Load Forecasting & Power Procurement Planning for Uttar Pradesh

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

GLOSSARY OF ABBREVIATIONS

ABT	-	Availability Based Tariff
ACS	-	Average Cost of Supply
ARR	-	Average Revenue Realized
AT&C	-	Aggregate Technical and Commercial
CEA	-	Central Electricity Authority
CERC	-	Central Electricity Regulatory Commission
CPMU	-	Central Programme Monitoring Unit
DDUGJY	-	Deendayal Upadhyaya Gram Jyoti Yojana
DISCOM	-	Distribution Company
DVVNL	-	Dakshinanchal Vidyut Vitran Nigam Limited
GAMS	-	General Algebraic Modelling System
GDP	-	Gross Domestic Product
GoI	-	Government of India/ Central government
GoUP	-	Government of Uttar Pradesh
IPDS	-	Integrated Power Development Scheme
KESCO	-	Kanpur Electricity Supply Company Ltd.
MVVNL	-	Madhyanchal Vidyut Vitran Nigam Limited
NRDC	-	Northern Region Dispatch Centre
NHPC	-	National Hydro Power Corporation
NTPC	-	National Thermal Power Corporation
POSOCO	-	Power System Operation Corporation Limited
PPA	-	Power Purchase Agreement
PTW	-	Private Tube Well
PuVVNL	-	Purvanchal Vidyut Vitran Nigam Limited
PVVNL	-	Paschimanchal Vidyut Vitran Nigam Limited
RGGVY	-	Rajiv Gandhi Grameen Vidyutikaran Yojana
RPMO	-	Reform Project Management Organization
RTC	-	Round the Clock
STW	-	State Tube Well
TOD	-	Time of Day (Tariff)
UDAY	-	Ujjwal DISCOM Assurance Yojana
UPJVNL	-	Uttar Pradesh Jal Vidyut Nigam Ltd. (Hydro Generation Co.)
UPRVUNL	-	Uttar Pradesh Rajya Vidyut Utpadan Nigam Ltd. (Thermal Generation Co.)
UNDP	-	United Nations Development Programme
UPERC	-	Uttar Pradesh Electricity Regulatory Commission
UPNEDA	-	Uttar Pradesh New and Renewable Energy Development Agency
UPPCL	-	Uttar Pradesh Power Corporation Limited
UPPTCL	-	Uttar Pradesh Power Transmission Corporation Limited
UPSLDC	-	Uttar Pradesh State Load Dispatch Centre

PREAMBLE

Access to electricity and procurement of reliable electrical energy at reasonable cost remains one of the key objective of an electric utility. Long-term demand of a state depends on the increase in consumers through new connection and the growing demand of existing consumers. Electric utilities need to take informed decision for power procurement planning and optimal resources utilisation. Electricity demand forecast is a key input for utilities to plan to plan for a long term power procurement. An optimal power procurement strategy choosed the most cost effective option for those to be available in future.

This report presents a long term electrical energy forecast upto 2026-27 for the state's discom and further developing a power procurement strategy till 2027. The developed electrical energy forecast has been developed using econometric analysis. We develop a load profile of the state discom for each year till 2026-27 under alternate growth scenarios. Projected load profile is based on historical load pattern of the state while taking into consideration the load profile of a few other states like Madhya Pradesh, Gujarat, and Haryana that exhibit certain similarities in electricity consumption pattern. A mathematical optimization model is developed for optimal power procurement planning using GAMS (General Algebraic Modelling System).

The ambitious target of developing electric energy demand and load forecast and a power procurement strategy for the state discom in relatively short time was a challenging task. This couldn't have been achieved without efforts by a number of individuals. I would like to thank Dr. Parul Mathuria, Mr. Kamal Gupta and Mr. Krunal Padwekar in contributing whole heartedly to the task in hand. My other colleagues, Abhishek, Mayank, Manpreet, Harpreet, Ravi, Garima and Snehlata contributions are notable in data compilation. Parul, Kamal and Piyush devoted skilful hands in documentation of draft report. The outcomes represented in this report would not have been accomplished without full cooperation of UPPCL, UPRVNUL, UPJVNL, UPSLDC, UPNEDA and UPERC. I would like to thanks Mr. Alok Sharma (Chairman UPPCL), Mr. Sanjay Singh (Director Commercial UPPCL) Mr. Deepak Raizada Sr. AE (Planning UPPCL), Mr. Vivek Dixit (…….), Mr. R.K. Jain (…….), Mr. Sidquqi (…….) for their immense contribution during course of this study.

The comments/suggestions/observations regarding study arewhole heartedly welcome.

Dr. Anoop Singh

EXECUTIVE SUMMARY

The government of Uttar Pradesh embarked upon an ambitious plan of providing 24×7 electricity to all consumers in the state by signing of the 'Power for All' (PFA) agreement with the central government. This not only aims to improve in the access to electricity but also its availability. While ample resources are being provided to enable accelerated electrification of remaining villages and households across the rural landscape of the state, the availability of electricity supply cannot rise at a short notice because it requires planning over a longer horizon. In order to tide over the immediate requirement of the newly connected households and the increasing demand of existing consumers, distribution utilities in the state have been resorting to short-term procurement of power through traders, bilateral contracts as well as the power exchanges.

In the above context, it is imperative for electric utilities in the state to develop a long-term power procurement strategy based on a reliable electricity demand forecast. A decision to enter into a power purchase agreement and/or to undertake investment to expand generation capacity in the state should be based on the economics of alternate strategies. This study aims to achieve this objective.

This study endeavours to aid the electric utilities of Uttar Pradesh in developing an optimal power procurement strategy for the next 10 years based on a long-term electricity demand forecast for the state till year 2026-27. The specific objectives of the study are as follows,

- Demand projection for the power system network of Uttar Pradesh* till 2027.
- Develop a system load profile based on the historical data and expected changes in near future including increase in integration of solar generation.
- Assess the need for power procurement based on existing and pipeline PPAs against the projected load without transmission constraints.
- Develop a power procurement scenario including long-term and medium-term PPA's (RTC versus peak hours etc.,), and short-term power procurement including that through power exchanges.

* The study covers whole of the state except NPCL area, which is empowered to take its own decision for power procurement.

This report highlights key findings of the study. The results of the study would help Uttar Pradesh Power Corporation Limited (UPPCL) to take informed decision about power procurement.

CHAPTER 1

INTRODUCTION

As India aims to achieve high economic growth and prosperity for its population, sufficient and reliable energy supply is basic requirement. However, the country is presently struggling to provide access to electricity to each of its inhabitants and its availability at reasonable prices. Reforms in the power sector carried out since the early 90's and subsequent enactment of the Electricity Act, 2003 has enabled substantial investment in power generation, transmission, distribution and supply. However, access to electricity still remains a piped-dream for millions of people particularly in the rural and remote areas. While a number of states like Kerala, Gujarat and Punjab have achieved hundred percent access to electricity for their population, Uttar Pradesh (U.P.) still continues to lag behind its counterparts.

A number of initiatives supported by the Central government like Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) and a more recently, Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY) have provided sufficient resources to the state governments for accelerating the process of rural electrification by strengthening the distribution and transmission infrastructure and by providing electricity connection to rural households. Access to electricity does not necessarily imply that the connected consumers are provided with reasonable hours of electricity supply. Hence, the availability of power and its supply to the households and agricultural consumers apart from those in the urban areas is required to be maintained for 24 hours a day throughout the year.

The 'Power for All' (PFA) initiative rolled out by the Central government has been signed by all state governments. The government of Uttar Pradesh has also embarked upon an ambitious plan of providing 24×7 electricity to all consumers in the state by improvement in access to electricity as well as its availability. While ample resources are being provided to enable accelerated electrification of remaining villages and households across the rural landscape of Uttar Pradesh, the availability of electricity supply cannot rise at a short notice because it requires planning over a longer horizon. In order to tide over the immediate requirement of newly connected households and the increasing electricity demand of existing consumers thereby, distribution utilities in the state have been resorting to short-term procurement of power through trades, bilateral exchanges as well as the power exchanges.

In the above context, it is imperative for other electric utilities in every state including Uttar Pradesh to develop an effective long-term as well as short-term power procurement strategies for mitigating the existing generation-demand mismatch as well as to cater the expected rise in electricity demand in future. Such objectives cannot be accomplished without a reliable load/demand forecast. The long-term power procurement and the short-term system operation require different approaches to forecast the electricity demand. A reliable long-term electricity demand forecast is necessary to ensure that any investments undertaken regarding the addition of generation capacities and/or entry into a power purchase agreement (PPA) for the required quantum of power and duration of time, are optimal. Besides, it also aids the decision-making process of the concerned utilities for upgradation of the existing transmission and distribution network to evacuate the power from generation resources to the corresponding load centres.

1.1 Scope of Work

To meet the gross demand for electricity in future, UPPCL entitled the task of long-term load projection and develop a power procurement strategy for Uttar Pradesh.

Identified scope of the project work are as follows

- Demand projection for the power system network of Uttar Pradesh till 2026-27.
- Develop a system load profile based on the historical data and expected economic, social and other changes in near future including increase in integration of grid connected solar generation.
- Assess the need for power procurement based on existing and pipeline PPAs to meet the projected demand considering transmission losses and associated costs. Based on this, developing a power procurement scenario including long-term & medium-term PPA's and short-term power procurement including that through power exchanges.
- Decision making and analysis of outcomes of study for recommendation of optimal procurement strategy upto year 2026-27 for the state, targeting minimum impact under possibility of error.

1.2 Methodological Approach

We developed an integrated formula to order the end to end objective begin from load forecast to power procurement strategy. The electricity demand forecast is based on econometric modelling that capture various socio-economic impact modelled income, electricity price and share of different economic activities. Further, we forecast electricity demand for four growth scenarios namely High, Realistic, Medium & Low Growth Scenario.

Based on developed pattern of the electricity load profile in Uttar Pradesh and some of its counterparts, we developed projected load profile for the state.

1.3 Principal Data Required

To accomplish the objectives of this project within stipulated time frame and derive conclusive outcomes, following data was needed on a timely basis for the analysis.

- Category-wise monthly sales for at least past years (state and DISCOM level).
- Category-wise yearly number of consumers and total connected load for past few years and daily load profiles of the past few years including hourly load shed.
- Monthly power procurement quantum and its cost components (fixed, variable, incentives/penalty, surcharge, adjustments etc.).
- Existing grid connected/rooftop solar capacity and projected additions.
- Solar generation curve for the state.
- Present practices of power procurement adopted by Uttar Pradesh Power Corporation Limited (UPPCL) including short term power procurement.
- Short term power procurement related information such as quantum, prices, procurement hours/time slots (daily, weekly, seasonal patterns) for last few years.
- PPA cost structure of all existing, pipelined and proposed PPA's including base charges and defined escalation factor and variable cost for different types of generation and historically used escalation factors.
- Plant capacity and average availability in a year including ramping and up/down time limits (plant type vice).
- Transmission losses and applicable charges for all PPAs.

1.4 Outline of Report:

Before discussing electricity demand forecast in the state of Uttar Pradesh over the next 10 years to assist development of prepare an optimal power procurement plan, we present an overview of power sector scenario in Uttar Pradesh. This is presented in next chapter. Chapter 3 details the solution methodological approach adopted for electricity demand forecast and power procurement planning. Chapter 4 presents and discusses key results for various scenarios. Finally, concluding remarks and recommendations pertaining to optimal power procurement are given last chapter.

CHAPTER 2

ELECTRIFICATION

2.1 24×7 Power for All

To embark upon the ambitious plan of providing uninterrupted supply of electricity to entire population of the nation for achieving the goal of national electrification by FY 2022 and rural electrification by FY 2019, the Central government in conjunction with the state governments has rolled out the 'Power for All' (PFA) initiative. With the commencement of this joint initiative, attempts are being made throughout the nation to avail every citizen irrespective of his/her location with the supply of electricity. The consumers belonging to all demand segments *i.e.* domestic, commercial, industrial and particularly agricultural are being taken into consideration for achieving the announced objectives within the set time frame. The Ministry of Power (MoP), Government of India (GoI) has authorized a Central Programme Monitoring Unit (CPMU) to monitor the co-ordinated actions undertaken under the PFA agreements by the respective state governments. The PFA agreements involve completion of ongoing projects and plans for future projects from the perspective of generation, transmission, distribution as well as consumption. Besides they are also aimed at achieving energy efficiency and promoting the use of renewable energy resources.

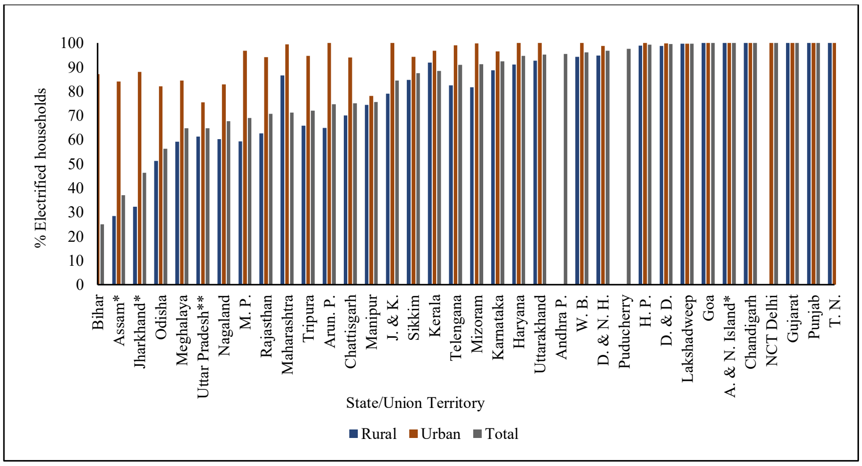

Figure 2.1: *Access to electricity in different states that have signed PFA-MOU's with the central government (So: PFA reports) *based on census 2011 **FY 2017 projections*

The motivation behind PFA initiative is the economic and social welfare of the society by electrification of the entire country keeping in view the increasing demand for electricity among existing consumers supplemented by the mismatch of demand and supply in different regions of the nation, with some of them exhibiting surplus electricity generation while the others being in a deficit. These discrepancies are expected to increase when every citizen of the nation is connected to the national grid. An analysis regarding the scenario of electrification (FY 2015) based on PFA reports (Figure 2.1) indicates that only a few states in India viz. Tamil Nadu, Punjab, Gujarat, Himachal Pradesh and all union territories *i.e.* national Capital Territory Delhi, Chandigarh, Andaman and Nicobar Islands, Goa, Lakshadweep, Daman and Diu and Puducherry have all or most of their households electrified. A few states like Bihar, Assam, Jharkhand, Odisha, Meghalaya and Uttar Pradesh exhibit less than 65% electrification, particularly in rural areas. The 24×7 power supply oriented aim of PFA cannot be achieved without providing electricity access to such areas. Hence, it is imperative for such states to immediately resort to planning and execute the strategies pertaining to fulfilling energy requirements while also strengthening the existing electricity distribution and transmission network.

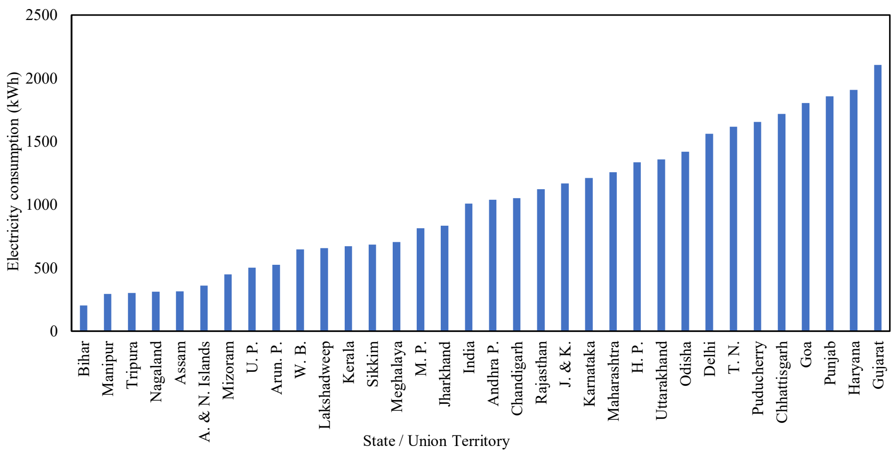

Figure 2.2: Per capita electricity consumption (2014-15) in several states *(So: CEA)*

Electrification of all households currently devoid of electricity supply will impose an additional load on the grid, thereby widening the gap between supply and demand. It is evident from Figure 2.1 and Figure 2.2 that the states/union territories that have 100% electrification[†] exhibit high per capita consumption. Per capita consumption of regions that require heavy electrification is also expected to rise in near future e.g. Uttar Pradesh currently exhibits nearly

[†] Dadar & Nagar Haveli (not shown in the Figure 2.2) exhibits the highest electricity consumption per person (13769 kWh) followed by Daman & Diu (6960 kWh) because these significantly less populated union territories.

50% of the national average per capita electricity consumption and is yet to electrify 35.28% of its households whereas the consumption per capita in Gujarat is close to 200% of the national average because all households in the state have already been connected to the grid. Thus, it is evident that proper implementation of the initiative of PFA will lead to an increase in demand and would require optimal power procurement strategy to be implemented to cater the rise in demand by building additional capacity and power purchase contracts. It also need to improve the existing generation, transmission and distribution facilities.

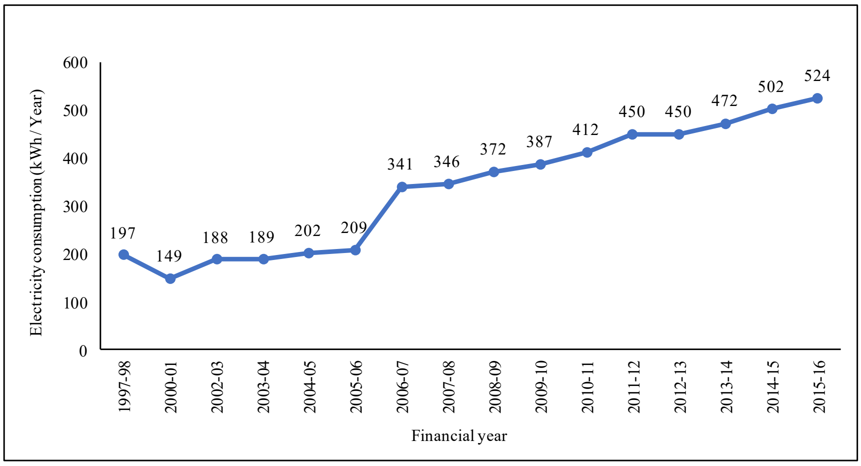

Figure 2.3: Per capita electricity consumption in Uttar Pradesh (So: CEA and UPPCL)

Figure 2.3 depicts the rise in electricity consumption per person in the state of Uttar Pradesh over the last decade accumulating to a growth of 166%. However, the national average (1075 kWh - FY 2016) is still far away. Thus, besides rural electrification, it is also necessary to plan for generation capacity addition and long-term power purchases, improve the operational efficiency of existing transmission and distribution networks and above all improve the consumption efficiency by undertaking appropriate consumer oriented initiatives. It is also required that the PFA agreements are undertaken in a well-coordinated manner based on properly governed actions by both the central and the state governments to avail an uninterrupted electric power supply to every citizen.

24×7 PFA is aimed at ensuring availability of power to every citizen of the nation throughout the year, but it cannot be fulfilled without strengthening inter and intra-state transmission and distribution besides commissioning adequate generation capacities. Majority of distribution companies in India have been unbundled from the erstwhile State Electricity Boards (SEBs) and are currently experiencing fiscal stress. To achieve financial turnaround of there utilities, the Central government has rolled out MoUs with every state under the Ujjwal DISCOM Assurance Yojana (UDAY) as detailed in the next section below for the state of Uttar Pradesh.

2.2 Tripartite MoU

UDAY is another initiative of the central government to assist transformation of the state-owned distribution companies for increasing their operational and financial performance by eradicating the economic deficiencies. As per the requirement of respective states, MoU's have been signed between the Central and state governments to avail the corresponding distribution utilities of certain financial benefits. Such schemes are necessary for achieving the aim of establishing a reliable distribution network in the nation simultaneously with 100% electrification to abolish the theft practices and ensure customer satisfaction.

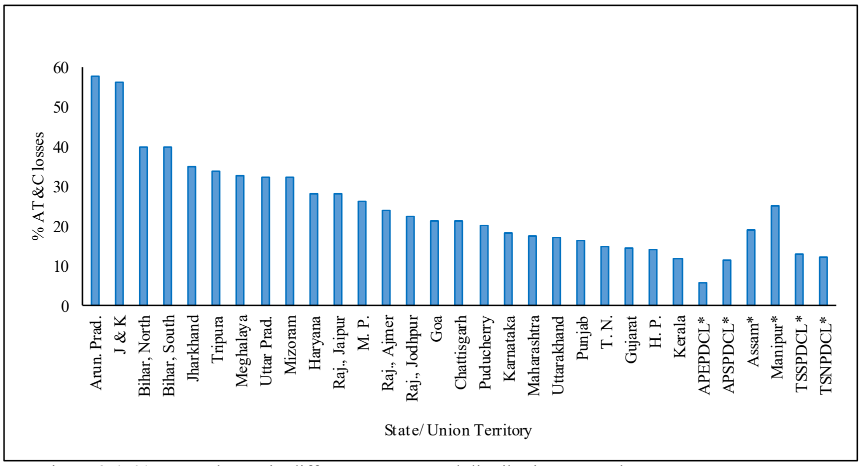

Figure 2.4: % AT&C losses in different state-owned distribution networks *(So: UDAY-MoU's) *FY 17*

Under the UDAY scheme for improvement of the operational and financial conditions of distribution companies owned and operated by state utilities, the central government (GoI), state government of Uttar Pradesh and UPPCL came to an agreement on 30th January 2016 for relieving the subsidiaries of UPPCL off their outstanding financial debts. It was decided that the central government will assist the government of Uttar Pradesh for clearing 75% debts (as on 30th September 2015) of the subsidiaries of UPPCL *i.e.* Dakshinanchal Vidyut Vitran Nigam Limited (DVVNL), Madhyanchal Vidyut Vitran Nigam Limited (MVVNL), Paschimanchal Vidyut Vitran Nigam Limited (PVVNL), Purvanchal Vidyut Vitran Nigam Limited (PuVVNL), and Kanpur Electricity Supply Company (KESCO) provided they reduce the aggregate technical and commercial (AT&C) losses in their respective distribution networks to 15% by FY 2019. Current statistics (Figure 2.4) indicate that AT&C losses in the state as of FY 2016 are 32.36%. This figure is an indication of unnecessary wastage of the generated electricity which otherwise could have been utilized for some useful purpose resulting in an increased availability of power supply besides reduction in the financial burden on distribution utilities. Upbringing of the distribution utilities cannot be envisioned without increasing efficiency of the network to supply power to the connected loads.

