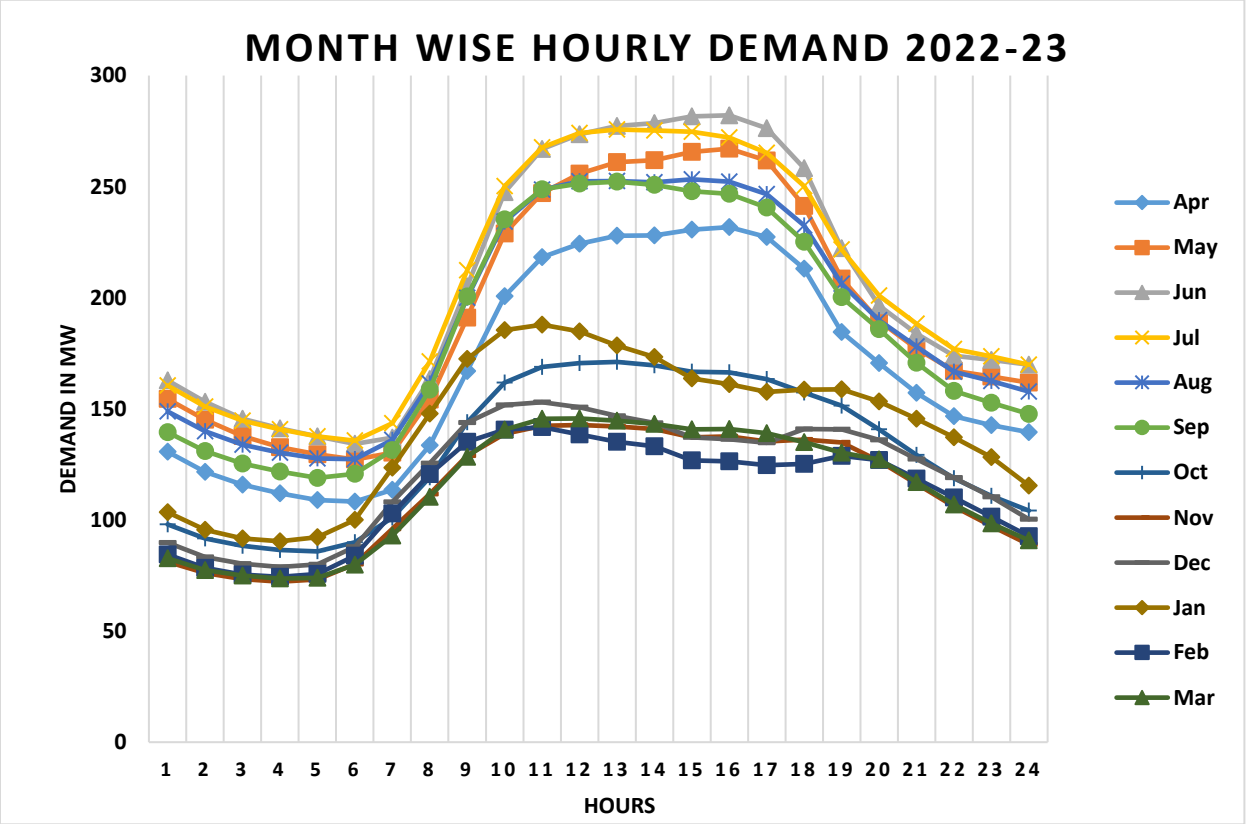


Figure 2 Month wise hourly average demand of utility in 2022-23

From the hourly demand of 2022-23 the daily peak during solar hours (06:00 to 18:00 hrs) and non-solar hours is plotted in the below figure. It is clearly visible that, the solar peak is higher than the non-solar peak throughout the year.

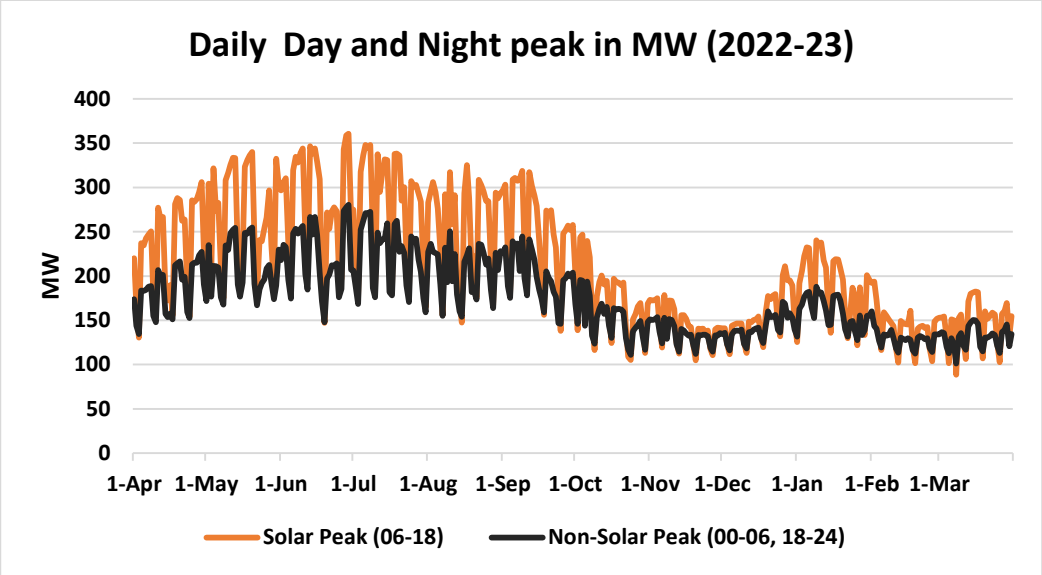


Figure 4 Day and Night Peak in MW of the utility(2022-23)

3.0 Inputs/Assumptions for the Study:

i) The electrical energy requirement projections and peak demand projections received from NDMC was compared with the projections in the 20th EPS. The following observations was found:

Table 2 Comparison in Energy requirement projections (MU)