Thus, it was necessary to ensure that the DISCOMs in Uttar Pradesh undergo transformation economically and achieve operational efficiency. This MoU was aimed at strengthening the existing network of DISCOMs in Uttar Pradesh to reshape them into reliable, efficient and profit-making companies. Deregulation of utilities has led to the formation of several government owned companies, but this alone isn't sufficient for economic upbringing of the national power-sector. Hence, such benefits from time to time are necessary to induce the notion of competition among such companies so that they can flourish in the competitive energy market environment.

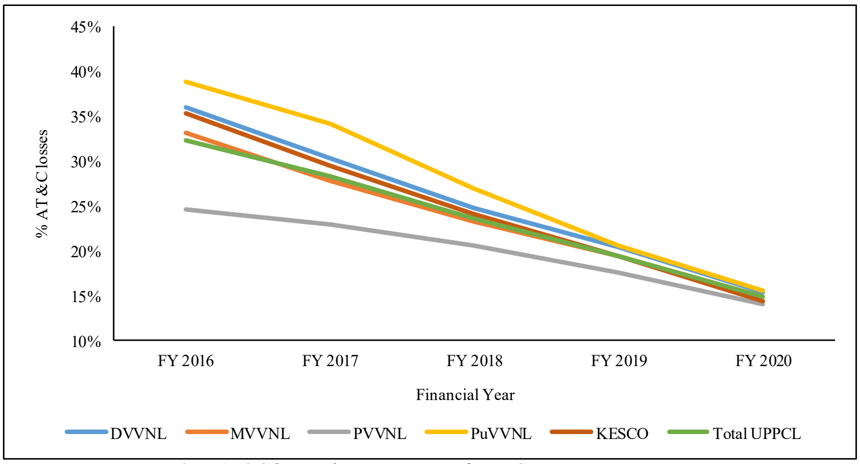

Figure 2.5: AT&C loss reduction targets of UPPCL (So: Tripartite MoU UDAY)

The statistics regarding current scenario of DISCOMs in Uttar Pradesh indicate that neither are these networks being operated appropriately nor is a large proportion of the connected load being metered properly because AT&C losses pertaining to all five subsidiary distribution networks of UPPCL accumulate to about 34% of which, 25% are technical losses in the network due of operational inefficiency and the remaining are commercial losses due to collection inefficiency. Theft of electricity is responsible to a large extent for such extensive loss because it contributes to power loss due to unbilled usage of electrical energy thereby, increasing financial burden of the company. Hence, in the lieu of financial support from the Central and state governments, UPPCL had proposed to achieve the target of 14.86% AT&C losses by 2020 (Figure 2.5). It was agreed upon by the DISCOMs to provide metered connections to new consumers and replace the existing ones by reliable smart meters besides distribution transformer and feeder metering. It would provide the network operator with ample information regarding connected load and the level of consumption to bring about transparency regarding the theft of electricity besides providing a more accurate data for carrying out load flow studies to understand the overloading/underloading of feeders and other necessary network parameters. Such analysis can aid the operators to select an appropriate strategy for optimizing the network's operation to increase its performance and reliability. Demand side management and energy efficiency were also emphasized upon to be considered while implementing consumer awareness programmes such as replacement of agricultural pumps by energy efficient pumps and dissemination of led bulbs to domestic and commercial customers as well as to the municipal corporation for street lighting purposes. The government of Uttar Pradesh also agreed to fund 5%, 10%, 25% and 50% of the previous year's losses in the network of DISCOMs for the FY 2018, FY 2019, FY 2020 & FY 2021 respectively to ease them of their financial difficulties so that they can invest their time and money for strengthening the existing network and planning to accommodate the new consumers after electrification.

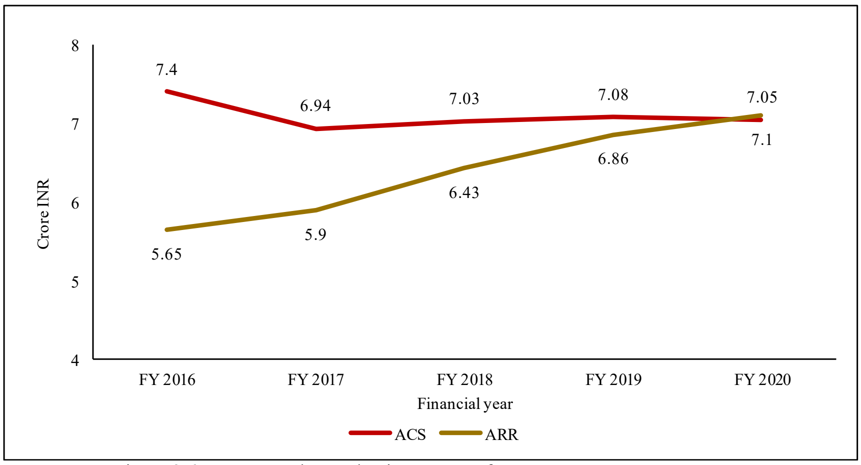

Figure 2.6: ACS-ARR loss reduction targets of UPPCL *(So: Tripartite MoU UDAY)*

Table 2.1: Debt to be taken over by Uttar Pradesh government

Year	% of the total debt to be taken over	Transfers in the form of grants (crore ₹)	Transfers in the form of loan (crore ₹)	Transfers in the form of equity (crore ₹)	Outstanding State loan of the DISCOMs
2015-16	50%	13303	6651	6651	6651
2016-17	25%	6651	3326	3326	9977

Commented [A1]: Why this?

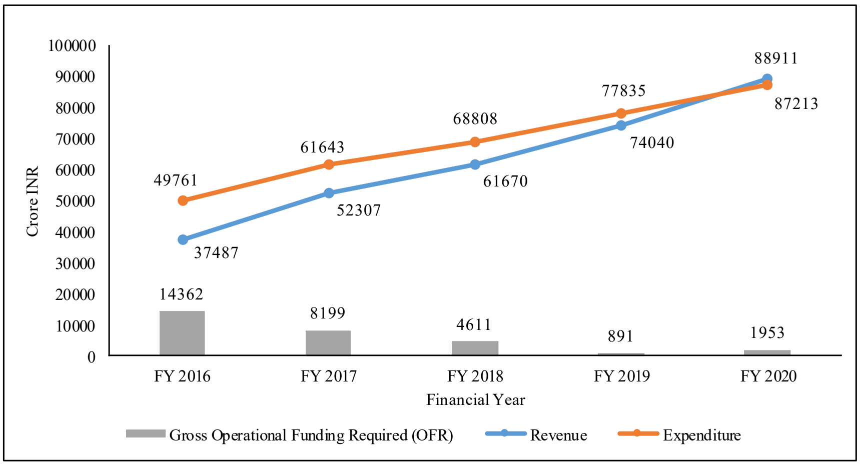

Figure 2.7: Gross operational funding requirement (OFR) by the DISCOMs of UPPCL *(So: Tripartite MoU UDAY)*

With sufficient financial support from the state and Central governments, the DISCOM subsidiaries of UPPCL expect their ACS-ARR gap to diminish by FY 2020 (Figure 2.6). In order to achieve the above objectives, it was decided to disseminate the funds among DISCOMS as per the following timeline for two financial years by taking over 50% of their debt (as on 30/09/2015) in 2015-16 and 25% in the subsequent year (Table 1). With implementation of the above procedures, the revenue collected by distribution utilities of UPPCL will increase gradually. Nevertheless, the costs associated with supply of electricity will keep on increasing due to unavoidable circumstances and hence it was felt necessary to avail them of the funding in a sequential manner (Figure 2.7). The gross operational funding requirement is inclusive of the subsidy provided by state government to the distribution companies. It is expected that such enormous financial support from the government will uplift the scenario of DISCOMs in Uttar Pradesh.

CHAPTER 3
POWER SECTOR SCENARIO OF UTTAR PRADESH

Uttar Pradesh, with a population of 19.98 Crores, is most populated state of India. A large proportion of the state is still deprived of electricity, *i.e.* only 64.72% of total households in the state had access to electricity by the year 2015 (Figure 3.1). It is also evident from the fact that the per capita electricity consumption in Uttar Pradesh is 524 kWh [22], is very much below the national average and far below the states exhibiting 100% electrification (Figure 3.1). Economic and social upbringing of the state cannot be envisioned without ample electrification. To accomplish such objectives, the Uttar Pradesh power sector underwent several transformations during Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY), Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY) *etc*. Still, to reach the targets of providing 24x7 power available to all households, industry, commercial businesses, public needs, any other electricity consuming entity and adequate power to agriculture farm holdings by FY 2019, Uttar Pradesh signed an MoU with the central government for Power for All (PFA). This also ensures for quality, reliability and affordability of electric power. A brief overview of the current power sector scenario of Uttar Pradesh would set the tone for the project objectives and analysis thereof.

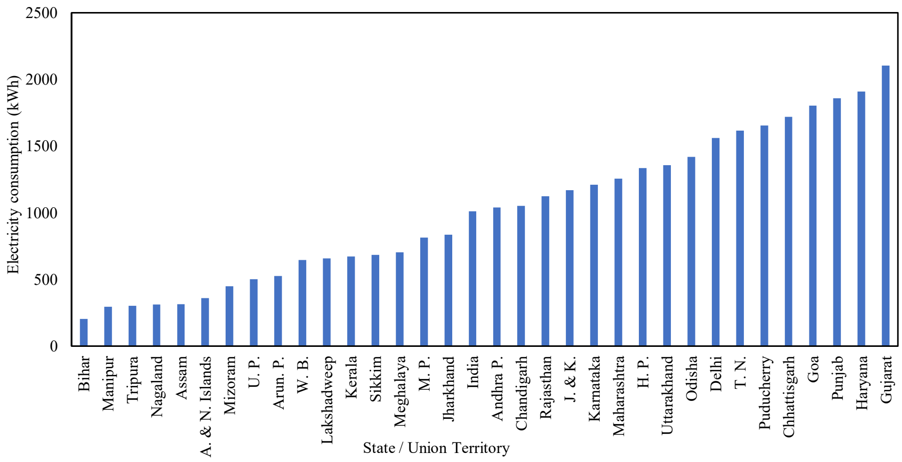

Figure 3.1: Per capita electricity consumption (2014-15) in several states (So: CEA)

3.1 Generation

Installed capacity of power utilities located in State Uttar Pradesh including allocated shares in joint & central sector utilities for the FY 2017 is 22,602 MW [PFA report]. This capacity consists of 6134 MW (27.1%) of state's existing thermal and hydro plant, 6067 MW (26.8%) of share in central power plants (NTPC, NHPC and NPCIL), 8157 MW (36.1%) from different Independent power producers and Joint Ventures (IPP/JV), 2022 MW from captive, cogenerating & other renewable sources, solar energy from other states about 222 MW (< 1%). Figure 3.1 shows source-wise bifurcation of existing contracted capacity for the state.

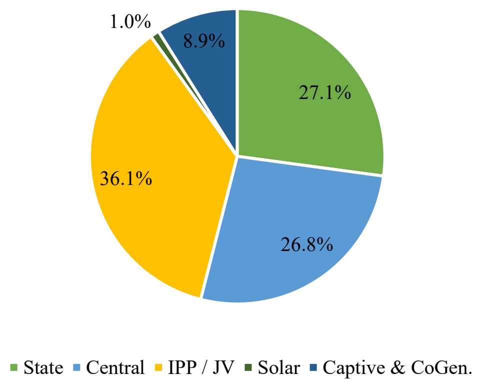

Figure3.1 Source-wise existing contracted capacity

Further, the state procures residual energy from power exchanges and short-term contracts to meet seasonal peak demand. This short-term procurement quantum varies based on day to day energy requirement of the state. However, looking at increasing energy requirements in future, the state has planned to increase its capacity by 11282 MW by year 2022 *via* setting up own generating plants and allocation in central generating plants [PFA report].

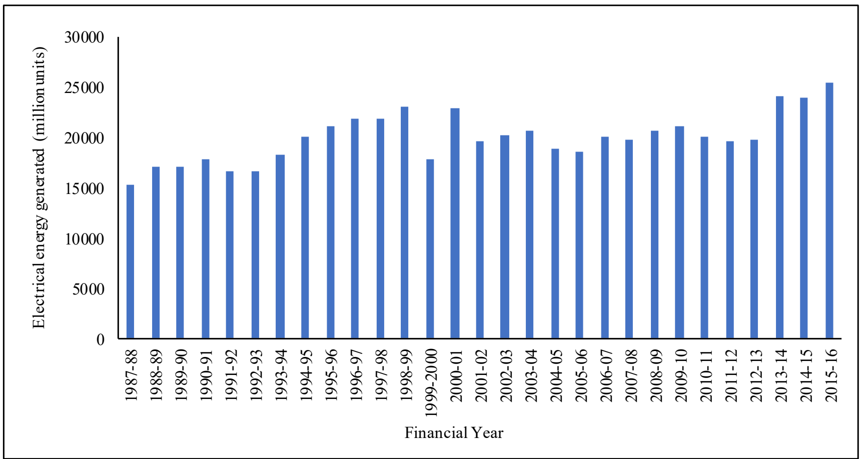

Figure 3.2: Thermal and Hydro based electrical energy generated in Uttar Pradesh (million units)

Figure 3.2 represents the net electrical energy generated in Uttar Pradesh from thermal (UPRVUNL - Uttar Pradesh Rajya Vidyut Utpadan Nigam Ltd.) and hydro (UPJVNL – Uttar Pradesh Jal Vidyut Utpadan Nigam Ltd.) power plants excluding auxiliary consumption within the plants, over the past three decades indicating an increase of 67.2% since then. These statistics indicate that till date a large proportion of electricity is extracted out of coal based power plants. However, to emphasize the use of renewable sources of energy the state has ambitious targets for solar PV generation.

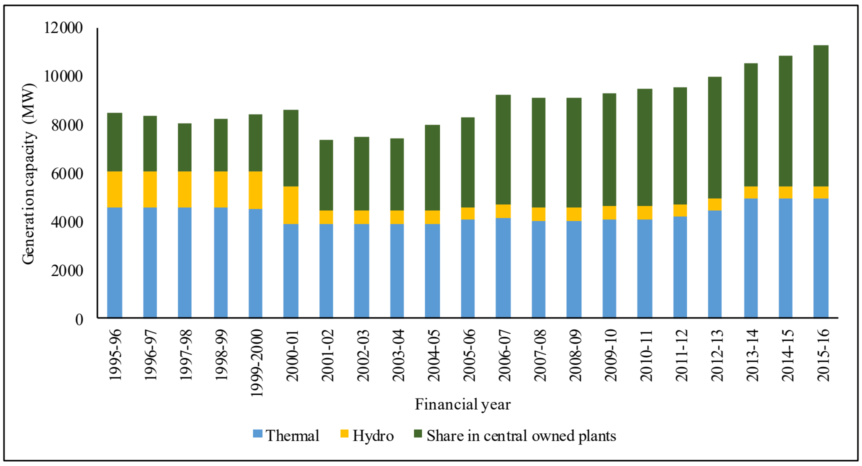

Figure 3.3: Public sector generation capacity in Uttar Pradesh source-wise

Looking at states generation capacity scenario in last few years it has been observed that there has been a gradual increase in the public-sector generation capacity of Uttar Pradesh after FY 2017 (Figure 3.3). Uttar Pradesh's share in central generating plants has tremendously increased from 28.7% in FY 1996 to 68.3% in FY 2016 whereas, the hydro generation owned and operated by UPJVNL underwent a steep decline in 2001. Overall the availability of electricity at busbars has increased over the past three decades.

Uttar Pradesh holds 20.09 % share of total installed generation capacity of India as shown in Figure 3.4. About 3.42% generation utilities (except the central power plants) are located in the state of Uttar Pradesh and most of them are operated by the state-owned companies.

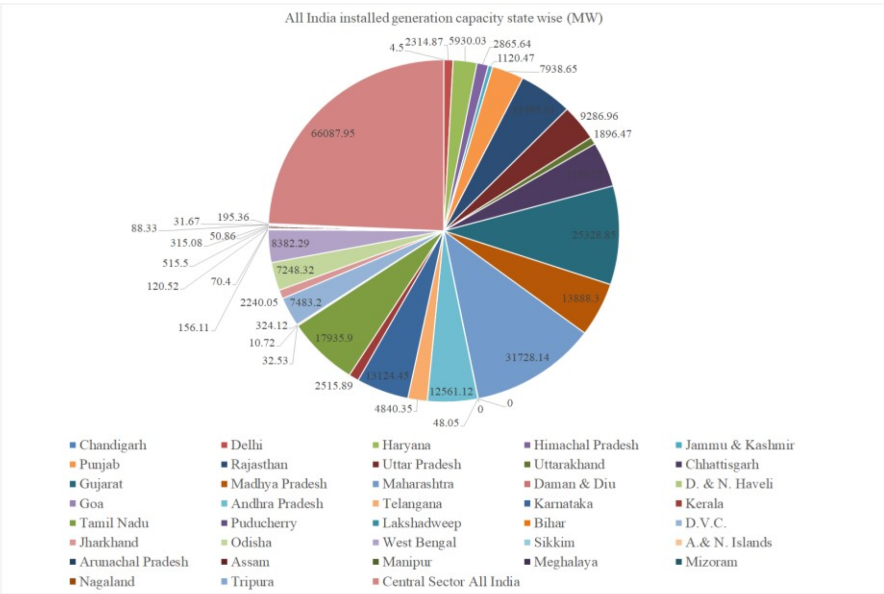

Figure 3.4: Installed generation capacity state wise utilities (year???)

As of 31-07-2017, the installed generation capacity of India is 330153.65 MW [CEA report], that has been a huge leap forward since 1950 when the capacity was merely 1713 MW (31/12/1950). This significant rise in the installed generation capacity is in response to the ever-increasing demand for electricity and a representative of growth in the electrical energy sector. The increase in capacity is consistent and large proportion is from thermal (coal based) generation both in terms of capacity and energy (Figure 3.5 and 3.6). However, there is a consistent increase in renewable capacity addition, due to emphasis of nation for promoting renewables.

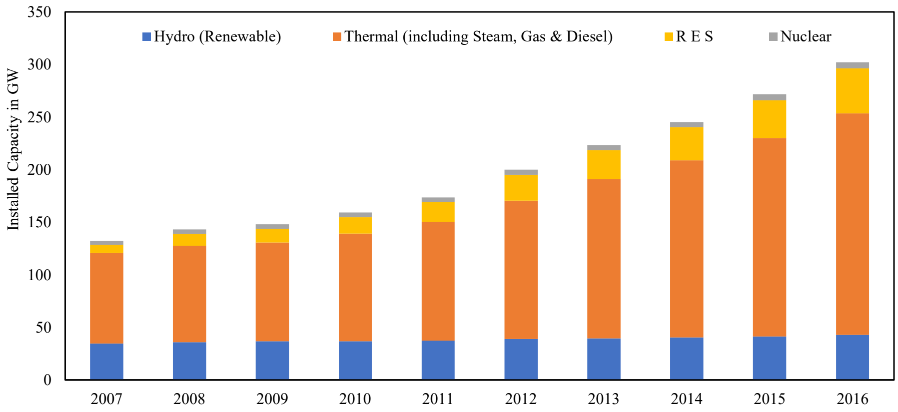

Figure 3.5 All India Installed Capacity

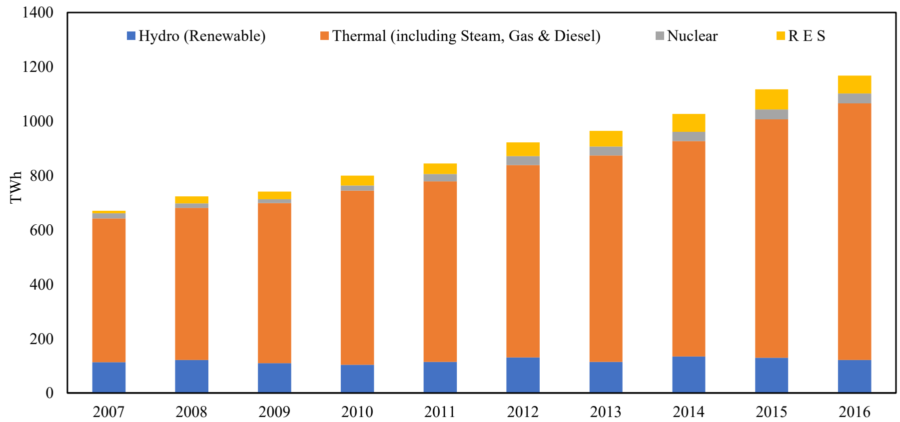

Figure 3.6 All India Energy generation

In nation, central government companies own and operate about 24.32% generation utilities in the nation including all nuclear power plants exclusively. Table 3.1 shows the overall generation statistics of India for FY 2016 revealing that nearly 70% of the total electricity generation is based on thermal power plants whereas the hydro and other renewable energy resources account for 14.2% of the net electricity generation each. About 2 % of the total generated electrical energy is procured from the nuclear energy.

Table 3.1: All India generation capacity in MW (So: for Utility only as on 31.03.2016) in MW (So: All India Electricity Statistics General Review 2016 CEA,)

Sector	**Hydro**	**Steam**	**Gas**	**Diesel**	**Total Thermal**	**Nuclear**	**Renewable Energy sources**	**Grand Total**
State	28092	64321	6975	439	71734	0	1964	101790

Central	11571	51390	7555	0	58945	5780	0	76297
Private	3120	69462	9978	555	79995	0	40886	124001
Total	42783	185173	24508	994	210675	5780	42849	302088

3.2 Transmission and Distribution

Addition of new generation capacities alone cannot serve the purpose of 100% electrification without an adequate inter-state and intra-state transmission network as well as a reliable distribution network within the state.

Table 3.2: Transmission network of Uttar Pradesh as of 2017

Voltage level (kV)	765	400	220	132
Length (circuit km)	1509	6193	10282	18130

Transmission network in the state extended more than 36114 circuit-km. Uttar Pradesh relies to a fair extent on power procured from sources outside the states as well as on the power exchanges. Thereby, it is necessary to strengthen the existing inter-state and intra-state transmission networks besides increasing efficiency of the existing distribution network(s). Transmission and distribution (T&D) losses in power system network of the state have reduced in the last decade from 32.6% in 2007-08 to 24.5% in 2015-16 due to efficient and optimal operating strategies. The T&D losses in Uttar Pradesh still remain more than those reported in other states (Figure 3.5).

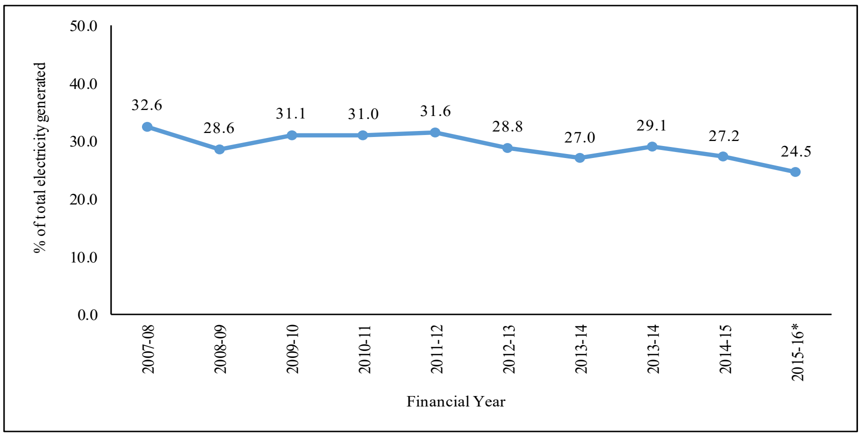

Figure 3.1: Transmission and distribution losses in the state of Uttar Pradesh over the last decade (So: Statistics at a Glance 2015-16, UPPCL)

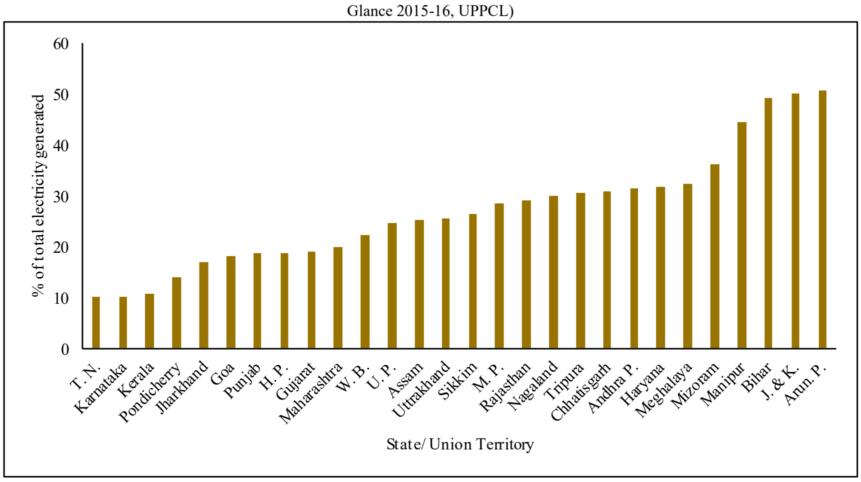

Figure 3.2: Transmission and distribution losses in power system network of various states in 2015-16

The network of transmission, sub-transmission and distribution lines has been extended since 1987 to permit flawless supply of electricity to the end consumers (Figure 3.6). The transformation capacity at grid substations has also been upgraded to avail the benefits of adding new lines.

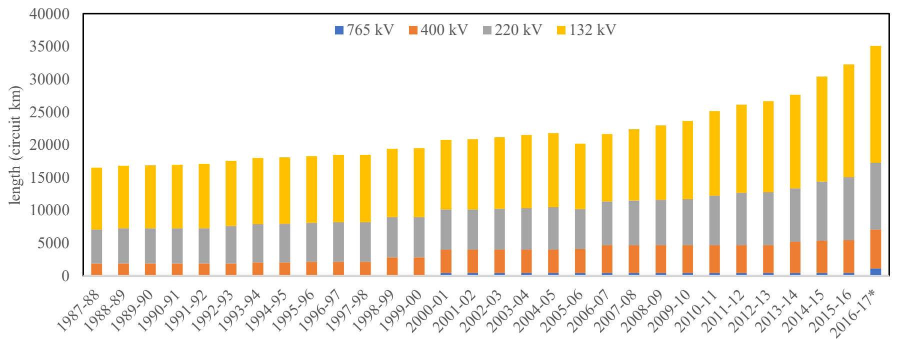

Figure 3.3: Energized transmission lines in Uttar Pradesh (So: UPPCL)

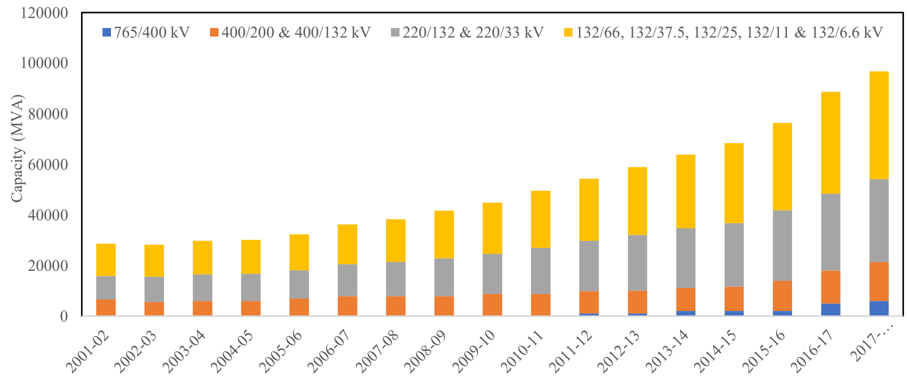

Figure 3.4: Transformation capacity at grid sub-stations (132 kV and above) (So: UPPCL)

Figure 3.7 shows the substantial increase in power transformation capacity at the respective substation to accommodate the incoming loads due to electrification of several rural segment consumers in the state. Information pertaining to the number of 11, 6.6 & 3.3 kV primary distribution feeders and the 440/220V distribution network lines energized after FY 2009 is unavailable, hence growth pertaining to these years has not been incorporated in the graph. The most important matter of concern for a distribution network operator is the network's operational efficiency and the extent to which the investment costs and other expenditure to supply electricity to all the connected consumers are recovered in the form of revenue.

Commented [PM2]: Or before???

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3.3 Consumption

Uttar Pradesh has traditionally witnessed deficit of electricity supply for its consumers. A primary reason for this is enormous population of the state and the lack of adequate generation capacity installed/contracted. Before attempting to rectify this situation, it is necessary to analyse consumption scenario of the state. As of the FY 2017 nearly 42.4% of electricity demand in the state is for domestic purposes whereas 21.1% of it is accounted by the industrial consumers. Agricultural consumer segment in Uttar Pradesh also has a significant proportion in the total demand for electricity as is evident from 3.8.

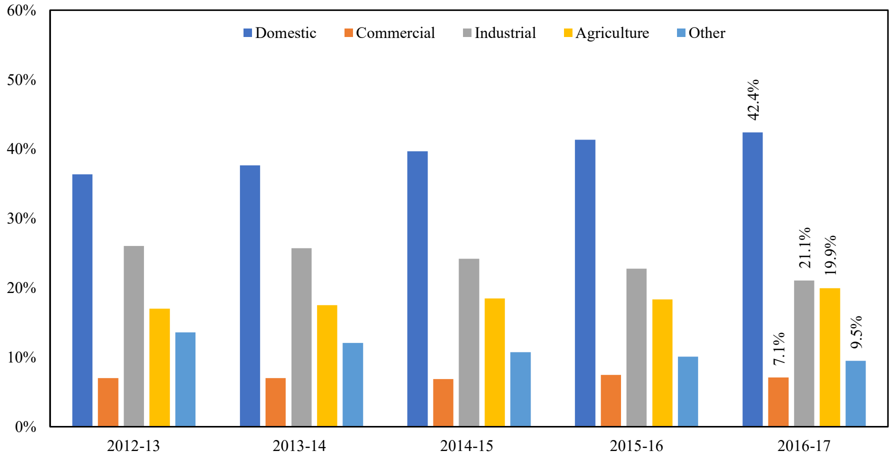

Figure 3.5: Category wise consumption in Uttar Pradesh . (So: UPPCL)

An overview of growth in the number of connected consumers belonging to different segments indicates that there has been a significant increase in domestic consumer due to electrification of villages (Figure 3.9). The connected domestic consumers have increased by 135% since FY 2002 whereas the commercial consumers (including the public and private institutions) by 87% over the same duration of time. Electrification of rural areas is expected to increase the connected domestic consumers even further in near future. However, commercial electrification will have a significantly lesser impact on load profile of the state.

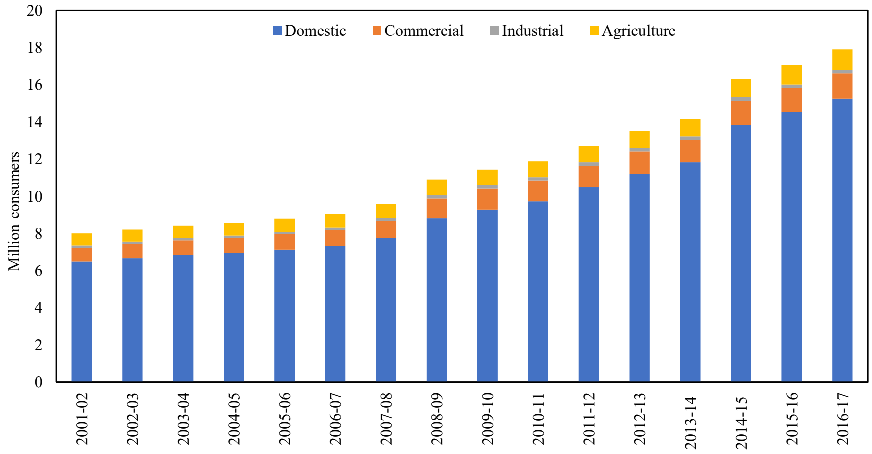

Figure 3.6: Category wise connected consumers in Uttar Pradesh *(So: UPPCL)*

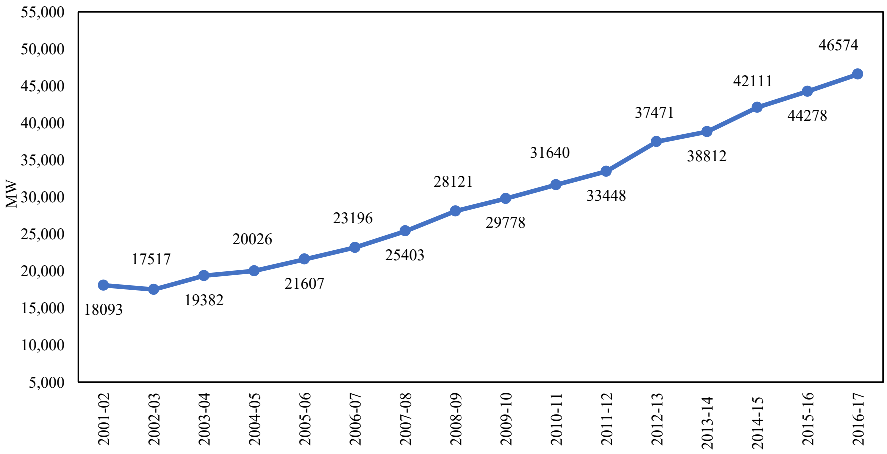

Figure 3.7: Total connected electrical load in Uttar Pradesh (UPPCL)

As far as the electricity sales are concerned, the trend suggests that the sales of electricity to domestic as well as heavy & large industrial consumers have drastically increased over the last decade (Figure 3.11). Overall sale of electricity in the state has increased by 212.4% as compared that in FY 2001. Increase in the demand for electricity in future has to be complemented by a proportional increase in supply and this task becomes challenging when a significant population of the state, particularly that residing in rural areas is yet to be electrified.

Nevertheless, as per recent policy direction [Uttar Pradesh PFA agreement report] power system network of the state has become capable of supplying 18 hours of electricity supply to the connected rural consumers till date. This achievement is required to be supplemented with eradication of the remaining 6 hours of unavailability and it has been agreed upon in the PFA agreement between the Central and state governments to achieve this target with 100% electrification in the state by year 2019.

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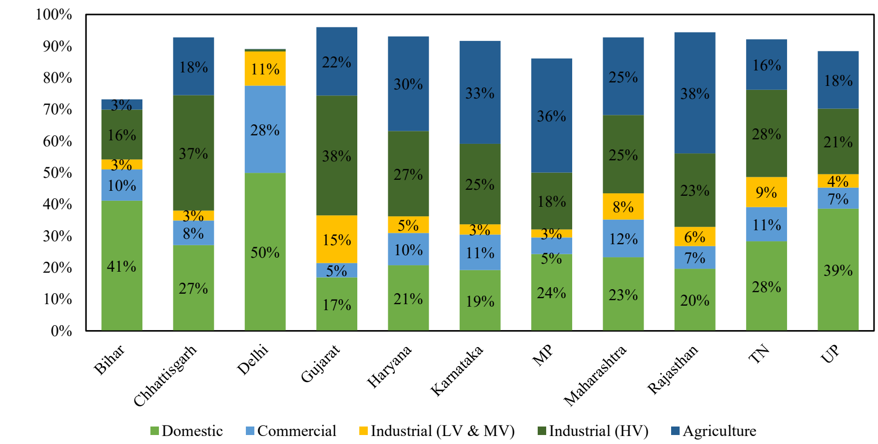

Figure 3.8: Share of consumer categories in electricity consumption for different states (So: CEA)

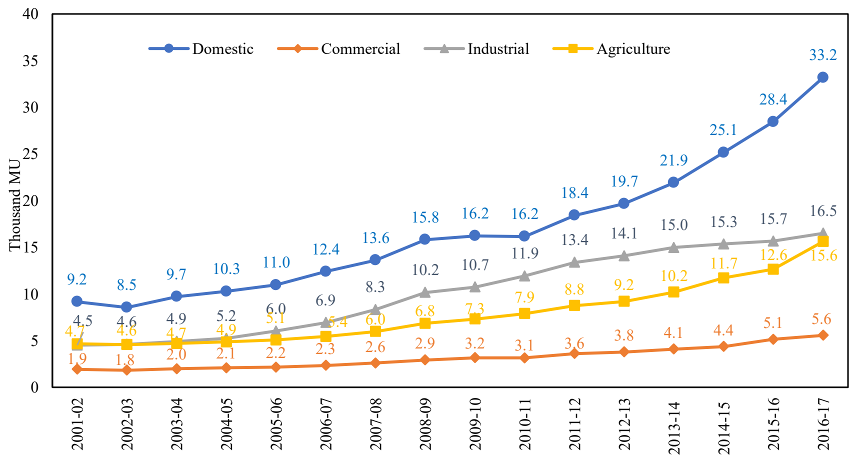

Figure 3.9: Category-wise electrical energy sales in Uttar Pradesh (So: Source)

A comparison of the consumption scenario of Uttar Pradesh with that of a few other states for the FY 2015 (Figure 3.12) reveals the fact that besides electrification, it is also necessary to focus towards energy efficiency in domestic consumption and improve supply of electricity for industrial and agricultural consumers to bring the state at par with other flourished states.

An increase in the number of consumers is also reflected in increased electricity demand in the state (Figure 3.10) and the corresponding electrical energy consumption in kWh (Figure 3.13). Connected load of the state had reached nearly 50,000 MW by the end of 2016-17 with a total annual consumption of 65,000 GWh and per capita consumption of 524 kWh (Figure 2.3).

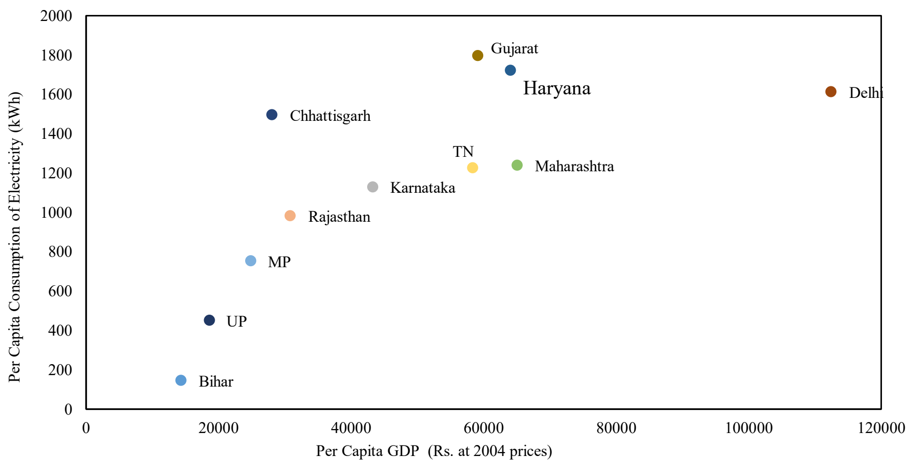

Figure 3.10: Per capita electricity consumption vs per capita GDP of different states (So:)

Average annual peak demand of Uttar Pradesh was around 17,355 MW in FY 2017 whereas the annual energy requirement was 1,08,853 million units. All these figures are expected to rise with electrification of the remaining consumers yet to be connected to the grid in the state.

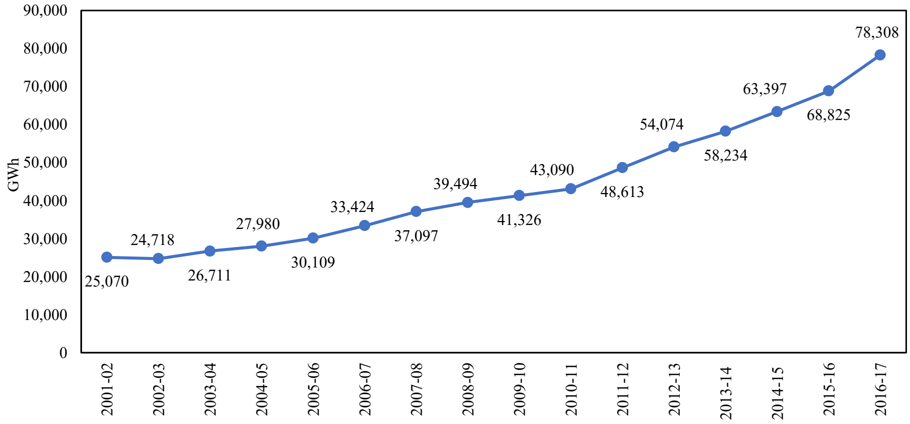

Figure 3.11: Electrical energy consumption (sales) of Uttar Pradesh (UPPCL)

Although a substantial increase has been observed in the demand for electricity in the state (Figure 3.10), the comparatively lesser per capita electricity consumption is evident from the fact that economic performance of Uttar Pradesh is quite poor as compared to that of other states in India (Figure 2.2).

It can be observed from Figure 3.14 that the states exhibiting higher per capita GDP have more requirement of electricity as a commodity and vice versa. Hence, Uttar Pradesh being an economically backward region exhibits lesser per capita electricity consumption.

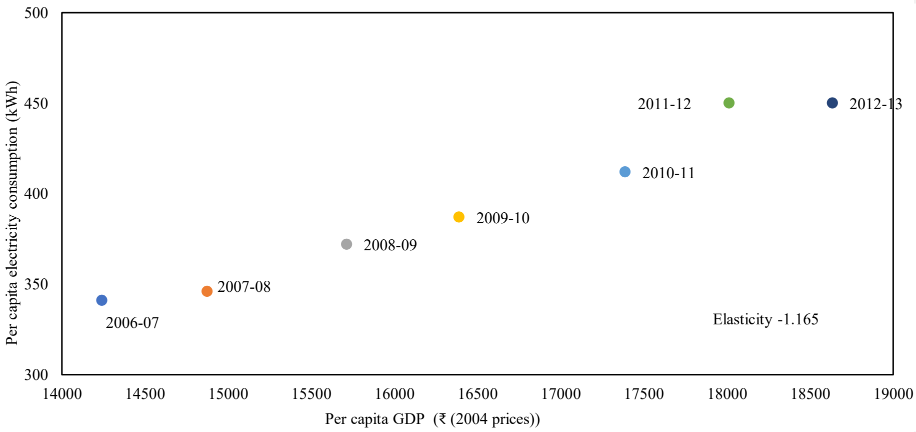

Figure 3.12: Per capita electricity consumption vs per capita GDP of Uttar Pradesh (So:)

Nevertheless, the economic performance of Uttar Pradesh has improved over the past few years as shown in Figure 3.15, validating the increased demand for electricity in the state. Perhaps the efforts by Central and state governments for economic and social upbringing of the state as well as the plans for rural electrification are bound to raise the demand for electricity in the state in near future that would require addition of new generation, transmission and distribution utilities and optimal planning therefore.

3.4 Load Profile

The analysis pertaining to generation, transmission, distribution and consumption scenario in the state of Uttar Pradesh clearly indicates the need for optimal utilization of all the available resources as well as addition of new viable resources and optimal planning therefor. This is necessary to cater the increase in connected load of the state (Figure 3.10) while ensuring economic uplift of the state-owned utilities. This goal cannot be achieved without an adequate emphasis on demand profile of the state. Load profile is the necessary information for a system operator to perform load flow studies and dispatch the generation optimally as well as for planners to take economically, socially and environmentally benign decisions.