Year	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34
As per 20th EPS	1,395	1,421	1,447	1,474	1,503	1,534	1,570	1,602	-	-
Year on Year Growth *(Energy)*	-	1.9%	1.8%	1.9%	2.0%	2.1%	2.3%	2.0%	-	-
As per NDMC	1,569	1,656	1,747	1,843	1,944	2,051	2,164	2,283	2409	2541
Year on Year Growth (Peak)	-	5.5%	5.5%	5.5%	5.5%	5.5%	5.5%	5.5%	5.5%	5.5%

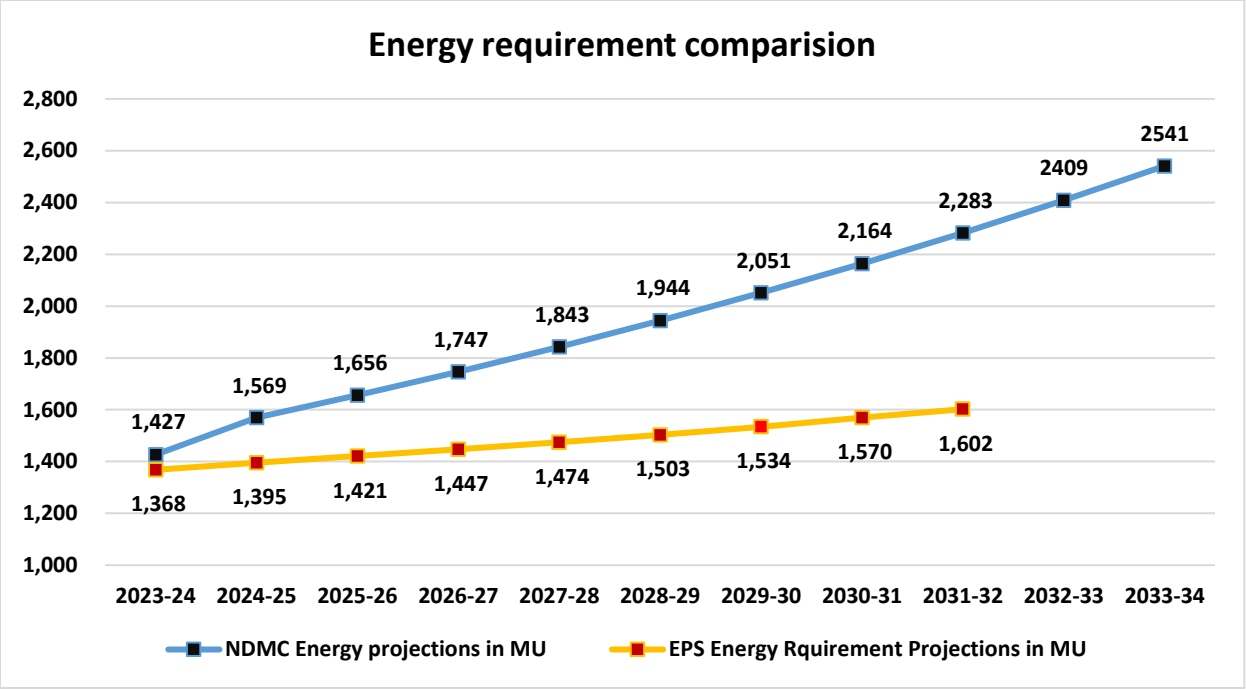


Figure 5 Graph on energy requirement comparison

Table 3 Comparison in peak demand projections (MW)

Year	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34
As per 20th EPS	390	403	416	430	443	457	470	483	-	-
Year on Year Growth *(Energy)*	-	3.3%	3.2%	3.4%	3.0%	3.2%	2.8%	2.8%	-	-
As per NDMC	420	440	464	490	517	545	575	607	641	676
Year on Year Growth (Peak)	-	4.7%	5.5%	5.5%	5.5%	5.5%	5.5%	5.5%	5.6%	5.5%

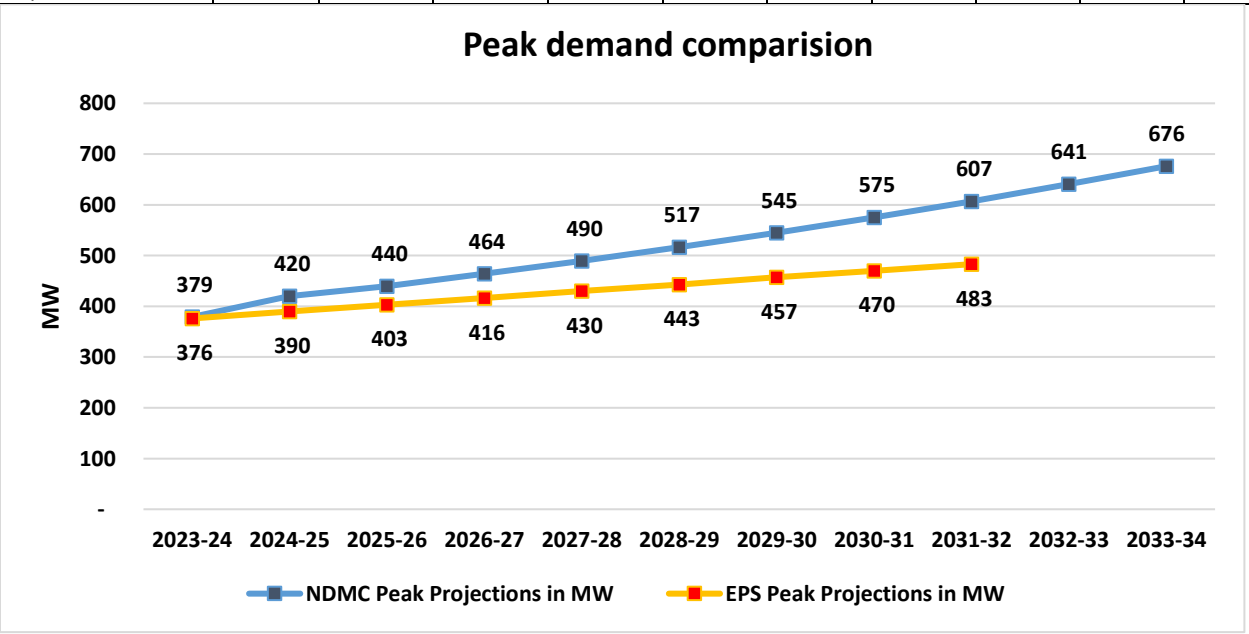


Figure 6 Graph on Peak Demand (MW) comparison

ii) Analysing the actual trend of demand growth over last few years and discussing with NDMC, the demand projections received from NDMC have been considered for the RA studies.