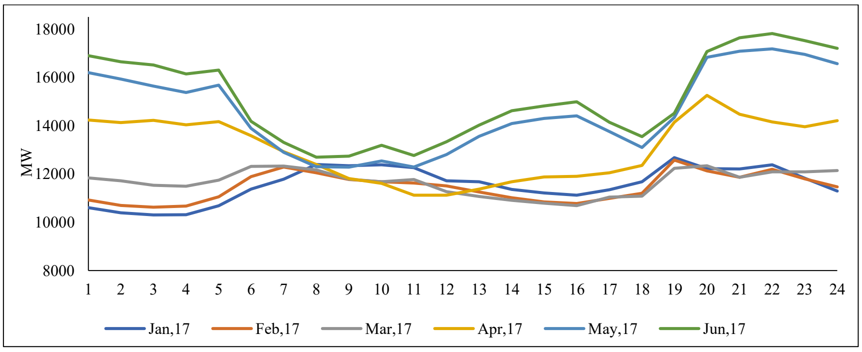

Figure 3.13: Monthly average load profile of Uttar Pradesh *(So: UPPCL)*

Based on the historical data of night reports by UPPCL, the average monthly load profile of the state for 2017 (till date) was as shown in Figure 3.16, however it was driven by the availability of supply. It can be observed that demand pattern of the state during summer season differs from what is usually expected because the peak load is encountered during the night instead of day time. This behaviour may possibly be due to electricity supply to rural and agricultural consumers of the state during the night. The load during winter season in the state is comparatively less on an average due to decrease in the requirement of electricity for cooling purposes with the peak demand being encountered during the day time.

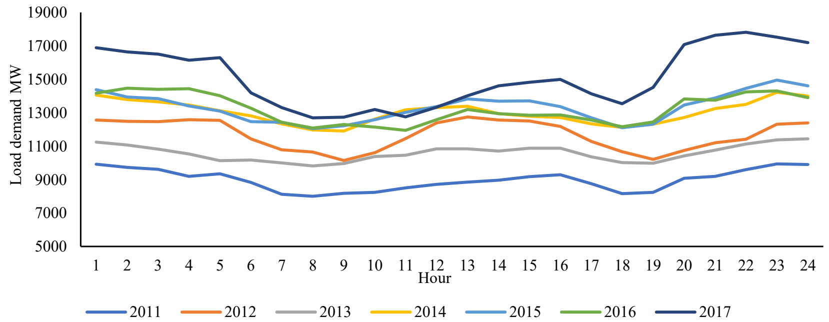

Figure 3.14: Load profile of Uttar Pradesh for the month of June *(So: UPPCL)*

Previous year, load demand in the state was as shown in Figure 3.17. Peak demand occurred during the month of September and was around 14921 MW. The months of January and February experienced afternoon peak, March-May had night peak whereas that seasonal demand pattern of June-September months showcased peak demand at mid-night while the remaining months had evening peak.

The increased demand of electricity during night can be attributed to the supply hours of electricity to agricultural and rural consumers particularly after rural electrification as mentioned before. It is to be noted that the load varies more during summers than during winters. These variations are driven by the availability of electricity supply. Nevertheless, the annual average load profile was very close to a flat profile however it is not a good representative of the consumption behavioural pattern. In order to be prepared for the worst-case scenario, it is necessary to give due attention to summer seasonal load profile because the electricity demand during this time of the year is maximum due to unavoidable circumstances.

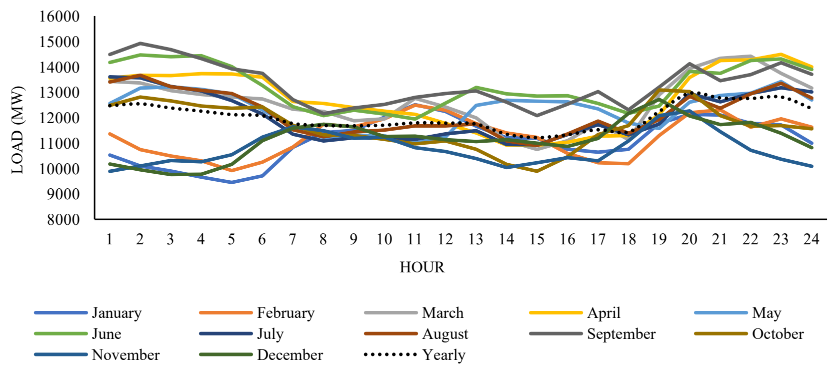

Figure 3.15: Monthly load profile of Uttar Pradesh (So: UPPCL)

Figure 3.18 describes historical load profile of the state for the month of June over the past five years. A substantial increase of about 79% has been observed in peak electricity demand of the state during the month of June over the past 6 years. These load profiles of the state of Uttar Pradesh as well as those of a few new neighbouring states exhibiting similar electricity utilization pattern are used in the model as described in the next chapter for predicting load demand in the state of Uttar Pradesh till 2027.

3.5 Power Sector Reforms (Uttar Pradesh)

Unbundling of state electricity boards in India was undertaken to promote competition in the power sector, increase the efficiency of generation, transmission and distribution and avail the economic and social benefits of technological advancements in power sector to the end consumers. The Indian Electricity Act, 1910 guided the power sector in India before independence that was replaced by The Electricity (Supply) Act, 1948 to promote regulated growth of the electricity industry in the country. Later, it was felt that the energy sector requires incorporation of private participation to enhance the power sector network by interconnecting all regional grids and to encourage competition therein. The Electricity Regulatory Commissions Ordinance, 1998 was promulgated by the then President of India on 25th April 1998. Main purpose of this act was to formulate Central Electricity Regulatory Commission (CERC) and State Electricity Regulatory Commissions (SERCs) to commence sequential reformation process of the power sector in India. Following reforms took place chronologically in the state of Uttar Pradesh since this act came into force.

Year	Reform/Amendment
1998	Uttar Pradesh Electricity Regulatory Commission, an autonomous body corporate is established. The commission is issuing year-wise tariff since FY 2001 and has approved the Uttar Pradesh Electricity Supply Code - 2005.
1999	Uttar Pradesh Electricity Reforms Act, 1999 is notified and it came into effect on 14/01/2000 in order to aid the restructuring process of electricity industry in Uttar Pradesh, rationalize the generation, transmission, distribution and supply of electricity in the state, provide an independent Electricity Regulatory Commission to regulate the purchase, distribution, supply and utilization of electricity besides monitoring the quality and reliability of service, dispatch tariff orders and other charges keeping in view the interest of the consumers and utilities. It is attempted to encourage the participation of private sector entrepreneurs in the electricity industry in the state and take appropriate

	measure towards development and management of power sector industry in the state in an efficient, economic and competitive manner.
2000	Uttar Pradesh Electricity Reforms Transfer Scheme, 2000 is notified and Uttar Pradesh state Electricity Board (UPSEB) is split into three corporations *i.e*. 1) Uttar Pradesh Rajya Vidyut Utpadan Nigam Limited (UPRVUNL) 2) Uttar Pradesh Jalvidyut Nigam Limited (UPJVNL) 3) Uttar Pradesh Power Corporation Limited (UPPCL) Under Uttar Pradesh Transfer of KESA Zone Electricity Distribution Undertaking Scheme 2000, KESA, a subsidiary of UPPCL is converted to Kanpur Electricity Supply Company Limited (KESCO), a company incorporated under the Companies Act, 1956.
2003	Uttar Pradesh Power Sector Reforms (Transfer of Distribution Undertakings) Scheme 2003 is notified by the government of Uttar Pradesh and four distribution companies were formed *i.e*. 1) Paschimanchal Vidyut Vitran Nigam Limited (PVVNL) 2) Madhyanchal Vidyut Vitran Nigam Limited (MVVNL) 3) Dakshiranchal Vidyut Vitran Nigam Limited (DVVNL) 4) Purvanchal Vidyut Vitran Nigam Limited (PuVVNL)
2004	Government of Uttar Pradesh notifies the modified Power Policy, 2003
2007	Uttar Pradesh Power Transmission Corporation Limited (UPPTCH) is gazetted as the state Transmission Utility (STU).
2009	New Energy Policy, 2009 is declared by the government of Uttar Pradesh to incentivise and simplify private participation in generation, transmission and distribution sectors. An agreement is made with Torrent Power Limited for transferring the responsibility of distribution works of KESCO and Agra district to Torrent Power.
2010	New distribution license is issued to the distribution companies replacing the distribution, retail and bulk supply license, 2000 issued to UPPCL. Uttar Pradesh Electricity Reforms Scheme, 2010 (Transfer of transmission and related activities including the assets, liabilities and related proceedings) is adopted to split UPPTCL out from UPPCL.

2014	Uttar Pradesh electricity regulatory commission (multi-year distribution tariff) regulations, 2014 are notified for determination of electricity tariff from 01/04 2015 to 31/03/2020 unless extended otherwise by an order of the regulatory commission

CHAPTER 4
SOLUTION METHODOLOGY

In order to meet the objectives of the study a detailed work plan was developed, taking into account the stages of work and methodological approach to be adopted therein and the required data. The magnitude of data required was quite extensive and time consuming. We approached UPPCL, UPSLDC, UPRVUNL and UPNEDA to provide us with relevant data. Appropriate data was also obtained from UPERC, CEA, CERC and POSOCO, to name a few. Multiple rounds of discussion were held with UPPCL officials and presentations were made to UPPCL officials at various stages of the work.

The methodological approach to achieve the above objectives include the following four steps

I. Projection of per capita electricity consumption projection and the associated demand for electrical energy through the year 2026-27.

II. Development of average annual load profile for the state considering the scenarios for demand side management (DSM) and the grid connected solar power generation (including rooftop solar)[‡].

III. Development of a model that minimises the overall social cost of electricity supply (including cost of unserved load).

IV. Analysis of the results obtained in the previous stage to identify the feasible set of economic scenarios in a preferential order.

The details pertaining to four step methodologies are presented in subsequent sections of this chapter.

4.1 Demand Projections

Long term/short term demand forecasts are required for planning/operation of the power system network. Planning concerned with addition of new generation capacity and long-term power purchase agreements requires long term demand projections. Peak load and energy requirements in future are the necessary variables to be predicted by estimation of long-term

[‡] Noida power company Ltd., being an independent licensee, which is allowed to procure its own electricity requirement, is excluded from the overall load profile projection which needs to be addressed by the state-owned distribution utilities. Further, we also appropriately exclude electricity demand to be met from captive power generation.

forecast. As per the requirement of this project a long-term demand projection following methods can be considered to predict the demand of electricity for state Uttar Pradesh.

4.1.1 Trend Analysis

Trend analysis is useful for preliminary estimate for forecast. it is usually used for short term forecast; however, it does not serve the purpose for long term electricity demand forecast. Trend analysis is non-causal type forecasting technique which does not explain underlying factors those are responsible for change in demand. It uses time factor for demand prediction, assuming pattern of demand in the past will continue into future. The mathematical function for projection is based on only time rather than any demographic, economic factor/variable, consumer category and their consumption behaviour/pattern.

The advantage of trend analysis is among all forecasting models it is comparatively easy to use and understand. The main disadvantage of this method is that it neglects underlying factors which may significantly impact demand forecast. For example, state GDP, consumer category and their distribution, urbanisation and electricity price and government initiatives etc.

4.1.2 End use method

Most engineering models are based on end use method because it refers to the bottom-up approach for the analysis which is relatively more accurate and complicated method of forecasting. End consumers are the bottom most segment of power system network, and are beneficiaries of the utility. This method requires analysis of the utility function of consumers belonging to every segment. Keeping in view the existing stock of consumer assets, the energy consumption patterns of different type of consumers are analysed and after integrating the possibility of technological advancements leading to energy efficient products as well as demand side management, the energy consumption of such consumer type in near future is predict.

Historical data concerned with the connected load as per consumer categories is analysed to draw inferences regarding past. However, in Uttar Pradesh a significant segment of the locality is yet to be electrified because it is among those few states that exhibit less than 65% of their households electrified as discussed in chapter 1 (Figure 2.1). After the PFA agreement with Central government, the state government of Uttar Pradesh is aiming to eradicate the lack of electricity supply within several rural segments of the state by 2019. An adequate amount of historical data pertaining to the number of connected and yet to be connected consumers in the state is required to be analysed to frame a realistic model of the demand forecasting.

Besides consideration of the rate of electrification, another matter of concern is the hour of supply for which connected loads in the state are provided with electricity supply. As per information obtained from UPPCL, by 2017, the rural consumer segment in Uttar Pradesh are 18 hours per day, which is expected to extend 24 hours by 2019. Both the rate of electrification and the availability of electricity supply are required to be incorporated in the analysis regarding requirement of power in near future. However, both are contradictory in nature because in order to provide electricity supply to new customers it would also be required to add an adequate generation capacity to satisfy the additional demand, but it might be a challenging task to accomplish for a state like Uttar Pradesh that is already experiencing a shortage of electricity. Also, the data pertaining to electrification rate in rural area of Uttar Pradesh and hour of supply are quite difficult to accumulate. Hence, this method of forecasting has not been resorted to for analysis purposes in this project.

4.1.3 Econometric Analysis

Econometric Analysis is a statistical technique used for long term demand forecast. This technique utilises information from historical data of electricity demand along with factors that influence electricity demand. Econometric analysis uses statistical methods to study economic theory /hypothesis between economic factor and demand. It can be used to estimate energy requirements and the relationship between per capita electricity consumption, variables related to economic activity like, State Gross Domestic Product (SGDP), share of different sectors (agriculture, industries etc.,) in GDP and electricity prices.

Multiple regression analysis can be used where per capita electricity consumption that need to forecast, as dependent variable and variable which may affect per capita electricity consumption are independent variable.

Per capita electricity consumption is an indicator of the average electricity demand that depends on the level of economic activity, the composition of economic activity, the rate of urbanization, consumer/end user awareness and the average price at which electricity is provided to the end consumers besides the power system network constraints other parameters.

Gross domestic product is a measure of gross economic activity in a country. Similarly, the state domestic product represents the economic activities being carried out in any state. The volume of economic activity depends on the availability of electricity supply in a state. Apart from this, the composition of economic activity has a significant influence on the overall electricity demand in a state. For example, during the early phase of development, agriculture remains the primary economic activity. Rise in electricity demand during the initial phase of development is primarily due to the mechanisation of agriculture and development of industrial activities, primarily linked to the agriculture. Having invested through various stages of development, one can observe the growing share of industrial activity that leads to a significant increase in the demand for electricity. More mature economies tend to depend significantly on the services sector. Alongside the development in industrial activity, commercial activity also expands in developing economies to provide for growing trade, entertainment and ancillary services. Such commercial activities often require the provision of air-conditioning that has a significant contribution to the rising demand of electricity.

Urbanisation also plays a significant role in determining the electricity demand due to a huge share of large organised housing equipped with a variety of energy guzzling appliances. Similar to the demand for any normal commodity, the demand for electricity is also influenced by changes in electricity prices as expensive electricity drives the consumers towards adoption of energy-efficient appliances and be concerned about electricity consumption in their premises.

Historic data for annual per capita electricity consumption, per capita connected load and category-wise consumption, category-wise connected load and midyear population are collected from General Review annual report, Central Electricity Authority (CEA). This data is collected from year 2002-03 to 2014-15. In methodology adopted by CEA, per capita electricity consumption is calculated on generation side which does not include transmission and distribution losses. Per capita electricity consumption is a ratio of gross electricity generation to mid-year population. Gross electricity generation includes generation from self-generation industries. The urban population ratio data for states are collected from Census of India 2001 & 2011 reports. The urban population ratio is interpolated for year between 2001 and 2011 and extrapolated with same rate after 2011. For regression analysis, data for all India (all states and union territories) is collected. States SGDP data is collected from Handbook of Statistics on Indian Economy, RBI[§]. Electricity price data is collected from tariff orders for all states' discoms. Weighted average price of electricity is used in regression analysis to find

[§]https://rbi.org.in/Scripts/AnnualPublications.aspx?head=Handbook%20of%20Statistics%20on%20Indian%20Economy effect of price on per capita electricity consumption. There is an effect of sectoral economic activity on electricity requirement, to find effect of agriculture, industrial and commercial on electricity demand, share of these sector in SGDP is also accounted in regression analysis. To make study more relevant for Uttar Pradesh few states (Mizoram, Meghalaya etc.,) where agriculture and industrial share is very low and has very high per capita electricity consumption, are excluded from regression analysis to mitigate outlier effect on estimates.

The per capita consumption of electricity is calculated based on parametric values derived from the econometric model and assumptions regarding future economic scenarios. It was decided to estimate energy requirement at bus bars for three energy forecast scenarios viz. high, medium and low growth pertaining different growth rates prospect for per capita GDP (Gross Domestic Product) growth in the future respectively. An additional realistic energy requirement scenario is also analysed based on a relatively high growth expectation as compared to the medium growth scenario.

A generic model for per capita electricity demand for a state can be provided as

$$Q = f\left(G, P_E, U, S_p, S_s\right) \quad (1)$$

where
Q = Per capita consumption of electricity
G = Per capita State Gross Domestic Product (SGDP)
P_E = Weighted electricity price
U = Percentage urban population
S_p = Share of primary sector in state GDP
S_s = Share of secondary sector in state GDP

Assumptions that have been made regarding growth in the per capita SGDP, rate of urbanization, sectoral contribution in SGDP *i.e.* share of agricultural, industrial and service sectors in SGDP as well as the prices of electricity are as follows.

- The per capita SGDP growth rate is assumed to be 8% p.a. in high growth scenario, 6% p.a. in medium growth scenario followed by a tapered reduction in growth and 4% p.a. in the low growth scenario.
- A differential growth rate is assumed for the realistic growth scenario *i.e.* 8% p.a. for the years 2015-16 to 2019-20 and 7% p.a. for the years 2021-22 to 2026-27.

- Share of urban population in the state is expected to grow by 1% each year and is expected to reach 25.9% by 2027 considering a similar growth rate data available from the census.
- Share of industrial sector in SGDP is expected to increase with an annual increment rate of 0.2% whereas agricultural share in SGDP is expected to decline with an annual decrement rate of 0.1% every year.
- Average electricity prices are assumed to grow by 4% annually.
- The population growth is assumed to follow the forecasted pattern as in Scenario B of the Population Foundation of India (PFI). The population growth rate is taken to be 1.82% for the years 2011-2021 and 1.52% for the next 10 years *i.e.* 2021-2031 and beyond.

A regression analysis is done using historical data for the state of Uttar Pradesh from 2003-04 to 2014-15 keeping in view the above-mentioned assumptions for building a mathematical model and projecting per capita electricity consumption in the state of Uttar Pradesh till 2027 based on the input values for independent variables. Several functional forms (linear or log-linear) for regression models are built based on economic theory and interpreting the factor. All regression models are presented in Appendix…. . The result of selected model is shown in Figure 4.1 and 4.2. Output of the regression model is calibrated with the available data of per capita electricity consumption for the FY 2016.

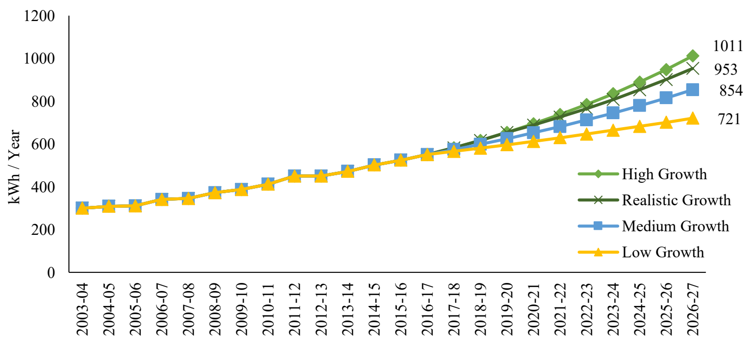

Figure 4.1: Projected per capita electricity consumption in the state of Uttar Pradesh

The per capita electricity demand for 2026-27 Uttar Pradesh for High Growth, Realistic Growth, Medium Growth and Low Growth scenarios is projected to be 1011 kWh, 953 kWh, 854 kWh and 724 kWh respectively (Figure 4.2). The corresponding demand for electrical energy for 2026-27 is projected to be 244.24 TWh, 230.4 TWh, 206.8 TWh and 175.2 TWh respectively.

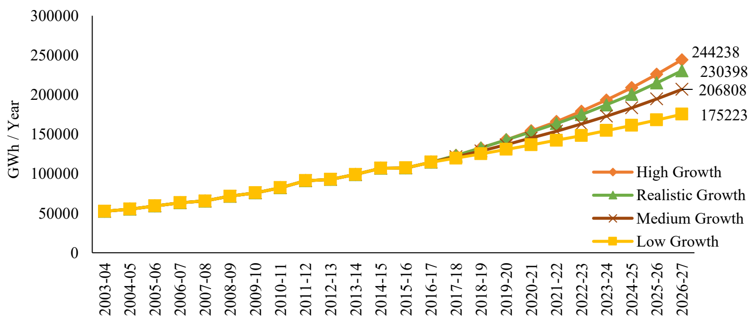

Figure 4.2: Projected energy requirement at bus-bars without captive generation

4.2 Projected Load Profile

Once the demand for electrical energy over the forecasting horizon is estimated, the next step is to translate this into an hourly load/demand curve of the state for the forecasting horizon.

The historical load profile of Uttar Pradesh has been significantly influenced by availability of power rather than its demand. From the historical data, we can observe that a significant amount of a demand is shared with planned rostering while additional demand is suppressed due to emergency rostering. The unconstrained daily demand curve for the state is obtained by adding back the planned and unplanned rostering. The daily load profile obtained is still not an appropriate representative of the hourly consumption profile for the state as almost the entire rural segment consumers as well as a significant proportion of the urban population do not get 24-hour supply of electricity. The suppressed demand of electricity in rural areas and a few urban areas is likely to be unshackled in near future through improved availability of electricity in the state leading to increased reliability of electric power supply. Thus, it is quite challenging to develop an hourly load profile for the state to be a representative of an unconstrained demand profile. Further, changes in electricity prices in the future especially those related to the day time tariff have a significant impact on shape of the load profile.

To derive a likely shape of load profile of the state for the next 10 years, we have used the existing unconstrained demand profile, short-term power procurement strategies leading to increased availability of power during the time of night and load profile of a few comparable states. Thus, keeping in view the author profile of Uttar Pradesh and those of some comparable states like Madhya Pradesh, Haryana, Gujarat etc., we have developed a likely load profile of the state.

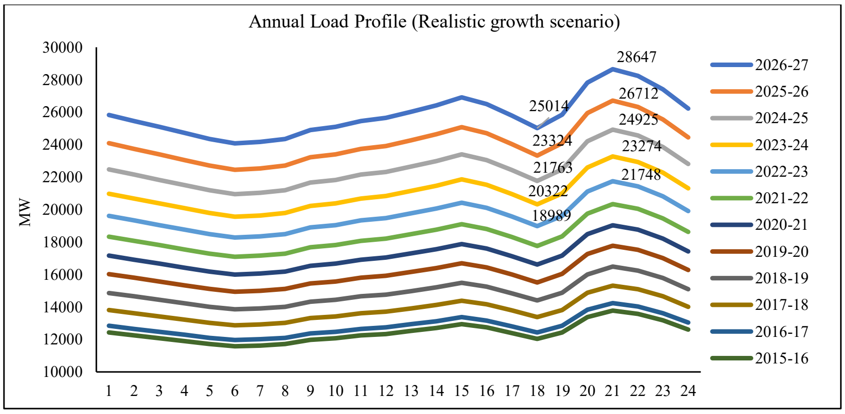

Figure 4.3: Projected load profile of Uttar Pradesh (Realistic growth scenario)

Average annual load profile for the state of Uttar Pradesh for all four scenarios is projected based on historical load pattern and energy requirement estimated from econometric analysis for the state while considering the load profile of a few other states like Madhya Pradesh, Gujarat, and Haryana that exhibit a similar electricity consumption pattern. Load profile of the state for each year till 2027 is developed to match projected energy demand in the respective year. The estimated load profile is a representative of consumption pattern in the state of Uttar Pradesh for a typical day of the entire year. The annual energy requirement is estimated after accounting for Demand Side Management (DSM), excluding demand for Noida Power Corporation Limited (NPCL) and neglecting the captive generation units.

The methodology used to develop load profile for a representative day is, energy consume in day is a ratio (one day to total number of days in a year, 1/365) of total energy projected for a year. Energy requirement in different months of year are studied from historical data from monthly report at CEA[**]. This helps to understand the distribution of gross energy required in months of year. It is useful for scheduling power to meet energy requirement and peak load assessment. Load profile and consumer consumption pattern depend on seasonal whether condition, so it is necessary to study seasonal load profile and energy requirement. The load profile of Uttar Pradesh is significantly different from other states. The electricity consumption is driven by availability. Since UPPCL has started supply electricity during

[**] Power Supply Reports, Source http://www.cea.nic.in/monthlypowersupply.html

evening and night (from 7 PM to 7 AM) load curve move steeply upward. For load profile this unusual supply driven behaviour is not consider. Load profile is built after studying other states (Madhya Pradesh, Gujarat, etc.) load curve.

The general behaviour observed after studying historical load profile for state. identified observations are as follow:

- Demand increasing after morning 6 and continuing till 3 to 4 PM. This behaviour is due to people start their day and move to their work place. After 8 AM industries and offices start.
- After 4 demand decreases due to change in day temperature and it reaches day low about 6 PM when office, institution and day running industries are closed.
- Demand increases after 6 due to lighting load at domestic, commercial and public lighting.
- Evening load is very much affected by cooling load (Coolers and Air conditioners). Since variation in load can be observer in summer and winter. Generally winter load profile for a day has low variation compare to summers.
- After 10 PM load profile decreases due to closing commercial store and Malls and public lighting.

Following are a few other assumptions:

- Captive generation will account for 10% of the total generation in future but it has not been incorporated in the analysis. Captive generation in state from FY 2007 to FY 2015 is given in appendix C.
- Agriculture DSM policy targets to replace 10 lakh agricultural pumps sets by 2022 have been considered.
- LEDs distributed in recent past would predominantly affect the lighting load during evening hours *i.e.* 7 PM. to 10 PM.
- Consumption/ load for NPCL is not accounted in load profile.

Captive generation contributes to about 11% of the total electricity generation in the state and is on a decline over the past few years as the supply of electricity has improved in the state. With the following assumptions, projected average annual load profile in the state of Uttar Pradesh is as shown in the Figure 4.3. The so predicted load profile is utilized for further analysis regarding optimal power procurement keeping in view the available and upcoming generation sources in the state of Uttar Pradesh, a few some surrounding states and those owned and operated by the Central government companies.

4.3 Simulation Based Optimization Model

In order to minimize total procurement cost for the planning period a simulation model on General Algebraic Modelling System (GAMS) based platform is created. GAMS is a high-level modelling system/platform for mathematical programming and optimization and is integrated with high-performance solvers. Optimization models created in GAMS utilizes available information from existing/planned/probable resources of electricity to satisfy projected demand for the planning period. The model considers one representative day in terms of 24 hours, for a year and obtains optimal procurement plans for future demand for a planning period in several years targeting minimum cost. This optimization model also considers all major operational constraints related to generating units, power purchase agreements, short term power procurement contracts and candidate plants.

The GAMS simulation model is coded implication of mathematical sets of equations. These mathematical equations include objective of cost minimization and relevant constraints. The objective function considers cost of electricity from various resources. In addition, it also considers a penalty cost for unmet load in order to discourage load shedding. Together these costs are addressed as Social Cost. It is to be noted that cost for load shedding is not paid by the utility (UPPCL) hence another cost is calculated for utility which is termed as Utility cost. Targeting minimizing Social Cost for entire planning period following points are also taken care in this model.

1. Optimum capacity utilization from available resources
2. Optimal year for new capacity addition
3. Comparative study for different power procurement portfolio/scenario
4. Avoiding solar generation curtailments
5. Demand supply matching
6. Discount rate for economic cost analysis and comparisons in terms of current year
7. Annual escalation/decline in costs as per contracts
8. Solar generation annual capacity addition and according cost
9. DSM and solar energy targets for UP
10. Transmission losses and transmission costs for interstate contracts
11. Availability of plants

12. Solar Generation profiles as per capacity for angle appropriate to UP

The objective of Social Cost minimization is subject to various technical and economic constraints. Following are the detailed list of constraints applied to the model.

1. Generator specific Constraints

    i. Technical minimum Criteria for Generators
    ii. Maximum Supply Criteria for Generators
    iii. Generator Ramp-Up and Ramp-down limiting constraints
    iv. Must run constraints with generator and commitment compulsion
    v. Energy available from power plants
    vi. Minimum uptime and down time limits for generators

2. Contract specific Constraints

    i. Fix term for contracts like PPAs
    ii. Contract duration once commissioned
    iii. Strict/relaxed starting Commercial Operation Date (year) after a fixed term
    iv. Availability of ST contracts in terms of time of the day
    v. minimum contract period for ST contracts

To meet future electricity requirement utility has identified a few sources which has their own capacity and cost associated to supply this energy. The overall objective is to identify all best possible combination of sources which able to meet future demand.

4.3.1 GAMS Model Inputs

For performing simulation different sets of data are considered as input information for the code. As existing source of electricity existing PPAs (signed PPA's) and plants, planned capacity addition and various short-term power procurement (STPP) options have been considered. The data for the same has been collected from various sources and logically assumed for analysis and simulations. The prospective sources of capacity addition can be new state-sector generating stations (SSGS), interstate generating stations (NTPC, NHPC, NPCIL etc.), independent power producers (IPP), cogeneration and short-term contracts including power exchanges. Also, projected demand in different economic growth scenarios obtained from regression analysis is also one of the input for the simulation model.

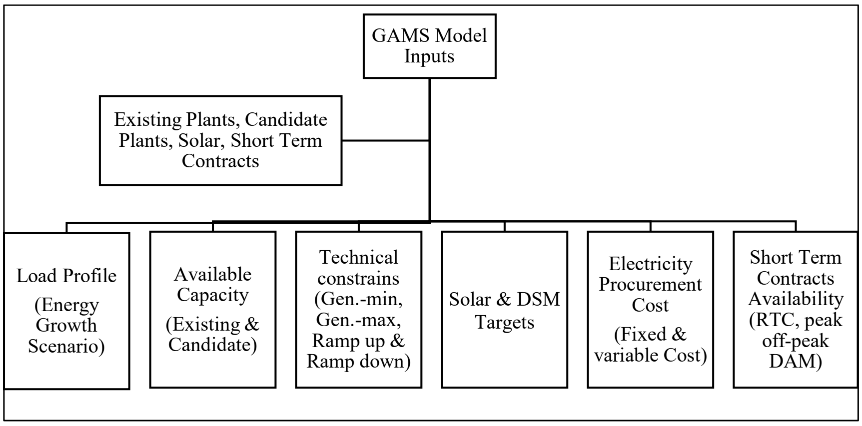

Figure 4.4: Optimization model input parameters

The optimization model built to fulfil the objective of minimizing procurement cost of energy to satisfy demand in overall planning period. Several input data sets required by the model are as represented in Figure 4.4.

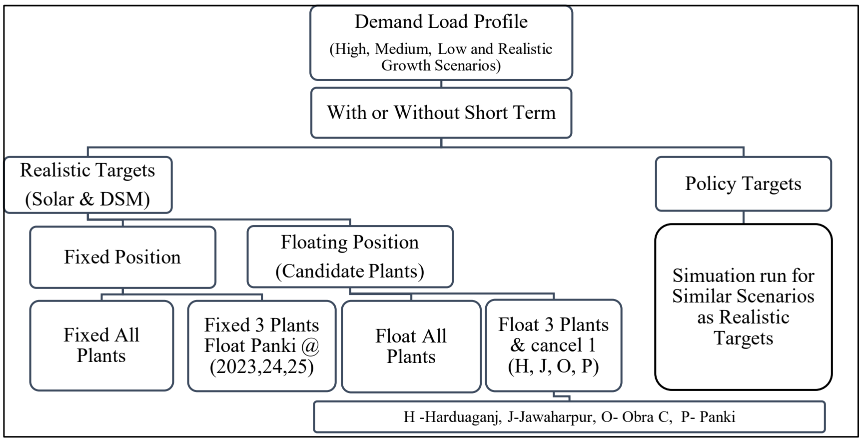

Figure 4.5 Optimization models' scenarios

Total procurement cost has components like fixed cost payable to plant for availability (usually on annual basis) and variable cost for energy served (for per MW energy served). These information is sourced from UPPCL, UPERC tariff orders and PFA report. However, some technical parameter like ramping, uptime down time etc. are logically assumed for different generation types. As the analysis is for several years, annual escalation in costs is also considered as shown in Table 4.1.

Table 4.1: Assumptions for existing PPAs and state generations for simulation model

Source for generation	Energy Availability	PPA tied up till 2027	Ramp Rate In% of Capacity	Min. Up time/down time (Hours)	Annual Escalation Rate Variable Cost	Annual Escalation Rate Fixed Cost
State Thermal Plants	90%	Yes	20%	4	5%	-2 %
State Hydro Plants	40%	Yes	100%	1	-1.5%	0%
NTPC Plants	85%	Yes	53%	4	5%	1%
HYDRO NTPC Plants	50%	Yes	100%	1	3%	0%
NHPC Plants	50%	Yes	100%	1	3.5%	3.5%
NPCIL Plants	55%	Yes	100%	8	5%	0%
IPPs/JVs Plants	50%	Yes	80%	4	3.5%	3.5%
Captive and Cogeneration	50%	Yes	25%	4	3%	0%
NVVN Coal Power Plant	100%	Yes	40%	4	5%	0%

Table 4.2: Generation Specifications for Candidate plants of state and outside

Plant Name	Fixed cost (Lakh Rs./year)	Variable Cost Rs. /MWh	Plant Capacity (MW)	Year of Commissioning	Availability	Ramp Rates in % of Capacity	Min. up/down time (Hours)	Annual Escalation Rate in Fixed Cost	Annual Escal. Rate in Var. Cost
Jawaharpur	2211	2380	1320	2022	85%	40%	4	-2%	5%
Harduaganj	1143	2330	660	2020	85%	40%	4	-2%	5%
Obra – C	2214	1930	1320	2022	85%	40%	4	-2%	5%
Panki	1139	2100	660	2022	85%	40%	4	-2%	5%
Meja - Unit-I	2390	2780	495	2018	85%	40%	4	-2%	5%
Meja - Unit-II	2390	2780	495	2019	85%	40%	4	-2%	5%
Ghatampur	2641	2780	1275	2021	85%	40%	4	-2%	5%
Bara	730	2330	594	2017	85%	40%	4	-2%	5%
Visnugarh Pipal Kothi	164	2510	166	2020	45%	100%	4	-2%	5%
Subansiri Lower-NHPC	174	2430	182	2021	45%	100%	4	-2%	5%
Tapovan - Vishnugarh	86	2140	102	2020	45%	100%	4	-2%	5%
Lata- Tapovan -HEP – NTPC	39	2930	34	2022	45%	100%	4	-2%	5%
Parbati-II – HEP	114	1860	155	2019	45%	100%	4	-2%	5%
Tanda – II	1489	1530	943	2019	85%	40%	4	-2%	5%
UPJVNL - Hydro	2	2640	2	2018	45%	100%	4	-2%	5%
Unchahar – IV	263	2890	222	2018	85%	40%	4	-2%	5%
Singarauli – III	2496	1740	1320	2022	85%	40%	4	-2%	5%
North - Karanpura	185	1740	98	2020	85%	40%	4	-2%	5%
Tawang – NHPC	161	2500	160	2022	45%	100%	4	-2%	5%
Upper – Karnali	272	2300	300	2022	85%	100%	4	-2%	5%
Kameng – HEP	163	2170	190	2018	85%	100%	4	-2%	5%

Table 4.3: Assumed Short Term Power Procurement (STPP) Options for simulation model

Contract Type	Price Range (Rs. / MWh)	Quantity (MW)	Availability in a day	Annual Escalation Rate in Cost
Round the Clock	3200-3400	500-300	Round the clock (24 Hours)	3%
Round the Clock DAM	3400	300	Round the clock (24 Hours)	3%
Mourning Shoulder	3000-3300	300-250	5 AM to 9 AM (4 Hours)	3%
Mourning Shoulder DAM	3300	250	5 AM to 9 AM (4 Hours)	3%
Mourning Peak	4000-4600	300-200	9 to 12 PM (3 Hours)	3%
Mourning Peak DAM	4600	200	9 to 12 PM (3 Hours)	3%
Shoulder	3000-3200	300-250	12 PM to 6 PM (6 Hours)	2%
Shoulder DAM	3200	250	12 PM to 6 PM (6 Hours)	2%
Evening Peak	5500-6100	300-200	6 to 11 PM (4 Hours)	3%
Evening Peak DAM	6100	200	6 to 11 PM (4 Hours)	3%
Off-Peak	2000-2200	300-250	11 PM to 5 AM (6 Hours)	3%
Off-Peak DAM	2200	250	11 PM to 5 AM (6 Hours)	3%

The assumptions made for existing PPAs and state generations are shown in Table 4.1. For candidate contracts/plants information is sourced from…………and UPPCL []. The assumptions and other information about specifications related to plant/contract are represented in Table 4.2. For Short Term Power Procurement (STPP) some possible contracts are assumed available for all years of procurement planning. Prices and types of contracts are based on the present short-term energy procurement scenario of state. The assumed data for STPP is shown in Table 4.3.

It is to be noted that a considerable part of energy gets wasted in transmission losses, which also need to be considered. To account this energy, transmission losses (interstate transmission losses 1.65%, intra state transmission losses 3.59%) are incorporated in optimization model. Transmission Losses are sampled average of the respective FY 2016 values taken from POSOCO []. Apart energy procurement from these sources utility also bears POC and Reliability charges for all type of power agreements (LTA, MTOA and STOA). Based on location of power plant POC charges are applied and this is taken care during calculation of total power procurement cost. POC Charges are taken From CERC reports of FY 2016 [].

4.3.2 Power procurement scenarios

Energy requirement analysis is done for four economic growth scenarios for the state Uttar Pradesh. These scenarios are i) High growth, ii) Medium growth, iii) Low growth and iv) Realistic growth scenario. For each of these scenarios, four different annual energy demands are projected based on which average annual load profiles are created for each of them. This is done in order to reduce the impact of error in demand projection in procurement planning.

In past years, utility has procured significant amount of energy from short term contracts including power exchange to meet peak demand. Since this energy is available at comparatively low cost but it also has risk of unavailability due to congestion or high price in peak hour. To study this, two scenarios are created wherein one has limited not to procure from short term.

To manage demand side management government has made several policies which include LED distribution, replace old agriculture pump sets with new energy efficient pump sets. Government has made aggressive targets which includes approximately replacement of 10 lakh pump set by 2020. To meet country solar target Uttar Pradesh also made target to achieve 6000 MW solar power install by 2020. Since govt is making its best possible to effort to meet target but it is difficult to achieve in given timeframe. A realistic targets scenario also made for DSM and solar.

There are several important decisions need to take care before adding capacity. These decisions include procurement cost (fixed and variable charges) and time, when to bring this capacity in portfolio. If power is procured before it is required, bring addition cost to utility of paying fixed cost without any energy purchase. If energy has procured at high charges than it will not get scheduled by SLDC due to lower priority in merit order. To analyse these conditions, models run to find best optimal position for each new capacity addition. This analysis helps to understand is there any cost saving possible to delay capacity without affecting energy requirements.

CHAPTER 5
CONCLUSIONS AND RECOMMENDTIONS

5.1 Power Procurement Planning

The optimisation model developed for the study is implemented on the General Algebraic Modelling System (GAMS), a modelling system for mathematical optimization. We develop a unit commitment model, which optimises the discounted social cost to meet the projected demand for each of the years till 2026-27 while considering the following key factors[††],

- Technical and economic characteristics like generation/contracted capacity, availability, technical minimum generation, annual fixed cost, per unit variable cost, ramp up and ramp down constraints, minimum uptime and minimum downtime constraints.

- The above characteristics are considered individually for each of the existing plants and the candidate plants. We also consider the expected capacity retirement especially in the context of the state generating units.

- The model considers transmission losses as well as the point of connection (PoC) charges for electricity supply from each generating plant up to the state periphery.

- Four state-level candidate plants - Jawaharpur, Harduaganj, Obra- C and Panki - remain the centre of analysis to evaluate various strategies.

- Historical PPAs signed by UPPCL with CPSUs for projects which are actively being pursued and are expected to provide supply of electricity to the state during the forecasting horizon.

- Two cases of power sale offers received by UPPCL for Upper Karnali and Kameng projects are also considered.

A list of existing as well as candidate plants/contracts are given in Appendix-A. The following power procurement strategy cases were constructed for analysing the power procurement for the state.

[††] We assume that necessary transmission capacity development would follow the proposed power procurement strategy and, hence, it is not considered to be a constraint in the study.

Table 5.5.1: Power Procurement Strategy Cases

Strategy Name	Description
All Fix	Retaining all plants at their commissioning year.
Fix Oth. (- H)	Cancelling Harduaganj, retaining others at their commissioning year.
Fix Oth. (- P)	Cancelling Panki, retaining others at their commissioning year.
Fix Oth. (- O)	Cancelling Obra-C, retaining others at their commissioning year.
Fix Oth. (- J)	Cancelling Jawaharpur, retaining others at their commissioning year.
Fix Oth. Float P	Allow Panki to find optimal commissioning year, retaining others at their commissioning year.
Fix Oth. P @ 2023	Shift Panki to 2023, retaining others at their commissioning year.
All Float	Allow plants (P, H, J, O) to find optimal commissioning year, retaining others at their commissioning year.
Float Oth. (- H)	Cancelling Harduaganj (H), Allow others (P, J, O) to find optimal commissioning year.
Float Oth. (- P)	Cancelling Panki (P), Allow others (H, J, O) to find optimal commissioning year.
Float Oth. (- O)	Cancelling Obra-C (O), Allow others (P, H, J) to find optimal commissioning year.
Float Oth. (- J)	Cancelling Jawaharpur (J), Allow others (P, H, O) to find optimal commissioning year.
Fix Oth. (+U, +K)	Retaining all plants at their commissioning/contract year including Upper Karnali and Kameng.
Fix Oth. Float (U, K, P)	Allow Panki, Upper Karnali and Kameng to find optimal commissioning year, retaining others at their commissioning year.
Fix Oth. (+U, +K), Float P	Allow Panki to find optimal commissioning year, retaining all plants at their commissioning/contract year including Upper Karnali and Kameng.

A ranking of the above listed strategy cases based on the savings/cost with respect to the 'All Fix' (Base Case) is presented in Tables 2-5 for High Growth, Realistic Growth and Medium Growth scenarios respectively[‡‡].

[‡‡] We exclude results pertaining to Low Growth Scenario in this short report.