iii) 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 analysed 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 2019-20 and 2022-23 are most representative of the current demand pattern for the state. Therefore, future hourly demand profile has been projected while considering the demand of the state for the year 2019-20 and 2022-23 as the base profile.

iv) The plants wise hourly solar, wind and hybrid generation profile is derived as per the historical hourly dispatch data received from NDMC for its respective contracts.

v) Capital cost of candidate plants for Coal, Battery and PSP have been referred from National Electricity Plan 2022-32 (Vol -I generation).

vi) Planned Capacity has been considered as per the information received from NDMC (List is attached at **Annexure-I**). The planned capacity addition is tabulated below:

Table 4 Year on Year source wise planned capacity addition

Resource	Y-o-Y Planned Capacity Addition(MW) till 2033-34										TOTAL
	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	
Solar	200	0	0	0	0	0	0	0	0	0	**200**
Hydro	0	50	0	50	50	0	0	0	0	0	**150**
Hybrid	170	0	0	0	0	0	0	0	0	0	**170**
Total	**370**	**50**	**0**	**50**	**50**	**0**	**0**	**0**	**0**	**0**	**520**
Battery	25	0	0	0	0	0	0	0	0	0	**25**

vii) Based on inputs from the utility, the additional requirement from solar and wind based contracts are considered from 2026-27 and additional coal based contracts are considered from 2027-28 onwards.

Renewable Purchase Obligation (RPO) trajectory: Ministry of Power gazette notification dated 20th October, 2023 had notified the source wise minimum share of consumption of non-fossil sources (renewable energy) by designated consumers, till the year 2029-30. In view of the country's energy transition goals as well as the long term net zero target of 2070, it is estimated that the share of RE generation in the generation mix will continue to increase beyond 2029-30. Therefore, the RPO trajectory is assumed to rise steadily beyond 2029-30 and hence, RPO targets till 2033-34 are given below:

Table 5 RPO trajectory

Sl. No.	Year	Wind renewable energy	Hydro renewable energy	Other renewable energy	Distributed renewable energy (DRE)	Total renewable energy
1	2024-25	0.67%	0.38%	27.35%	1.50%	29.91%
2	2025-26	1.45%	1.22%	28.24%	2.10%	33.01%
3	2026-27	1.97%	1.34%	29.94%	2.70%	35.95%
4	2027-28	2.45%	1.42%	31.64%	3.30%	38.81%
5	2028-29	2.95%	1.42%	33.10%	3.90%	41.36%
6	2029-30	3.48%	1.33%	34.02%	4.50%	43.33%
7	2030-31	41.00%			4.50%	45.50%
8	2031-32	42.50%			4.50%	47.00%
9	2032-33	43.80%			4.50%	48.30%
10	2033-34	45.00%			4.50%	49.50%

The RPO trajectory up to 2029-30 is determined based on the Ministry of Power's RPO gazette notification dated October 20, 2023. The RPO trajectory for Wind, Hydro, and other RE sources beyond 2029-30 is based on the renewable energy generation envisaged in the National Electricity Plan (Volume I: Generation) for the period 2022-32. The RPO trajectory for Distributed Renewable Energy (DRE) beyond 2029-30 is capped at 4.50% due to the constraints highlighted by the utility. These include the limited available area for rooftop solar installations and the fact that Delhi is already among the top three states in terms of rooftop solar capacity installed per square kilometer, indicating a saturation point has been reached.

Based on the trajectory specified, RPO quantum in million units (MUs) from hydro, wind, other (solar, biomass, etc.) and distributed renewable energy (DRE) is calculated and tabulated below:

*Table 6 Energy required in fulfilment of RPO trajectory**

Sl. No.	Year	Wind renewable energy (MU)	Hydro renewable energy (MU)	Other renewable energy (MU)	Distributed renewable energy (MU)	Total renewable energy (MU)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	2024-25	10.51	5.96	429.23	23.54	469.41
2	2025-26	24.01	20.20	467.57	34.77	546.55
3	2026-27	34.41	23.41	522.99	47.16	627.97
4	2027-28	45.15	26.17	583.09	60.82	715.23
5	2028-29	57.35	27.61	643.53	75.82	804.12
6	2029-30	71.38	27.28	697.78	92.30	888.74
7	2030-31	887.24			97.38	984.62
8	2031-32	970.28			102.74	1073.01
9	2032-33	1054.92			108.38	1163.31
10	2033-34	1143.45			114.35	1257.80

*Considering the fungibility aspect of RPO targets among Wind, Hydro and other RE generation

The year-wise total renewable energy for Wind, Hydro and Other RE met with the existing and planned capacity along with the deficit is shown in Table 6 below:

Table 7 Renewable Energy other than DRE, Surplus(+)/Deficit(-)

Sl. No.	Year	Renewable energy required to meet RPO		Renewable energy available		Surplus(+)/ Deficit (-)
		(MU)	(%)	(MU)	(%)	(%)
1	2024-25	445.9	28.41%	469.5	29.92%	1.51%
2	2025-26	511.8	30.91%	1019.2	61.55%	30.64%
3	2026-27	580.8	33.25%	1030.3	58.99%	25.74%
4	2027-28	654.4	35.51%	903.0	49.00%	13.49%
5	2028-29	728.3	37.46%	972.6	50.03%	12.57%
6	2029-30	796.5	38.83%	1451.2	70.75%	31.92%
7	2030-31	887.2	41.00%	1516.4	70.08%	29.08%
8	2031-32	970.3	42.50%	1560.4	68.35%	25.85%
9	2032-33	1054.9	43.80%	1584.0	65.77%	21.97%
10	2033-34	1143.5	45.00%	1601.1	63.01%	18.01%