Table 5.5.2: Savings (Social Cost) without Short Term Contracts

Ranking	Savings in Social Cost (Rs. Cr.)	High Growth Scenario	Savings in Social Cost (Rs. Cr.)	Realistic Growth Scenario	Savings in Social Cost (Rs. Cr.)	Medium Growth Scenario
I	5809	All Float	6690	All Float	9270	All Float
II	2286	Float Oth. (- H)	4040	Float Oth. (- H)	8616	Float Oth. (- H)
III	1842	Float Oth. (- P)	3691	Float Oth. (- P)	8349	Float Oth. (- P)
IV	1177	Fix Oth. Float (U, K, P)	970	Fix Oth. Float (U, K, P)	7237	Float Oth. (- J)
V	457	Fix Oth. Float P *	794	Float Oth. (- J)	6345	Float Oth. (- O)
VI	395	Fix Oth. P @ 2023	564	Fix Oth. Float P #	1354	Fix Oth. (- H)
VII	0	All Fix	424	Fix Oth. P @ 2023	1114	Fix Oth. P @ 2023
VIII	-181	Fix Oth. (+U, +K), Float P *	0	All Fix	688	Fix Oth. Float (U, K, P)
IX	-707	Fix Oth. (+U, +K)	-225	Float Oth. (- O)	681	Fix Oth. Float P $
X	-2064	Fix Oth. (- H)	-520	Fix Oth. (+U, +K), Float P #	139	Fix Oth. (- J)
XI	-2457	Float Oth. (- J)	-801	Fix Oth. (- H)	49	Fix Oth. (- P)
XII	-3274	Fix Oth. (- P)	-1062	Fix Oth. (+U, +K)	0	All Fix
XIII	-3536	Float Oth. (- O)	-2026	Fix Oth. (- P)	-1015	Fix Oth. (- O)
XIV	-6932	Fix Oth. (- J)	-4175	Fix Oth. (- J)	-1216	Fix Oth.(+U, +K), Float P $$
XV	-8187	Fix Oth. (- O)	-5401	Fix Oth. (- O)	-1960	Fix Oth. (+U, +K)

* Panki at 2024, # Panki at 2025, $ Panki at 2025, $$ Panki at 2026

Table 5.5.3: Savings (Social Cost) with Short Term Contracts

Ranking	Savings in Social Cost (Rs. Cr.)	High Growth Scenario	Savings in Social Cost (Rs. Cr.)	Realistic Growth Scenario	Savings in Social Cost (Rs. Cr.)	Medium Growth Scenario
I	7738	All Float	8555	All Float	11148	All Float
II	6018	Float Oth. (- H)	7805	Float Oth. (- H)	10946	Float Oth. (- H)
III	5740	Float Oth. (- P)	7483	Float Oth. (- P)	10761	Float Oth. (- J)
IV	3814	Float Oth. (- J)	6353	Float Oth. (- J)	10749	Float Oth. (- P)
V	2883	Float Oth. (- O)	5460	Float Oth. (- O)	10062	Float Oth. (- O)
VI	759	Fix Oth. Float (U, K, P)	985	Fix Oth. (- H)	2085	Fix Oth. (- H)
VII	529	Fix Oth. Float P *	605	Fix Oth. Float (U, K, P)	858	Fix Oth. Float P $
VIII	393	Fix Oth. P @ 2023	551	Fix Oth. Float P #	858	Fix Oth. Float (U, K, P)
IX	82	Fix Oth. (- H)	323	Fix Oth. P @ 2023	780	Fix Oth. (- P)
X	0	All Fix	0	All Fix	743	Fix Oth. (- O)
XI	-933	Fix Oth. (+U, +K), Float P *	-274	Fix Oth. (- P)	0	All Fix
XII	-1201	Fix Oth. (- P)	-364	Fix Oth. (- J)	-62	Fix Oth. (- J)
XIII	-1438	Fix Oth. (+U, +K)	-1185	Fix Oth. (+U, +K), Float P #	-1212	Fix Oth.(+U, +K), Float P $$
XIV	-2265	Fix Oth. (- J)	-1571	Fix Oth. (- O)	-1669	Fix Oth. P @ 2023
XV	-3505	Fix Oth. (- O)	-1773	Fix Oth. (+U, +K)	-2120	Fix Oth. (+U, +K)

* Panki at 2025, # Panki at 2025, $ Panki at 2026, $$ Panki at 2027

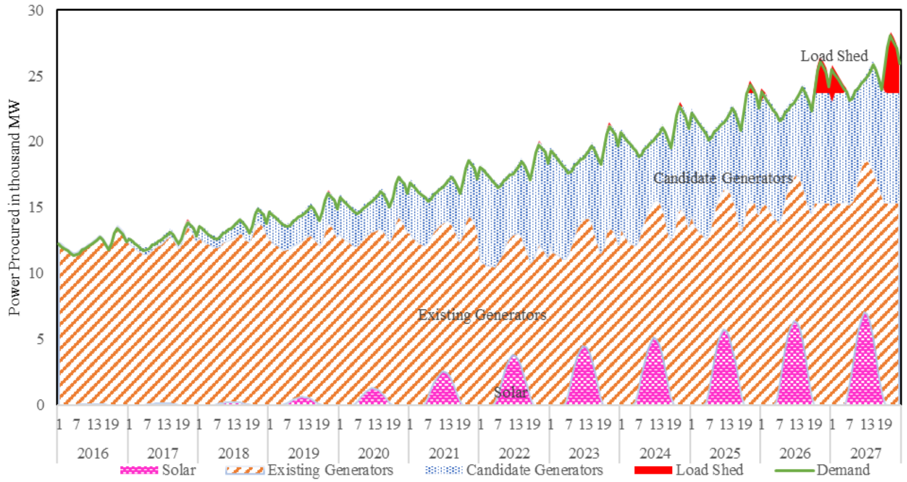

Figure 6 Optimal power procurement for representative days for FY2016 to FY2017 (Scenario: Fix others float Panki for real demand growth without considering STPP)

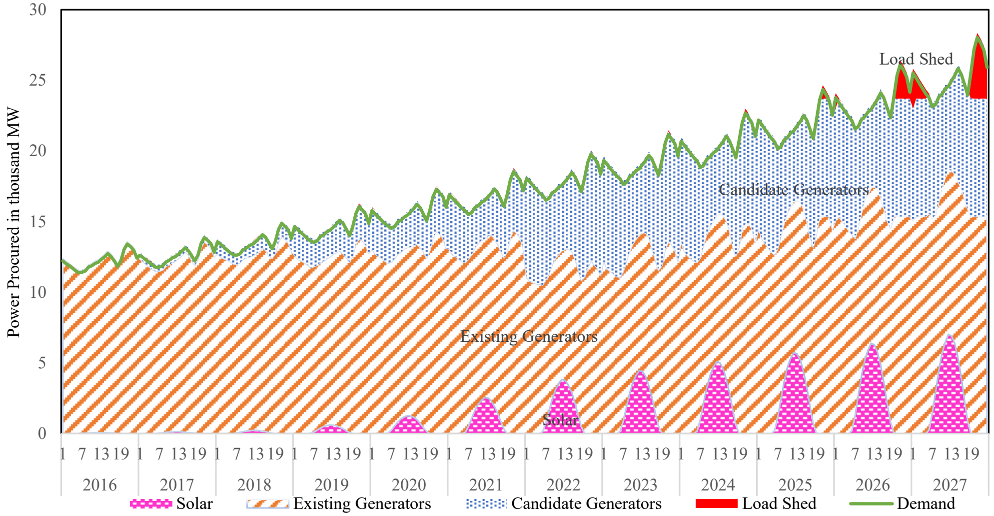

Figure 7 Optimal power procurement for representative days for FY2016 to FY2017 (Scenario: Fix all for real demand growth without cons idering STPP)

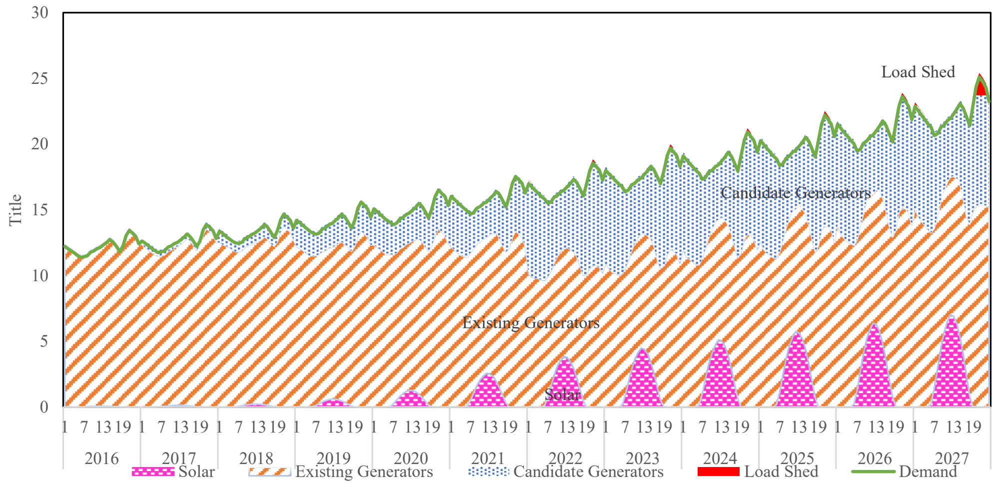

Figure 8 Optimal power procurement for representative days for FY2016 to FY2017 (Scenario: Fix others float Panki for medium demand growth without considering STPP)

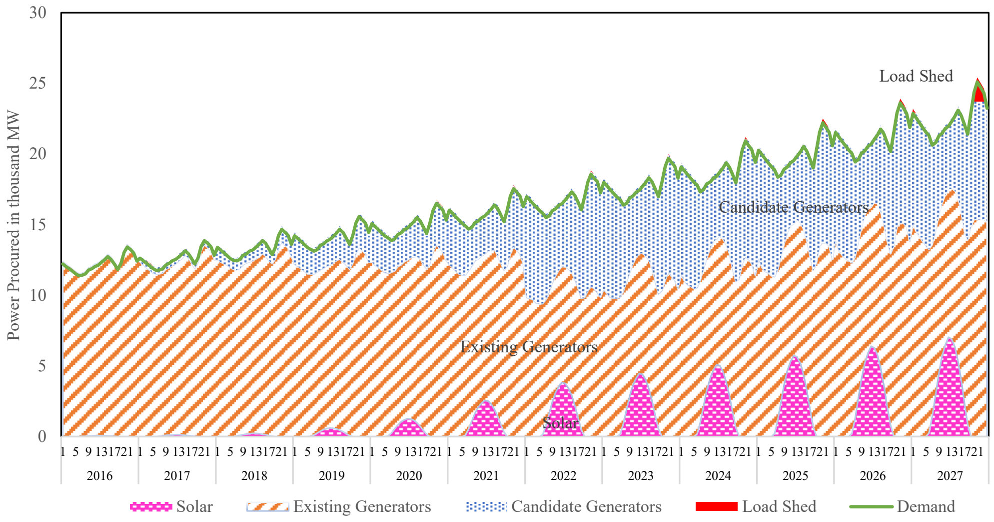

Figure 9 Optimal power procurement for representative days for FY2016 to FY2017 (Scenario: Fix others for medium demand growth without considering STPP)

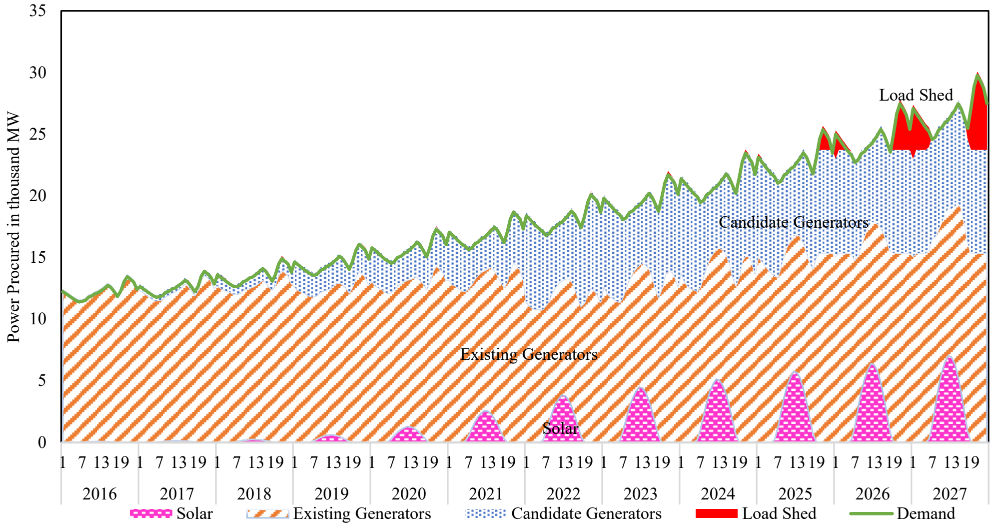

Figure 10 Optimal power procurement for representative days for FY2016 to FY2017 (Scenario: Fix others float Panki for high demand growth without considering STPP)

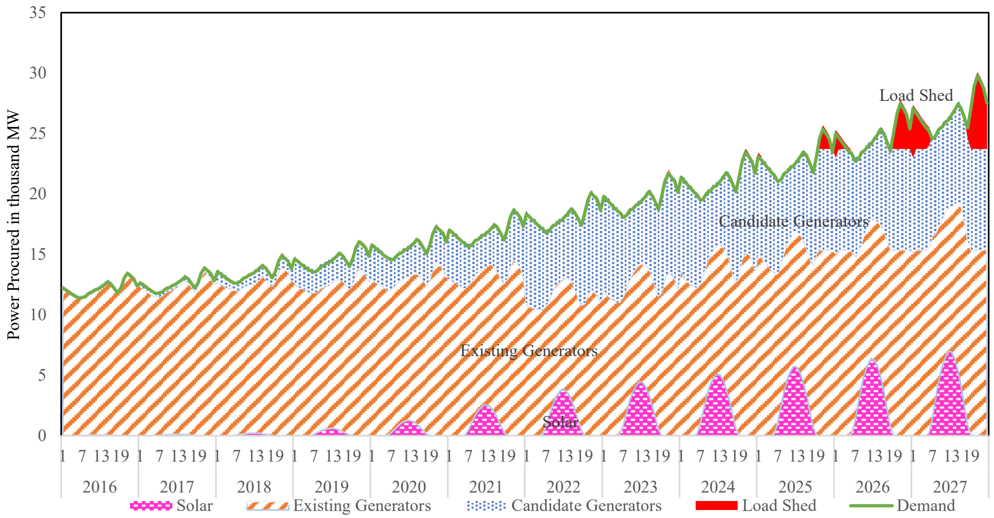

Figure 11 Optimal power procurement for representative days for FY2016 to FY2017 (Scenario: Fix others for high demand growth without considering STPP)

Table 5.5.4: Savings (Utility Cost) without Short Term Contracts

Ranking	Savings in Utility Cost (Rs. Cr.)	High Growth Scenario	Savings in Utility Cost (Rs. Cr.)	Realistic Growth Scenario	Savings in Utility Cost (Rs. Cr.)	Medium Growth Scenario
I	10223	Float Oth. (- J)	9482	Float Oth. (- J)	11471	Float Oth. (- J)
II	9246	Float Oth. (- O)	9130	Float Oth. (- H)	10661	Float Oth. (- H)
III	8113	Float Oth. (- H)	8782	Float Oth. (- P)	10181	Float Oth. (- P)
IV	7625	Float Oth. (- P)	8464	Float Oth. (- O)	9952	All Float
V	6233	All Float	7524	All Float	9836	Float Oth. (- O)
VI	4914	Fix Oth. (- J)	4390	Fix Oth. (- J)	2996	Fix Oth. (- J)
VII	3647	Fix Oth. (- O)	3141	Fix Oth. (- O)	2592	Fix Oth. (- H)
VIII	3467	Fix Oth. (- H)	3106	Fix Oth. (- H)	1838	Fix Oth. (- O)
IX	2128	Fix Oth. (- P)	1782	Fix Oth. (- P)	1262	Fix Oth. (- P)
X	585	Fix Oth. Float P *	609	Fix Oth. Float P #	906	Fix Oth. Float P $
XI	378	Fix Oth. P @ 2023	455	Fix Oth. P @ 2023	810	Fix Oth. Float (U, K, P)
XII	0	All Fix	0	All Fix	0	All Fix
XIII	-265	Fix Oth. Float (U, K, P)	-101	Fix Oth. Float (U, K, P)	-193	Fix Oth. P @ 2023
XIV	-1884	Fix Oth. (+U, +K), Float P *	-1726	Fix Oth. (+U, +K), Float P #	-1269	Fix Oth.(+U, +K), Float P $$
XV	-2440	Fix Oth. (+U, +K)	-2318	Fix Oth. (+U, +K)	-2218	Fix Oth. (+U, +K)

* Panki at 2024, # Panki at 2025, $ Panki at 2025, $$ Panki at 2026

Table 5.5.5: Savings (Utility Cost) with Short Term Contracts

Ranking	Savings in Utility Cost (Rs. Cr.)	High Growth Scenario	Savings in Utility Cost (Rs. Cr.)	Realistic Growth Scenario	Savings in Utility Cost (Rs. Cr.)	Medium Growth Scenario
I	9534	Float Oth. (- J)	10273	Float Oth. (- J)	11782	Float Oth. (- H)
II	8660	Float Oth. (- H)	9677	Float Oth. (- H)	11628	Float Oth. (- P)
III	8572	Float Oth. (- O)	9349	Float Oth. (- P)	11549	All Float
IV	8383	Float Oth. (- P)	9347	Float Oth. (- O)	11180	Float Oth. (- J)
V	8352	All Float	9109	All Float	10493	Float Oth. (- O)
VI	3084	Fix Oth. (- J)	2783	Fix Oth. (- J)	2058	Fix Oth. (- H)
VII	2410	Fix Oth. (- H)	2289	Fix Oth. (- H)	911	Fix Oth. (- O)
VIII	1799	Fix Oth. (- O)	1575	Fix Oth. (- O)	805	Fix Oth. Float P $
IX	1128	Fix Oth. (- P)	1030	Fix Oth. (- P)	805	Fix Oth. Float (U, K, P)
X	459	Fix Oth. Float P *	634	Fix Oth. Float P #	753	Fix Oth. (- P)
XI	350	Fix Oth. P @ 2023	359	Fix Oth. Float (U, K, P)	18	Fix Oth. (- J)
XII	36	Fix Oth. Float (U, K, P)	323	Fix Oth. P @ 2023	0	All Fix
XIII	0	All Fix	0	All Fix	-1138	Fix Oth.(+U, +K), Float P $$
XIV	-1802	Fix Oth. (+U, +K), Float P *	-1467	Fix Oth. (+U, +K), Float P #	-1594	Fix Oth. P @ 2023
XV	-2337	Fix Oth. (+U, +K)	-2086	Fix Oth. (+U, +K)	-2045	Fix Oth. (+U, +K)

* Panki at 2025, # Panki at 2025, $ Panki at 2026, $$ Panki at 2027

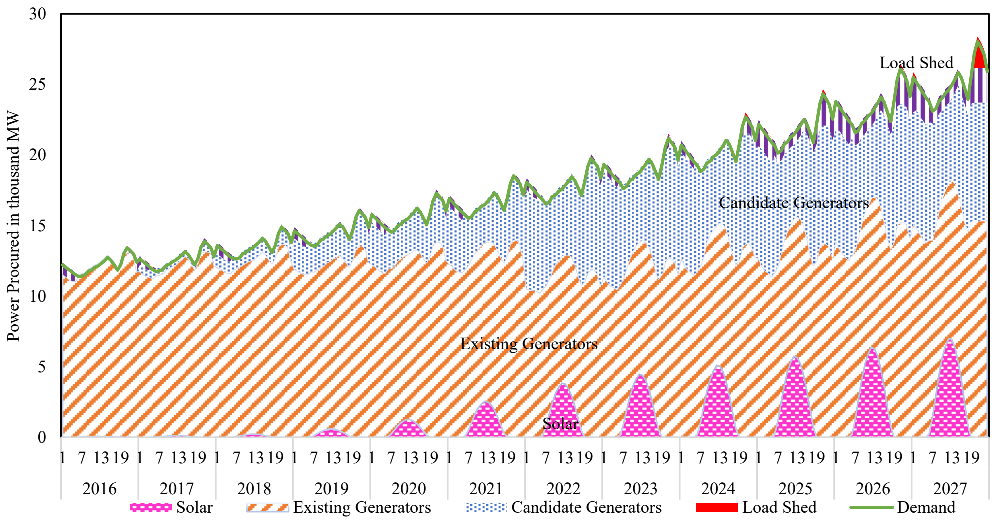

Figure 12 Optimal power procurement for representative days for FY2016 to FY2017 (Scenario: Fix others float Panki for real demand growth considering STPP)

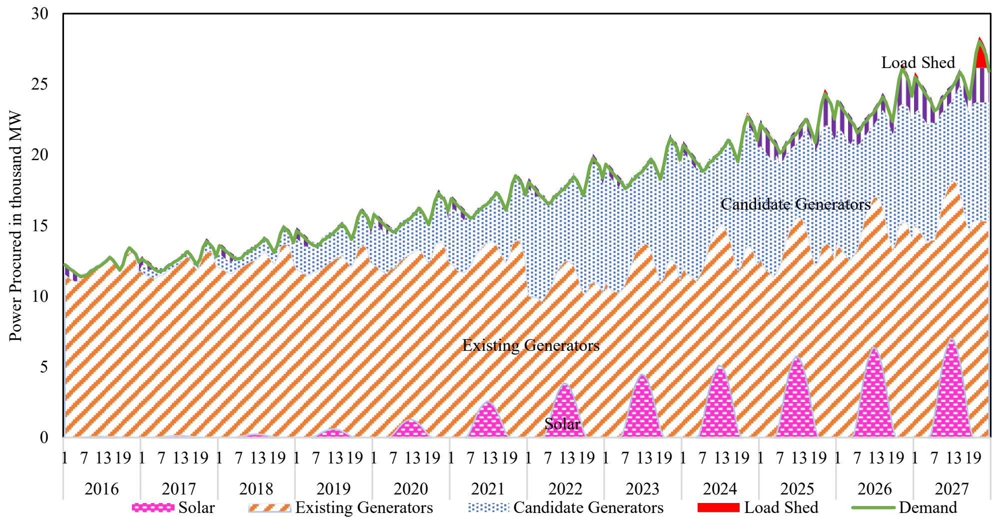

Figure 13 Optimal power procurement for representative days for FY2016 to FY2017 (Scenario: Fix all for real demand growth considering STPP)