The year-wise total renewable energy for Distributed Renewable Energy (DRE) met with the existing planned capacity along with the deficit is shown in Table 7 below:

Table 8 Distributed Renewable Energy (DRE) Surplus(+)/Deficit(-)

Sl. No.	Year	DRE required to meet RPO		DRE available		Surplus(+)/ Deficit (-)
		(MU)	(%)	(MU)	(%)	(%)
1	2024-25	23.5	1.50%	0	0%	-1.50%
2	2025-26	34.8	2.10%	0	0%	-2.10%
3	2026-27	47.2	2.70%	0	0%	-2.70%
4	2027-28	60.8	3.30%	0	0%	-3.30%
5	2028-29	75.8	3.90%	0	0%	-3.90%
6	2029-30	92.3	4.50%	0	0%	-4.50%
7	2030-31	97.4	4.50%	0	0%	-4.50%
8	2031-32	102.7	4.50%	0	0%	-4.50%
9	2032-33	108.4	4.50%	0	0%	-4.50%
10	2033-34	114.3	4.50%	0	0%	-4.50%

Accordingly, in addition to the planned capacity contracts of NDMC, the year on year additional DRE (in MW) required to meet its RPO from 2026-27 onwards has been estimated and is tabulated below:

Table 9 Recommended year on year Capacity Addition (in MW)

Resource	Y-o-Y Planned Capacity Addition (MW) till 2033-34										TOTAL
	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	
DRE	0	0	38	10	12	13	4	4	5	4	**95**

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.

5.0 Demand variation:

The variation in demand pattern of NDMC, Delhi for last 2 years has been analyzed. The hourly demand variation for consecutive years (i.e. 2022-23 and 2021-22) has been analyzed.

The Demand pattern variation of 2022-23 and 2021-22 is shown below:

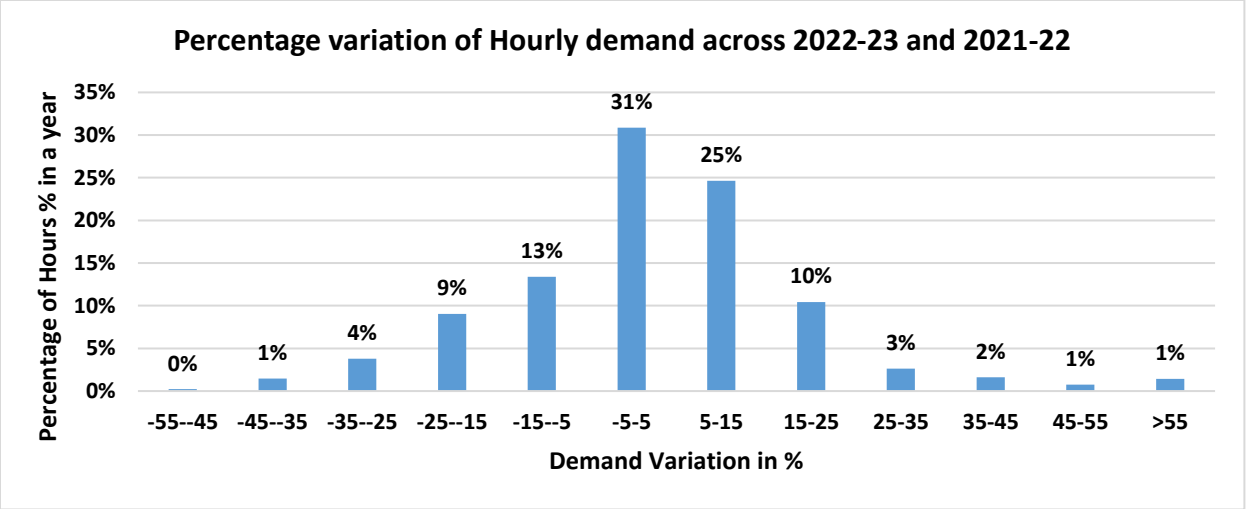


Figure 7 Percentage Variation in hourly Demand across years

It can be observed that the hourly demand typically varies ±15% and for 68 % of instances (i.e, hours) from corresponding hour in previous years (Normalized figure). 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 ±15% by introducing a random variable (with normal distribution) for demand as per the observed behavior over the years.

5.1 RE variation

In the Long-term capacity expansion planning studies, a particular profile for Solar and Wind Plants are considered based on the observed solar and wind generation data to determine the optimal capacity mix. However due to intermittent nature of these sources the generation from these non-dispatchable sources may vary across years. As per the analyses carried out based on historical generation data, solar generation and wind generation has been varied by 10% and 50% respectively to incorporate the variation in these generation sources and plan for requisite measures to mitigate such behavior.

5.2 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.

6.0 Results of the study

6.1 Unserved Energy Projections

The study was carried out considering existing capacity, planned capacity & capacity required to fulfil the RPO obligations. It was observed that the total unserved energy in the year 2033-34 is about 446 MU. The year-wise likely unserved energy with the planned capacities is given below.

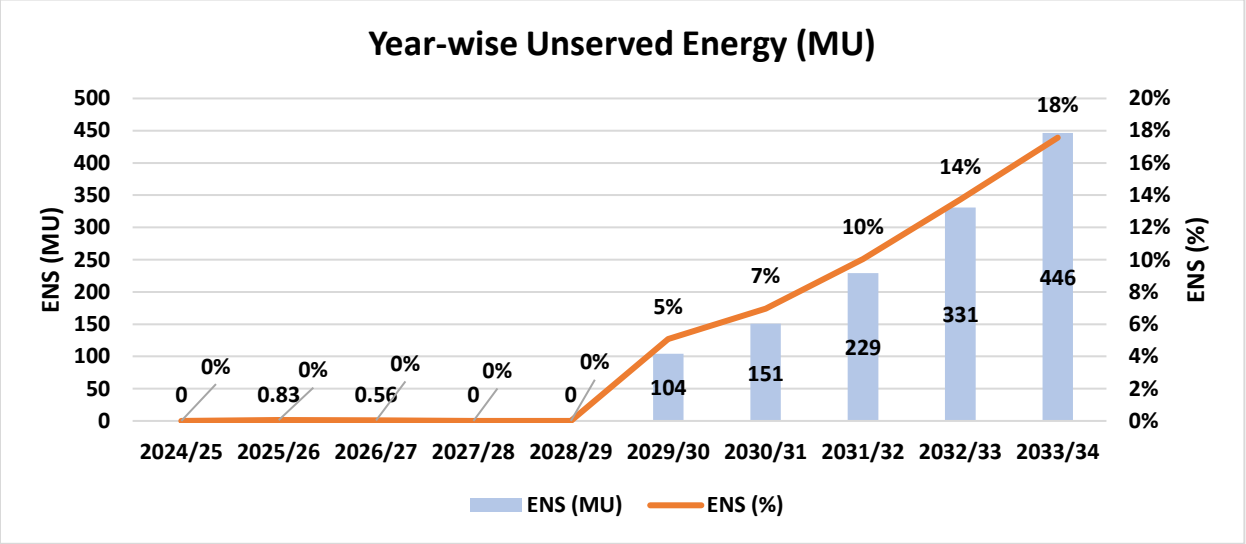


Figure 8 Yearly likely unserved energy with the planned capacities for NDMC (in MU)

Note: The unserved energy as derived in the studies is based on assuming that the demand projection for energy and peak is as per NDMC projections, and the projected demand is met from existing, upcoming planned contracts and additional RE contracts required to fulfill the RPO obligation (from 2026-27 onwards).

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

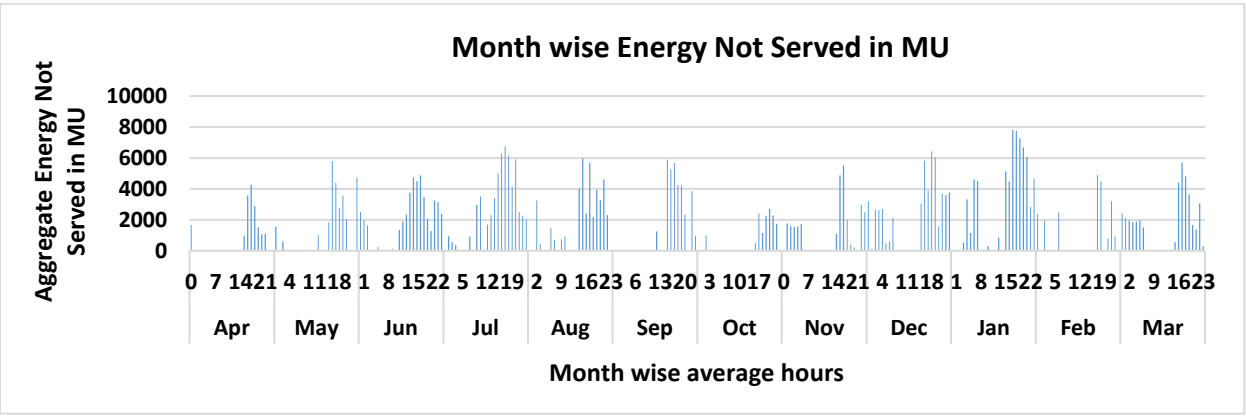


Figure 9 Month wise Aggregate Energy Not Served in 2033-34 (in MU)

6.2 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 from 2032-33 onwards.

ii) The STOA/MTOA requirement can be fulfilled through power procurement from markets or bilateral agreements.

iii) The STOA/MTOA value represents the peak demand requirement in MW as well as MW required to meet the reliability indices.

The capacity projections for NDMC are given below:

Table 10 Year-wise capacity projections (in MW)

Year	COAL	GAS	BIOMASS	HYDRO	SOLAR	HYBRID	TOTAL	BATTERY	DRE	STOA
2024/25	387	200	2.44	0	200	170	959	25/50	0	0
2025/26	237	200	2.44	50	200	170	859	25/50	0	71
2026/27	237	200	2.44	50	200	170	859	25/50	38	76
2027/28	237	200	2.44	100	200	170	909	25/50	48	39
2028/29	237	200	2.44	150	200	170	959	25/50	60	39
2029/30	0	200	2.44	150	200	170	722	25/50	73	106
2030/31	0	200	2.44	150	200	170	722	25/50	77	119
2031/32	0	200	2.44	150	200	170	722	25/50	81	133
2032/33	74	200	2.44	150	200	170	797	32/78	86	86
2033/34	99	200	2.44	150	200	170	821	32/78	90	100