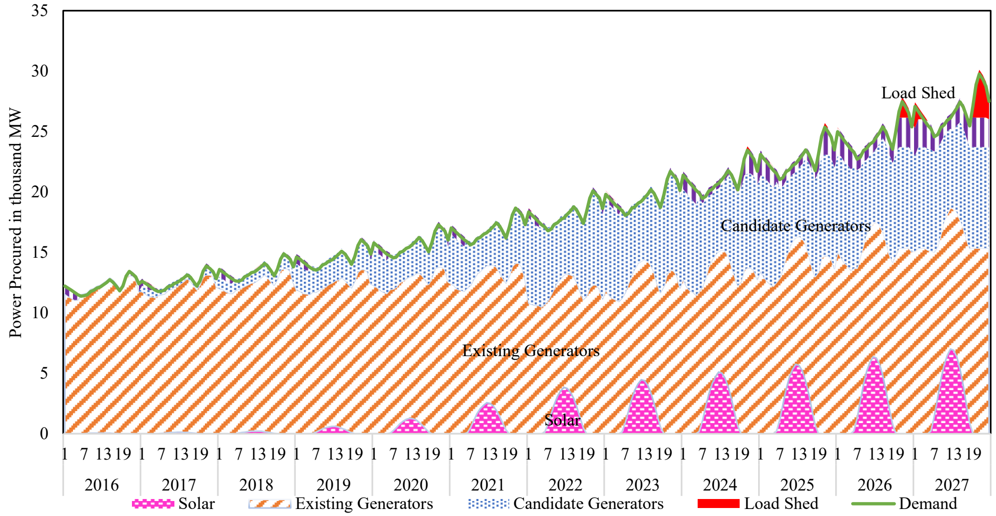

Figure 14 Optimal power procurement for representative days for FY2016 to FY2017 (Scenario: Fix others float Panki for medium demand growth considering STPP)

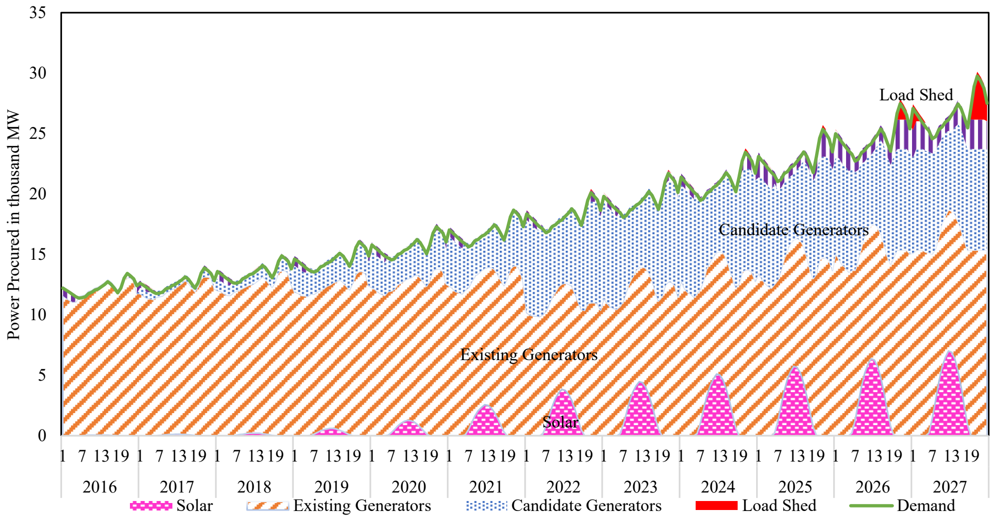

Figure 15 Optimal power procurement for representative days for FY2016 to FY2017 (Scenario: Fix all for medium demand growth considerin g STPP)

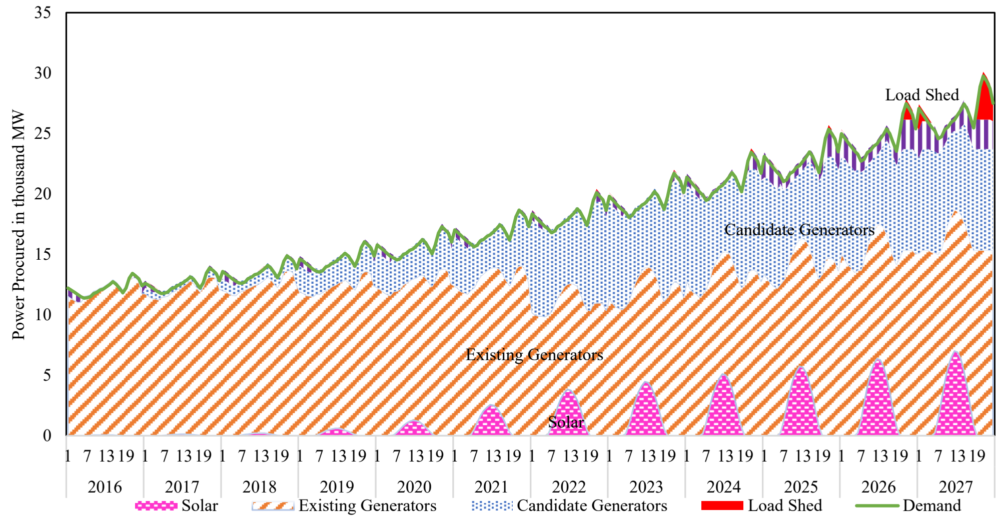

Figure 16 Optimal power procurement for representative days for FY2016 to FY2017 (Scenario: Fix all for high demand growth considering STPP)

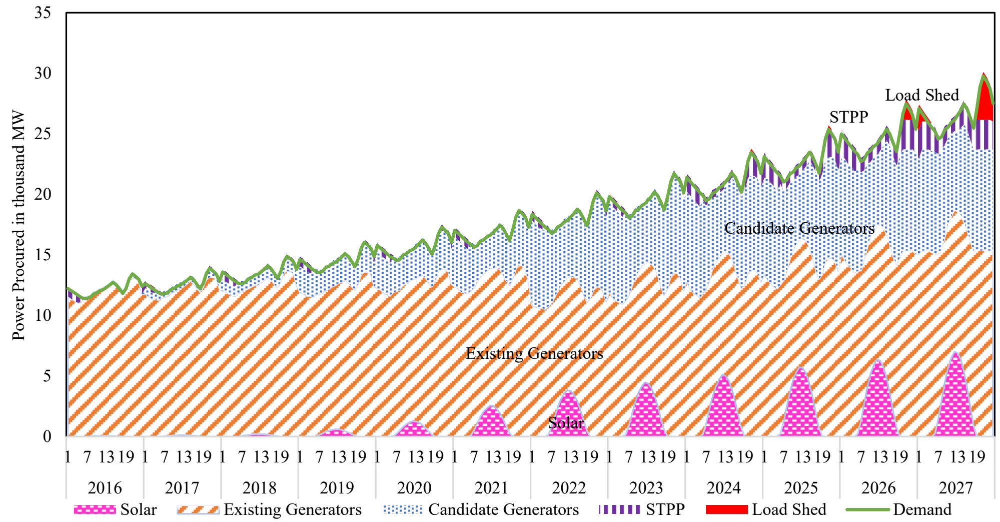

Figure 17 Optimal power procurement for representative days for FY2016 to FY2017 (Scenario: Fix others float Pank i for high demand growth considering STPP)

Detailed results and graphs for the selected cases for the High Growth, Realistic Growth and Medium Growth Scenarios are placed in the Appendix-B, Figure 4-15.

5.2 Power Procurement Strategy - Key recommendations

Based on the optimal power procurement analysis, while keeping in consideration the social cost of delivering the forecasted electricity demand for Uttar Pradesh, the key observations are

(i) The results, unambiguously, highlight the need for **optimal power procurement analysis to be conducted by the state utilities from time to time**. Significant social (and utility) cost savings could have been achieved if this type of analysis was done prior to considering setting up of power plants by the UPRVUNL.

(ii) It is suggested that the **developed methodology be applied at least every three years** after considering the latest observed electricity demand and its profile so as to develop an optimal power procurement strategy for the next five years and onwards. The results presented in this report would then be revised in the light of the latest available data.

(iii) One can note that the discounted utility cost savings are higher than the discounted social cost savings for the corresponding power procurement strategy[§§]. Even while one may suggest that the utility may save substantial cost based on its own private interest, the social objectives of electricity provision may convince it to consider discounted social cost for its decision making. Thus, the key outcomes discussed herein are derived on the basis of discounted social cost implications for the state. Detailed results for social cost and utility cost for each of the scenarios under the identified Power Procurement Strategy cases are given in Appendix-B. These results can be used to select the appropriate strategy considering other relevant aspects.

(iv) The **most optimal strategy with respect to the social cost is identified to be for 'All Float' case**, wherein the four candidate plants of the state (J, H, O and P) are allowed to find their optimal COD. The estimated discounted savings in social cost without STPP (with STPP) for the High Growth Scenario, Realistic Growth Scenario and Medium Growth Scenario are Rs. 5,809 crore (Rs. 7,738 crore), Rs. 6,690 crore (Rs. 8,555 crore) and Rs. 9,270 crore (Rs. 11,148 crore) respectively. **Considering the discounted social cost over the study horizon**

[§§] The model places a penalty on load shedding thus making best effort to supplement power availability so as to maximise social welfare.

for the 'All Fix' as the base case, these represent 1% (1.4%), 1.2% (1.55%) and 1.75% (2.12%) of cost savings.

(v) The discounted savings in the utility cost without STPP (with STPP) for the 'All Float' strategy for the High Growth Scenario, Realistic Growth Scenario and Medium Growth Scenario are estimated to be Rs. 6,233 crore (Rs. 8,352 crore), Rs. 7,524 crore (Rs. 9,109 crore) and Rs. 9,952 crore (11,549 crore) respectively. **Considering the discounted utility cost over the study horizon for the 'All Fix' as the base case, these represent 1.13% (1.5%), 1.38% (1.66%) and 1.88% (2.19%) of cost savings.**

(vi) The **most optimal strategy with respect to the utility cost is identified to be 'Float Others (-J)' case**, wherein Jawaharpur plant is cancelled and the other three candidate plants of the state (H, O and P) are allowed to find their optimal COD. The estimated discounted savings in utility cost without STPP (with STPP) for the High Growth Scenario, Realistic Growth Scenario and Medium Growth Scenario are Rs. 10,223 crore (Rs. 9,534 crore), Rs. 9,482 crore (Rs. 10,273 crore) and Rs. 11,471 crore (Rs. 11,782 crore) respectively.

(vii) In High Growth, Realistic Growth and Medium Growth Scenarios without STPP, cancellation of Jawaharpur, may result in utility cost savings of Rs. 4914 Crore, Rs. 4390 Crore and Rs. 2996 Crore respectively. In High Growth and Realistic Growth Scenarios with STPP, cancellation of Jawaharpur, may result in utility cost savings of Rs. 3084 Crore and Rs. 2783 Crore respectively. For the Medium Growth Scenario with STPP, cancellation of Harduaganj, may result in utility cost savings of Rs. 2058 Crore. However, social cost savings are much less in the corresponding cases, with certain cases to witness even higher social costs as well (Tables 2-3).

(viii) It is highlighted here that the state generating company, UPRVUNL, has already initiated the process of construction of Jawaharpur, Harduaganj and Obra-C by awarding EPC contracts and have committed financial expenditure towards the same. The financial implication of delay includes increase in escalation of capital cost of the project, increase in IDC for the expenditure already committed and financial/legal due to the EPC contract. UPRUVNL, considering the financial and legal implications, may explore the option of delaying some of the plants.

(ix) As revising CoD for the four candidate plants of the states would be subject to the associated cost of delay, the model was used to identify optimal CoD individually for these four plants while keeping the CoD of non-state candidate plants fixed as per the currently projected CoD. We also identify optimal CoD for Jawaharpur, Harduaganj, Obra-C and Panki for Realistic Growth Scenario in below Tables 6-7

Table 5.5.6: Strategy Ranking based on Savings (Social Cost) Comparison - Realistic Growth Scenario

Realistic Growth Without STPP			Realistic Growth With STPP		
Strategy (I)	Savings in Social Cost (Rs. Cr.) (II)	New COD Year (III)	Strategy (IV)	Savings in Social Cost (Rs. Cr.) (V)	New COD Year (VI)
All Float	8555		All Float	6690	
Float Oth. (- H)	7805		Float Oth. (- H)	4040	
Float Oth. (- P)	7483		Float Oth. (- P)	3691	
Float Oth. (- J)	6353		Fix Oth. Float H	1535	2026 (2020)
Float Oth. (- O)	5460		Fix Oth. Float J	1234	2026 (2022)
Fix Oth. Float H	1627	2025 (2020)	Fix Oth. Float (U, K, P)	970	
Fix Oth. Float J	1461	2025 (2022)	Float Oth. (- J)	794	
Fix Oth. (- H)	985		Fix Oth. Float O	718	2025 (2022)
Fix Oth. Float O	786	2024 (2022)	Fix Oth. Float P	564	2025 (2022)
Fix Oth. Float (U, K, P)	605		Fix Oth. P @ 2023	424	
Fix Oth. Float P	551	2025 (2022)	All Fix	0	
Fix Oth. P @ 2023	323		Float Oth. (- O)	-225	
All Fix	0		Fix Oth. Fix U & K, Float P	-520	
Fix Oth. (- P)	-274		Fix Oth. (- H)	-801	
Fix Oth. (- J)	-364		All Fix (+U, +K)	-1062	
Fix Oth. Fix U & K, Float P	-1185		Fix Oth. (- P)	-2026	
Fix Oth. (- O)	-1571		Fix Oth. (- J)	-4175	
All Fix (+U, +K)	-1773		Fix Oth. (- O)	-5401	

Note: Column (III) & (VI) show the optimal COD year for plants. Original/Planned COD for plant is given in the parenthesis.

(x) From social cost perspective, choosing optimal COD for Harduaganj, Jawaharpur, Obra-C and Panki could reduce discounted social cost by Rs. 1,535 crore (Rs. 1,627 crore), Rs. 1,234 crore (Rs. 1,461 crore), Rs. 718 crore (Rs. 786 crore) and Rs. 564 crore (Rs. 551 crore) respectively for the Realistic Growth Scenario without STPP (with STPP). Given the overall cost base for the study horizon, this saving represents less than one-third percent equivalent of cost saving.

(xi) Apart from delaying all the state candidates, a case for delay of Panki plant, for which no significant amount of expenditure has been committed, was considered. Key findings for High Growth and Realistic Growth Scenarios, suggest marginal savings from deferral of only Panki candidate plant. Based on discounted social cost consideration without STPP (with STPP), the optimal COD for Panki power plant is suggested to be beginning of FY 2024 (FY 2025) for High Growth scenario, FY 2025 (FY 2025) for Realistic Growth Scenario, FY 2025 (FY 2026) for Medium Growth Scenario from the planned COD of year 2022.Estimated savings, on account of deferral of Panki, in discounted social cost for the High Growth Scenario, Realistic

Growth Scenario and Medium Growth Scenario without STPP (with STPP) are estimated to be Rs. 457 crore (Rs. 529 crore), Rs. 564 crore (Rs. 551 crore), Rs. 681 crore (Rs. 858 crore) respectively. The savings from delay, as identified above, should be compared with the potential cost escalation for the plant.

Table 5.5.7: Strategy Ranking based on Savings (Utility Cost) Comparison - Realistic Growth Scenario Savings

Realistic Growth Without STPP			Realistic Growth With STPP		
Strategy (I)	**Savings in Utility Cost (Rs. Cr.) (II)**	**New COD Year (III)**	**Strategy (IV)**	**Savings in Utility Cost (Rs. Cr.) (V)**	**New COD Year (VI)**
Float Oth. (- J)	9482		Float Oth. (- J)	10273	
Float Oth. (- H)	9130		Float Oth. (- H)	9677	
Float Oth. (- P)	8782		Float Oth. (- P)	9349	
Float Oth. (- O)	8464		Float Oth. (- O)	9347	
All Float	7524		All Float	9109	
Fix Oth. (- J)	4390		Fix Oth. (- J)	2783	
Fix Oth. (- O)	3141		Fix Oth. (- H)	2289	
Fix Oth. (- H)	3106		Fix Oth. Float H	1710	2026 (2020)
Fix Oth. (- P)	1782		Fix Oth. (- O)	1575	
Fix Oth. Float H	1611	2025 (2020)	Fix Oth. Float J	1551	2026 (2022)
Fix Oth. Float J	1563	2025 (2022)	Fix Oth. (- P)	1030	
Fix Oth. Float O	983	2024 (2022)	Fix Oth. Float O	875	2025 (2022)
Fix Oth. Float P	609	2025 (2022)	Fix Oth. Float P	634	2025 (2022)
Fix Oth. P @ 2023	455		Fix Oth. Float (U, K, P)	359	
All Fix	0		Fix Oth. P @ 2023	323	
Fix Oth. Float (U, K, P)	-101		All Fix	0	
Fix Oth. Fix U & K, Float P	-1726		Fix Oth. Fix U & K, Float P	-1467	
All Fix (+U, +K)	-2318		All Fix (+U, +K)	-2086	

Note: Column (III) & (VI) show the optimal COD year for plants. Original/Planned COD for plant is given in the parenthesis.

(xii) Since EPC contracts had been entered into for setting up of Harduaganj, Jawaharpur and Obra-C generation units and certain costs have been incurred towards the same, the cost of cancellation or deferral of these projects (including the associated legal aspects) may outweigh the benefits to be derived from cancellation or deferral of these projects. Further, in the case of deferral of any of these projects, which are reflected in the power procurement strategies involving 'Float' cases, the overall cost of the project may increase due to deferral, leading to the increase in the fix cost of the project to be finally paid by the consumers.

(xiii) **Cases involving Short-term Power procurement suggest additional social cost savings for all scenarios and utility cost savings for Medium Growth scenario.** Based on assumptions regarding short-term contracts, these savings/costs are evident from results presented in Appendix B, STPP can be used (i) to address short term demand-supply mismatch in the short-term while long-term procurement plans are in place, and (ii) to optimise cost if total cost of short-term power procurement is less than the variable cost of existing plants/contracts. Such decisions should be evaluated across relatively shorter horizons while considering recent and expected trends in system demand, expected supply from existing contracts, prevailing variable cost of such plants and quantum, cost and term of power supply from short-term contracts including through competitive tendering and procurement from power exchanges (PXs).

(xv) UPPCL/Discoms should **develop and implement a Short-term Power Procurement Strategy** in consultation with stakeholders and get it approved from UPERC. This should include development of a framework that helps identify short-term need of power so as to optimize the overall cost of power procurement from all available sources. **This should be supplemented with development of Short-term Load Forecasting methodology for the distribution utilities.**

(xvi) There is also a need for revamping of the Merit Order Dispatch procedure adopted by the SLDC. Another ongoing study has revealed significant savings through adoption of a proper MoD schedule.

(xvii) **Detailed scrutiny of the results lead us to identify certain existing plants/PPAs that are not in-frequently scheduled for electricity supply.** These plants are the ones with relatively higher variable cost. Although such plants are scheduled for electricity supply (and fixed cost continue to be incurred for the same) after 2022, 2023 or later, feasibility of alternate supply discovered through a process of competitive bidding should be explored based on overall economics in the context of cost of modification/cancellation of such contracts. Detailed analysis regarding the same would be provided in the final report.

(xviii) The study considers policy as well as realistic DSM and solar power generation capacity addition in the state. **Progress on DSM and Solar capacity addition should be reviewed periodically to take a medium-term perspective about power procurement**, especially those through power procurement for the evening peak hours, if required.

(xix) The study is based on the projected metered supply at the periphery of the state. In case of exponential growth of connected consumers, as envisioned through Power for All initiative, **appropriate planned and effective measures should be in place for metering, meter reading, billing and collection (with as much IT application as feasible) thereof of all**

existing as well as new consumers. In the absence of the same, the unhindered growth in demand may be significantly outstrip the projected numbers without commensurate growth in revenue collection. This could place significant strain on the finances of the state discoms.

(xx) Given that the load profile of the state is expected to witness an evening peak, measures should be in place to continuously monitor load profile and take appropriate short-term, medium-term and long-term measures so that additional capacity addition solely to meet the peak demand could be avoided. Appropriate demand side measures include **deployment of energy efficiency measures at the utility as well as consumer end and, extension of Time of Day (ToD) tariff for all large consumers. ToD tariff should be designed on the basis of studies including historical flexibility exhibited in the load profile of such consumers with ToD tariffs.**

(xxi) Variations on account of RE supply, particularly that based on Solar energy be assessed and addressed through appropriate **forecasting of RE generation**. All attempts be made to ensure that necessary solar energy generation from all large plants be monitored in real time with 15-minute time interval so as to assist development of forecasting models for the state.

(xxii) This study presents a long-term load forecast scenario. Day ahead and intra-day system operation necessitates development of capacity to undertake Short-term Load Forecasting based on sound methodologies. This would help address system deviation thereby avoiding DSM charges levied on state entities. Increasing share of variable RE, particularly solar, in the state further highlights the need for reliable short-term load forecasting.

(xxiii) During the course of study, it was found that competitively bid projects in general, have resulted in lower cost of supply as compared to those entered through the MoU route. The burden of expensive power falls finally on the end consumers. In case of higher variable cost, such planned would be scheduled less often, leading to even higher per unit burden from such power procurements. **The state utilities should adopt a policy for fair and transparent competitive bidding for all its power procurement needs in future.**

(xxiv) **In future, state utilities could adopt a state-level UMPP model, where in all necessary approvals including land procurement, fuel supply arrangements are put in place before competitive bidding.** This lowers the risk perception of the investors and enhances competition, thereby bringing down the cost of power procurement.

(xxv) In case of state's plants being retired due to higher heat rate and regulatory mandate to retrofit such plants with environmental friendly technologies (as notified by CEA), utilisation of residual coal supply from the available allocations/linkages[***] be explored. **Based on the total available coal from such pants in future, competitive bidding could be adopted for setting up new plants once the proposed plants have been operationalized and an assessment of the future demand is undertaken.**

[***] Avenues for extension of coal supply duration from such sources and allocation of new coal supply be explored so that appropriate scale economies can be reaped.