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

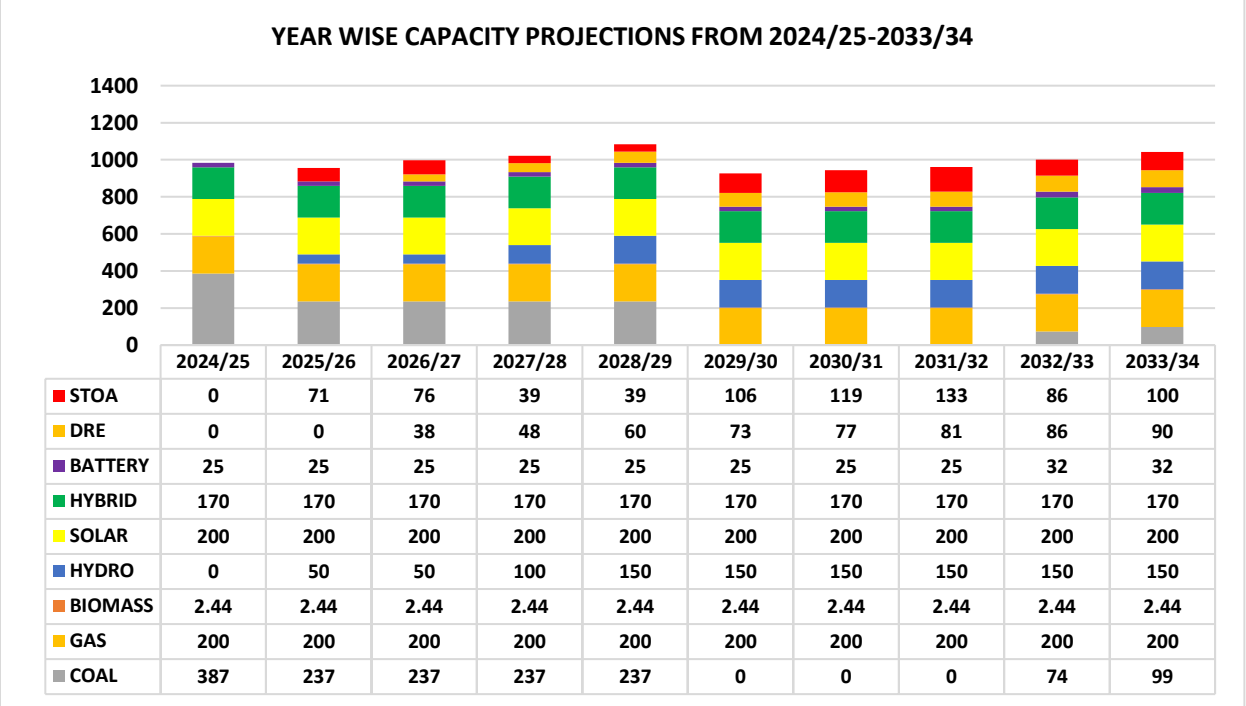


Figure 10 Projected Capacity Mix Year-wise (MW) for NDMC

As per the Resource Adequacy studies, the total projected Capacity for the year 2033-34 is 821 MW (along with 32 MW/78 MWh of Storage from Battery and 90 MW from Distributed Renewable Energy (DRE)) which consist of 99 MW of coal, 200 MW of Gas, 2.44 MW of Biomass, 150 MW of Hydro, 200 MW of Solar and 170 MW of Hybrid. Additionally, 100 MW from short term/medium term/market based tie ups may be required. This estimated Installed Capacity (IC) is likely 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 NDMC has been assessed as 6%. Further, the projected contracted capacity fulfils the stipulated Renewable Purchase Obligation from 2026-27 onwards.

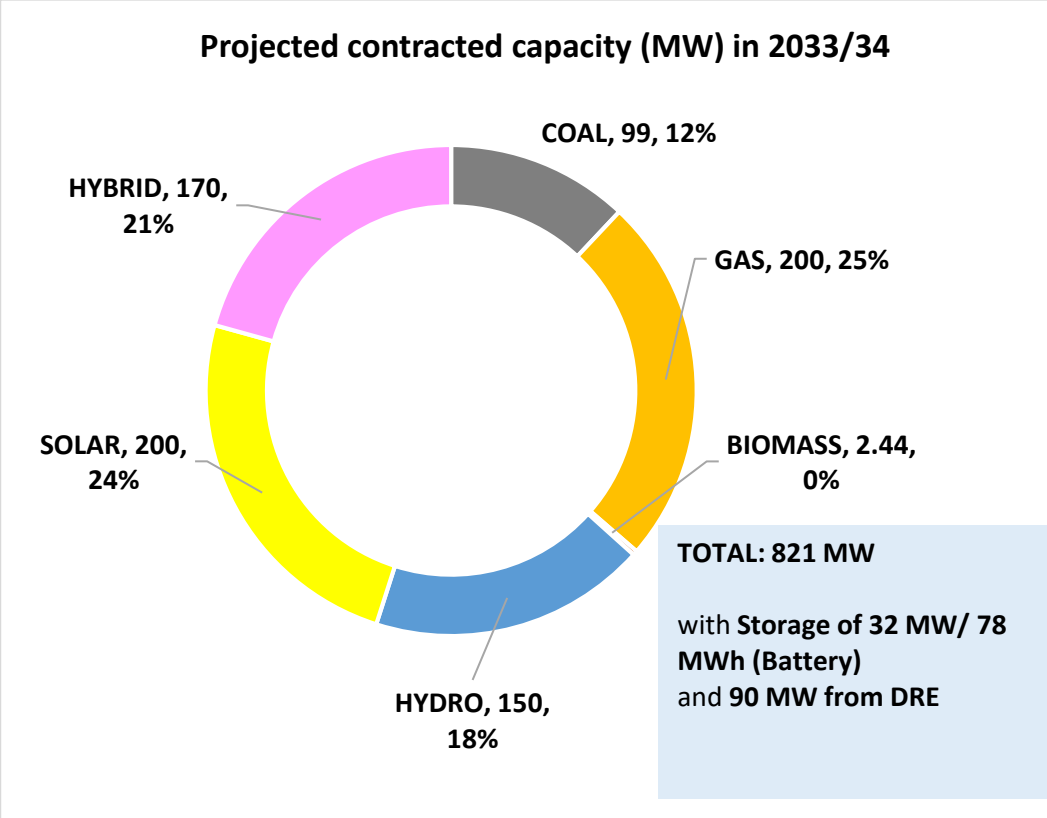


Figure 11 Contracted Capacity Mix in 2033-34 with 6% PRM

The share of non-fossil fuel-based capacity in the total contracted capacity is projected to increase to around 64 % (excluding storage and DRE) in 2033-34 from 9% in 2023-24 with higher contribution from non-fossil fuel-based capacities in alignment with RPO trajectory.

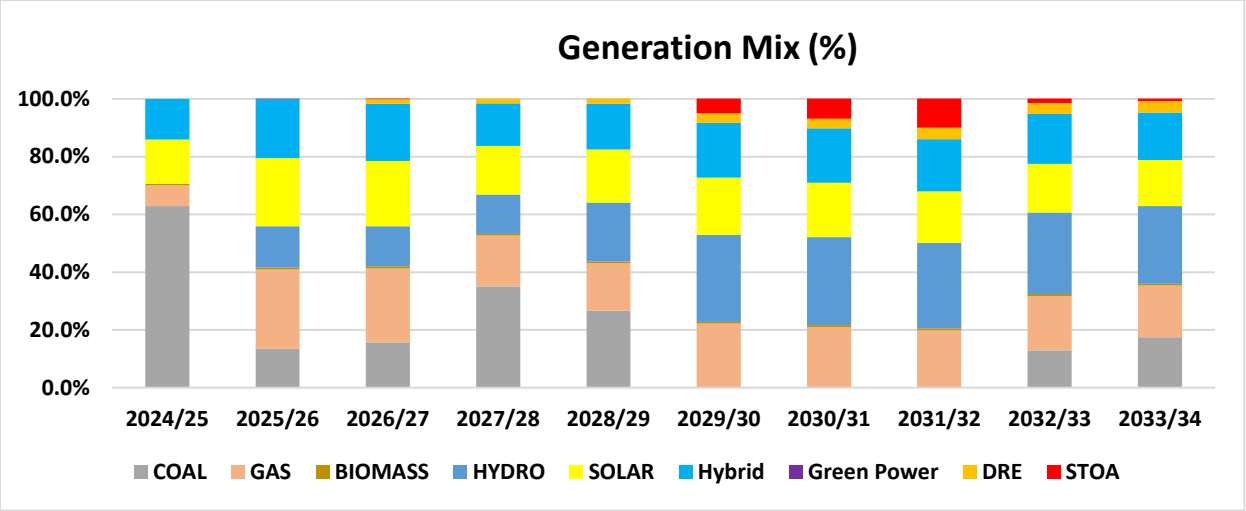


Figure 12 Yearly Source wise Generation (Net) mix

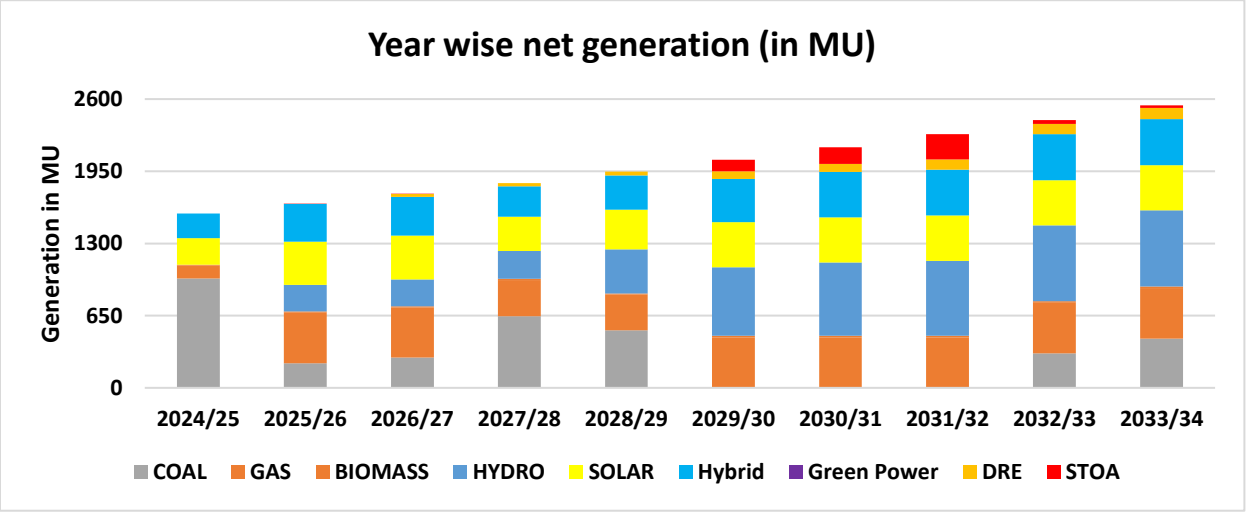


Figure 13 Source wise net generation in each year

6.3 Day-wise Surplus Capacity NDMC (in MW)

The pattern of surplus capacities has been observed as below. Available Surplus capacity can be due to seasonal variation of demand. 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. NDMC has likely surplus capacity available till 2027-28 which can be shared with other states. For the year 2032-33 the coal surplus is observed from additional coal of 98.6 MW.

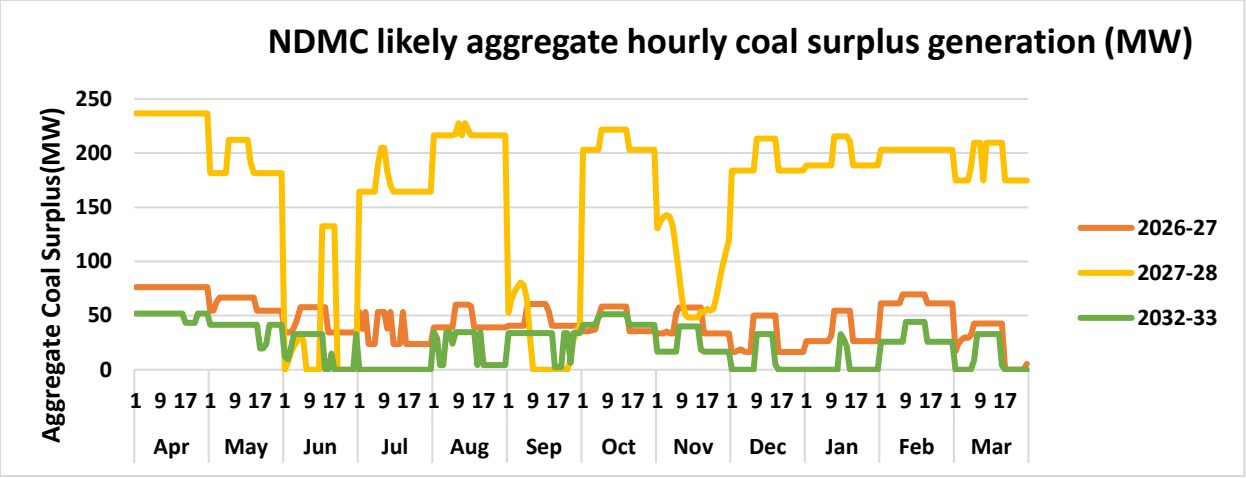


Figure 14 Surplus Coal Capacity Year-wise (MW)

7.0 Capacity contract requirement for future

It has been found out in the studies that NDMC needs to contract following capacities (planned and additional) year on year, to meet its demand reliably along with fulfilment of its RPO from 2026-27 onwards as notified by Ministry of Power.

Table 11 Year wise Capacity Addition for NDMC (in MW)

	COAL	HYDRO	SOLAR	HYBRID	TOTAL		STORAGE (BESS) in MW/ MWh		Distributed RE
Year	Additional Requirement	Planned Contracts	Planned Contracts	Planned Contracts	Planned contracts	Additional Requirement	Planned contracts	Additional Requirement	Additional Requirement
2024/25	0	0	200	170	370	0	25	0	0
2025/26	0	50	0	0	50	0	0	0	0
2026/27	0	0	0	0	0	0	0	0	38
2027/28	0	50	0	0	50	0	0	0	10
2028/29	0	50	0	0	50	0	0	0	12
2029/30	0	0	0	0	0	0	0	0	13
2030/31	0	0	0	0	0	0	0	0	4
2031/32	0	0	0	0	0	0	0	0	4
2032/33	74	0	0	0	0	74	0	7/28	5
2033/34	24	0	0	0	0	24	0	0	4
	98	**150**	**200**	**170**	**520**	**98**	**25/50**	**7/28**	**95**

8.0 Conclusions

Based on the RA studies carried out for the NDMC utility, the following conclusions may be drawn:

1. The study has been done based on the hourly load pattern of the years 2019-20 and 2022-23. Based on the demand pattern of last few years, it is seen that the peak demand season is typically from June to July with peak demand occurring during day time. The demand during the months from October to March remains significantly low as compared to other months, reflecting the 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.
2. The study has considered peak demand and energy requirement projections as per the projections furnished by NDMC which envisages that the peak demand for the utility is likely to grow at a CAGR of 5.96% and while the annual energy requirement is likely to grow at a CAGR of 5.94% for the period of 2023-24 to 2033-34.
3. NDMC is likely to witness energy deficit ranging from 100 to 450 MUs in different years from 2029-30 to 2033-34 with the existing and planned capacity addition.
4. The projected capacity and generation mix outlined in the report meet the utility's RPO requirements for the years 2026-27 to 2033-34.
5. NDMC 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. NDMC requires additional coal-based capacities to be procured other than the capacity already planned and additional contracts needed for RPO fulfilment. The quantum of coal-based capacities required to be contracted is about 74 MW in the year 2032-33 which increases to around 100 MW in the year 2033-34.
6. The Reliability studies have been carried out to adhere to the reliability criteria of Loss of Load Probability (LoLP) and Normalised Energy Not Served (NENS) as provided in National Electricity Plan (NEP) (0.2% and 0.05% respectively). The Planning Reserve Margin (PRM) for NDMC has been assessed at 6%.
7. The current capacity mix in NDMC has 91% of contracted capacity from fossil fuel sources. The share of fossil fuel based capacity is likely to reduce to 36% in 2033-34. In 2033-34, in view of the RPO fulfillment, the RE based generation (that includes hydro, solar, hybrid, biomass and DRE) capacity are likely to constitute around 67% of the total installed capacity.
8. The energy requirement to be met from STOA/MTOA (short term/medium term/market based contracts) is around 1% of the total energy requirement.

Annexure-I

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

Sr. No.	Tied capacity name	Type of generation	Expected COD/ Remark	NDMC share
1.	150 MW Hybrid NHPC	Hybrid	2024-25	120
2.	LT BESS IPGCL_SECI	Battery	2024-25	25
3.	LT Hybrid Power SECI	Hybrid	2024-25	50
4.	LT Solar Power SECI	Solar	2024-25	200
5.	Rangit-IV	Hydro	2025-26	50
6.	Ratle	Hydro	2027-28	50
7.	Teesta-VI	Hydro	2028-29	50

Assumption for Resource Adequacy Studies for NDMC

1. Energy requirement & peak demand as per the projections furnished by NDMC.
2. Demand Profile: Based on hourly demand profile of 2019-20 and 2022-23.
3. Existing & Planned Capacity: As per the information received from NDMC.
4. Future Capacity addition: based on RPO trajectory.
5. Cost parameters: based on information received from NDMC and available in NEP.

RE CUF considered

Hydro	44-48 %
Solar	24%
DRE existing and additional for RPO	14.583 %
Hybrid (planned addition)	30 %
Bioenergy	75 %

RPO Trajectory

Sl. No.	Year	Wind renewable energy	Hydro renewable energy	Distributed renewable energy	Other renewable energy	Total renewable energy
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1.	2024-25	0.67%	0.38%	1.5%	27.35%	29.91%
2.	2025-26	1.45%	1.22%	2.1%	28.24%	33.01%
3.	2026-27	1.97%	1.34%	2.7%	29.94%	35.95%
4.	2027-28	2.45%	1.42%	3.3%	31.64%	38.81%
5.	2028-29	2.95%	1.42%	3.9%	33.10%	41.36%
6.	2029-30	3.48%	1.33%	4.5%	34.02%	43.33%

In consideration of the fungibility clause as and when available.

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	75	2	-	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)	Amortization/Life time (in years)
Coal	8.34 Cr	19.54 Lakh	25
Nuclear	12 Cr	20 Lakh	30
Hydro	6 Cr to 20 Cr	2.5% of Capex	40
Solar	4.5 Cr to 4.1 Cr	1 % of Capex	25
Wind	6 Cr	1% of Capex	25
Biomass	9 Cr	2% of Capex	20
Pumped Storage	3 Cr to 8 Cr	5 % of Capex	40
Battery Energy Storage (4-Hour)	8.22 Cr to 4.72 Cr	1 % of Capex	14
Battery Energy Storage (5-Hour)	9.77Cr to 5.51 Cr	1 % of Capex	14
Battery Energy Storage (6-Hour)	11.31 Cr to 6.30 Cr	1 % of Capex	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.