Results for a scenario where cancelling of plants id considered

Plant specifications

Plant Name	Name Plate Capacity	OWNER	Fixed Cost (Rs. Cr. / Year)	Fixed Cost per kWhr (Rs.)	Variable Cost per kWh (Rs.)
Dadri Thermal	84	NTPC	49	0.67	4.15
Dadri Extension	148	NTPC	156	1.20	3.92
Tanda	440	NTPC	330	0.86	3.52
Rosa Power Project 1	600	IPPs/JVs	690	1.31	4.33
Rosa Power Project 2	600	IPPs/JVs	690	1.31	4.33
IGSTPP Jhajhjhar	51	IPPs/JVs	58	1.29	4.39

High demand with STPP

YEAR	Dadri Thermal	Dadri Extension	Tanda	Rosa Power Project 1	Rosa Power Project 2	IGSTPP, Jhajhjhar
2016	0	0	0	0	0	0
2017	0	0	0	0	0	0
2018	0	0	0	0	0	0
2019	0	0	0	0	0	0
2020	0	0	0	0	0	0
2021	0	0	0	0	0	0
2022	0	0	0	0	0	0
2023	0	0	0	0	0	0
2024	0	0	0	0	0	0
2025	0	0	0	52%	52%	0
2026	55%	56%	55%	58%	58%	57%
2027	63%	66%	65%	66%	66%	65%

High demand without STPP

YEAR	Dadri Thermal	Dadri Extension	Tanda	Rosa Power Project 1	Rosa Power Project 2	IGSTPP Jhajhjhar
2016	0	0	49%	0	0	0
2017	0	0	0	0	0	0
2018	0	0	0	0	0	0
2019	0	0	0	0	0	0
2020	0	0	0	0	0	0
2021	0	0	0	0	0	0
2022	0	0	0	0	0	0
2023	0	0	0	0	0	0
2024	0	0	51%	52%	52%	0
2025	58%	58%	58%	58%	58%	58%
2026	65%	66%	66%	66%	66%	66%
2027	71%	72%	71%	71%	71%	71%

Real demand with STPP

YEAR	Dadri Thermal	Dadri Extension	Tanda	Rosa Power Project 1	Rosa Power Project 2	IGSTPP Jhajhjhar
2016	0	0	0	0	0	0
2017	0	0	0	0	0	0
2018	0	0	0	0	0	0
2019	0	0	0	0	0	0
2020	0	0	0	0	0	0
2021	0	0	0	0	0	0
2022	0	0	0	0	0	0
2023	0	0	0	0	0	0
2024	0	0	0	0	0	0
2025	0	0	0	0	0	0
2026	0	53%	53%	53%	52%	0
2027	58%	58%	58%	59%	59%	58%

Real demand Without STPP

YEAR	Dadri Thermal	Dadri Extension	Tanda	Rosa Power Project 1	Rosa Power Project 2	IGSTPP Jhajhjhar
2016	0	0	49%	0	0	0
2017	0	0	0	0	0	0
2018	0	0	0	0	0	0
2019	0	0	0	0	0	0
2020	0	0	0	0	0	0
2021	0	0	0	0	0	0
2022	0	0	0	0	0	0
2023	0	0	0	0	0	0
2024	0	0	0	0	0	0
2025	0	0	0	0	0	0
2026	0	0	52%	52%	52%	0
2027	55%	58%	57%	58%	58%	57%

Ranking	High Growth without Short Term	Savings in Utilty Cost	Realistic Growth without Short Tern	Savings in Utilty Cost
I	Fix Others (-JJR,- R1,-R2)	16270	Fix Others (-JJR,- R1,-R2)	15285
II	Fix Others (-JJR,- R1)	8441	Fix Others (-JJR, T, -DE, -DT)	8271
III	Fix Others (-JJR, T, -DE, -DT)	8440	Fix Others (-JJR,- R1)	7996
IV	Fix Others Float panki	585	Fix Others Float panki	609
V	Fix All	0	Fix All	0

Ranking	High Growth with Short Term	Savings in Utilty Cost	Realistic Growth with Short Term	Savings in Utilty Cost
I	Fix Others (-JJR,- R1,-R2)	14229	Fix Others (-JJR,- R1,-R2)	13620
II	Fix Others (-JJR, T, -DE, -DT)	7659	Fix Others (-JJR, T, -DE, -DT)	7422
III	Fix Others (-JJR,- R1)	7412	Fix Others (-JJR,- R1)	7073
IV	Fix Others Float panki	459	Fix Others Float panki	634
V	Fix All	0	Fix All	0

Ranking	High Growth without Short Term	Savings in Social Cost	Realistic Growth without Short Tern	Savings in Social Cost
I	Fix Others (-JJR,- R1,-R2)	5299	Fix Others (-JJR,- R1,-R2)	7539
II	Fix Others (-JJR, T, -DE, -DT)	4863	Fix Others (-JJR, T, -DE, -DT)	5529
III	Fix Others (-JJR,- R1)	3213	Fix Others (-JJR,- R1)	4240
IV	Fix Others Float panki	457	Fix Others Float panki	564
V	Fix All	0	Fix All	0

Ranking	High Growth with Short Term	Savings in Social Cost	Realistic Growth with Short Term	Savings in Social Cost
I	Fix Others (-JJR,- R1,-R2)	9239	Fix Others (-JJR,- R1,-R2)	10760
II	Fix Others (-JJR, T, -DE, -DT)	6098	Fix Others (-JJR, T, -DE, -DT)	6625
III	Fix Others (-JJR,- R1)	5045	Fix Others (-JJR,- R1)	5875
IV	Fix Others Float panki	529	Fix Others Float panki	551
V	Fix All	0	Fix All	0

1. [1] 2. "Draft National Energy Policy," NITI Aayog, Government of India, Version as on 27.06.2017.

3. [2] 4. CRISIL Limited, "24 X 7 Power for All, Uttar Pradesh," CRISIL Limited, 2017.

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Appendix - A

Table A.0.1: List of Existing and Candidate Plants

List of Existing Plants						Candidate Plants	
S.no	Plants	S.no	Plants	S.no	Plants	S.no	Plants
1	Anpara A	26	Singrauli	51	TALA POWER	1	Jawaharpur
2	Anpara B	27	Tanda	52	Koteshwar	2	Harduaganj
3	Harduagunj	28	Unchahar-I	53	Srinagar	3	Obra C
4	Obra A	29	Unchahar-II	54	Sasan	4	Panki
5	Obra B	30	Unchahar-III	55	Case I KSK MHND	5	Meja Unit I
6	Panki	31	Farakka	56	Case I B PTC MB	6	Meja Unit II
7	Parichha	32	Kahalgaon St I	57	Case I C PTC TRN	7	Ghatampur
8	ParichhaExtn	33	KahalgaonSt II Ph II	58	Case I D RKM PGN	8	Bara
9	ParichhaExtn Stage II	34	Koldam Hydro	59	Karcham-Wangtoo	9	Visnugarh Pipal Kothi
10	Harduaganj Ext	35	Rihand-III	60	VISHNUPRAYAG	10	Subansiri Lower NHPC
11	Anpara D	36	Chamera	61	TEHRI STAGE-I	11	Tapovan Vishnugarh
12	Khara	37	Chamera II	62	Rosa Power Project 1	12	Lata Tapovan HEP NTPC
13	Matatila	38	Chamera III	63	Rosa Power Project 2	13	Parbati II HEP
14	Obra Hydel	39	Dhauliganga	64	Bara	14	Tanda II
15	Rihand	40	Salal I II	65	Anpara C	15	Upjvnl hydro
16	UGC Power Stations	41	Tanakpur	66	IGSTPP Jhajhjhar	16	Unchahar IV
17	BelkaBabail	42	Uri	67	Bajaj Hindusthan	17	Singarauli III
18	Sheetla	43	Dulhasti	68	Lalitpur	18	North Karanpura
19	Anta	44	Sewa II JuneJuly 2010	69	Captive and Cogen	19	Tawang NHPC
20	Auriya	45	Uri-II	70	NVVN Coal Power	20	Upper Karnali
21	Dadri Thermal	46	Parbati III			21	Kameng HEP
22	Dadri Gas	47	NAPP				
23	Dadri Extension	48	RAPP 3 4				
24	Rihand-I	49	RAPP5 6				
25	Rihand-II	50	NATHPA JHAKRI HPS				

Appendix - B

Table B.1: Econometric Model Results

Regression Models								
	Response Variable	**Independent Variable**						
Model 1	**Log (Per capita consumption)**	**Intercept**	**log (Per capita SGDP)**	**% urban population**	**% primary share**	**% secondary share**	**Time**
		-4.20 ***	**0.861 *****	**0.013*****	**2.631*****	**2.711*****	**-0.020**
Model 2	**Log (Per capita consumption)**	**Intercept**	**log (Per capita SGDP)**	**% urban population**	**% primary share**	**% secondary share**	
		-3.50 ***	**0.772*****	**0.01 *****	**2.42 *****	**2.797*****	
Model 3	**Log (Per capita consumption)**	**Intercept**	**Per capita SGDP**	**% urban population**	**% primary share**	**% secondary share**	
		3.83 ***	**8.61E-06 *****	**0.02 *****	**2.81 *****	**3.64 *****	
Model 4	**Per capita consumption**	**Intercept**	**Per capita SGDP**	**% urban population**	**% primary share**	**% secondary share**	
		-910 ***	**7.36E-03 *****	**10.97 *****	**1853.00 *****	**1788 *****	
Model 5	**Per capita consumption**	**Intercept**	**Per capita SGDP**	**% urban population**	**P % primary share**	**% secondary share**	**Price**
		-870 ***	**1.10E-02 *****	**8.02 *****	**1682.00 *****	**2098.00 *****	**-41.69 ***
Model 6	**Log (Per capita consumption)**	**Intercept**	**Per capita SGDP**	**% urban population**	**% primary share**	**% secondary share**	**Price**
		3.87 ***	**1.40E-05 *****	**0.02 *****	**2.70 *****	**4.11 *****	**-0.07 ****
Model 7	**Log (Per capita consumption)**	**Intercept**	**log (Per capita SGDP)**	**% urban population**	**% primary share**	**% secondary share**	**Price**
		-5.10 ***	**0.94 *****	**0.01 *****	**2.18 ****	**3.24 *****	**-0.06 ****
Model 8	**Log (Per capita consumption)**	**Intercept**	**log (Per capita SGDP)**	**% urban population**	**% primary share**	**% secondary share**	**log(Price)**
		-4.90 ***	**0.91 *****	**0.01 *****	**2.14 *****	**3.29 *****	**-0.12 ***

Appendix - C

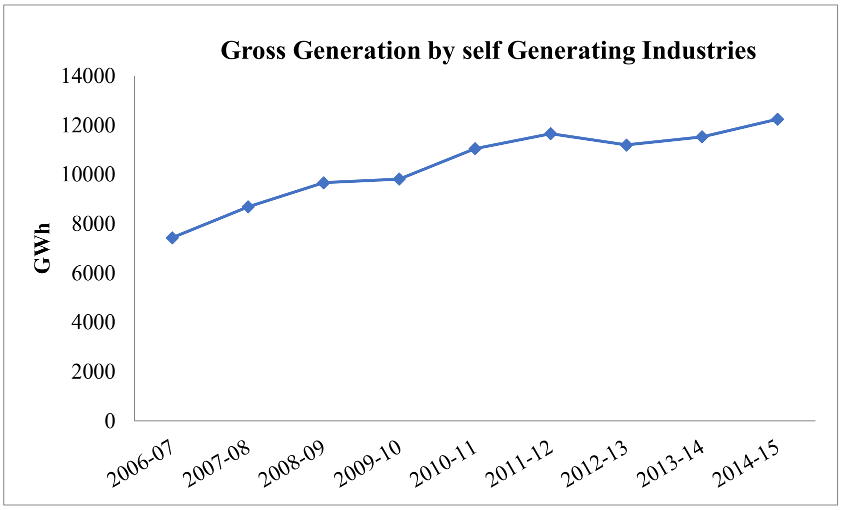
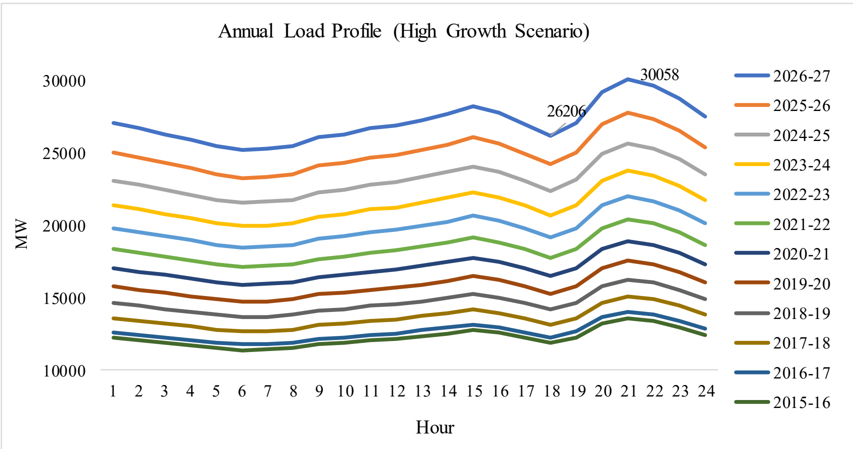


Figure C.0.1: Captive generation

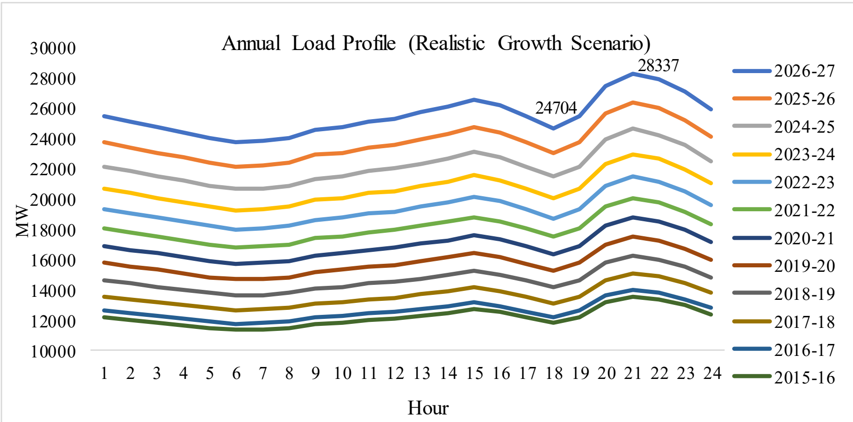
Appendix - D

Annual Energy Requirement (in MU)				
Year	**High Growth Scenario**	**Realistic Growth Scenario**	**Medium Growth Scenario**	**Low Growth Scenario**
2015-16	107240	107240	107240	107240
2016-17	114512	114512	114512	114512
2017-18	123163	123163	121405	119646
2018-19	132613	132613	128781	125020
2019-20	142942	142942	136678	130647
2020-21	154237	153068	145138	136539
2021-22	166115	163562	153757	142298
2022-23	179088	174908	162976	148314
2023-24	193263	187180	172839	154601
2024-25	208757	200459	183396	161172
2025-26	225702	214833	194700	168041
2026-27	244238	230398	206808	175223



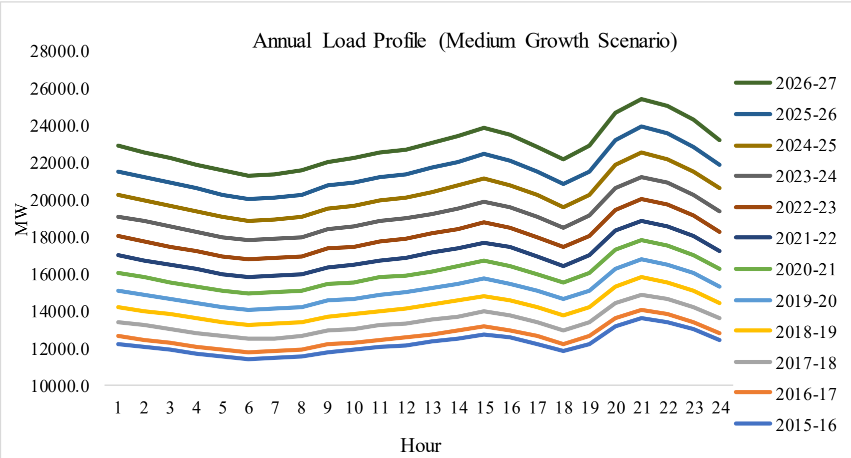
Annual Average Load Profile Data (High Growth Scenario)

↓Hour/Year→	2026-27	2025-26	2024-25	2023-24	2022-23	2021-22	2020-21	2019-20	2018-19	2017-18	2016-17	2015-16
1	27068	25001	23111	21384	19805	18361	17040	15783	14636	13586	12626	12222
2	26681	24643	22780	21078	19521	18098	16795	15557	14425	13391	12445	12046
3	26285	24276	22441	20764	19231	17828	16545	15325	14210	13191	12259	11866
4	25894	23915	22107	20455	18944	17562	16298	15096	13998	12994	12076	11689
5	25508	23559	21777	20149	18661	17300	16054	14870	13788	12799	11895	11514
6	25214	23287	21526	19917	18446	17100	15869	14698	13629	12651	11757	11381
7	25314	23379	21611	19996	18518	17168	15931	14756	13683	12701	11804	11426
8	25508	23559	21777	20149	18661	17300	16054	14870	13788	12799	11895	11514
9	26085	24092	22271	20606	19084	17692	16419	15208	14102	13090	12165	11776
10	26285	24276	22441	20764	19231	17828	16545	15325	14210	13191	12259	11866
11	26681	24643	22780	21078	19521	18098	16795	15557	14425	13391	12445	12046
12	26882	24828	22952	21236	19668	18234	16922	15674	14534	13492	12539	12137
13	27286	25202	23298	21557	19965	18509	17177	15911	14754	13696	12729	12321
14	27697	25581	23648	21882	20266	18789	17437	16151	14977	13903	12921	12507
15	28209	26055	24086	22287	20642	19137	17760	16451	15255	14162	13161	12740
16	27776	25654	23716	21944	20324	18842	17486	16197	15020	13943	12958	12543
17	27022	24957	23071	21347	19771	18329	17010	15756	14610	13563	12605	12201
18	26206	24204	22374	20702	19173	17775	16495	15279	14167	13151	12222	11831
19	27083	25014	23124	21396	19816	18371	17049	15792	14644	13594	12634	12229
20	29179	26951	24915	23054	21353	19796	18372	17019	15781	14651	13616	13180
21	30058	27763	25667	23750	21998	20395	18928	17533	16259	15094	14028	13579
22	29615	27354	25288	23400	21673	20093	18648	17274	16019	14871	13821	13378
23	28748	26553	24547	22713	21037	19504	18100	16766	15548	14433	13414	12984
24	27491	25391	23472	21719	20115	18648	17306	16031	14865	13799	12825	12414



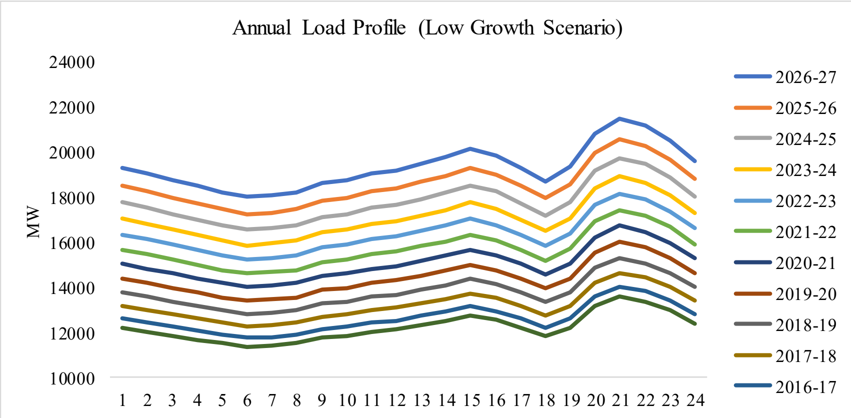
Annual Average Load Profile Data (Realistic Growth Scenario)

↓Hour/Year→	2026-27	2025-26	2024-25	2023-24	2022-23	2021-22	2020-21	2019-20	2018-19	2017-18	2016-17	2015-16
1	25517	23782	22181	20702	19337	18075	16908	15783	14636	13586	12626	12222
2	25152	23442	21863	20406	19060	17816	16666	15557	14425	13391	12445	12046
3	24778	23093	21538	20102	18776	17550	16417	15325	14210	13191	12259	11866
4	24409	22749	21217	19802	18495	17288	16172	15096	13998	12994	12076	11689
5	24045	22410	20900	19507	18219	17030	15931	14870	13788	12799	11895	11514
6	23768	22151	20659	19281	18009	16833	15746	14698	13629	12651	11757	11381
7	23862	22239	20741	19357	18080	16900	15809	14756	13683	12701	11804	11426
8	24045	22410	20900	19507	18219	17030	15931	14870	13788	12799	11895	11514
9	24589	22917	21374	19949	18632	17416	16292	15208	14102	13090	12165	11776
10	24778	23093	21538	20102	18776	17550	16417	15325	14210	13191	12259	11866
11	25152	23442	21863	20406	19060	17816	16666	15557	14425	13391	12445	12046
12	25341	23618	22028	20559	19203	17950	16791	15674	14534	13492	12539	12137
13	25723	23974	22360	20870	19493	18221	17045	15911	14754	13696	12729	12321
14	26110	24335	22697	21184	19787	18496	17302	16151	14977	13903	12921	12507
15	26593	24786	23117	21577	20154	18839	17623	16451	15255	14162	13161	12740
16	26184	24404	22762	21245	19843	18549	17352	16197	15020	13943	12958	12543
17	25473	23741	22143	20667	19303	18044	16879	15756	14610	13563	12605	12201
18	24704	23024	21473	20042	18719	17497	16368	15279	14167	13151	12222	11831
19	25531	23795	22193	20714	19347	18085	16918	15792	14644	13594	12634	12229
20	27508	25639	23913	22320	20848	19488	18231	17019	15781	14651	13616	13180
21	28337	26412	24635	22994	21478	20077	18782	17533	16259	15094	14028	13579
22	27920	26023	24271	22654	21161	19781	18505	17274	16019	14871	13821	13378
23	27101	25260	23560	21990	20540	19200	17961	16766	15548	14433	13414	12984
24	25916	24154	22528	21026	19639	18358	17173	16031	14865	13799	12825	12414



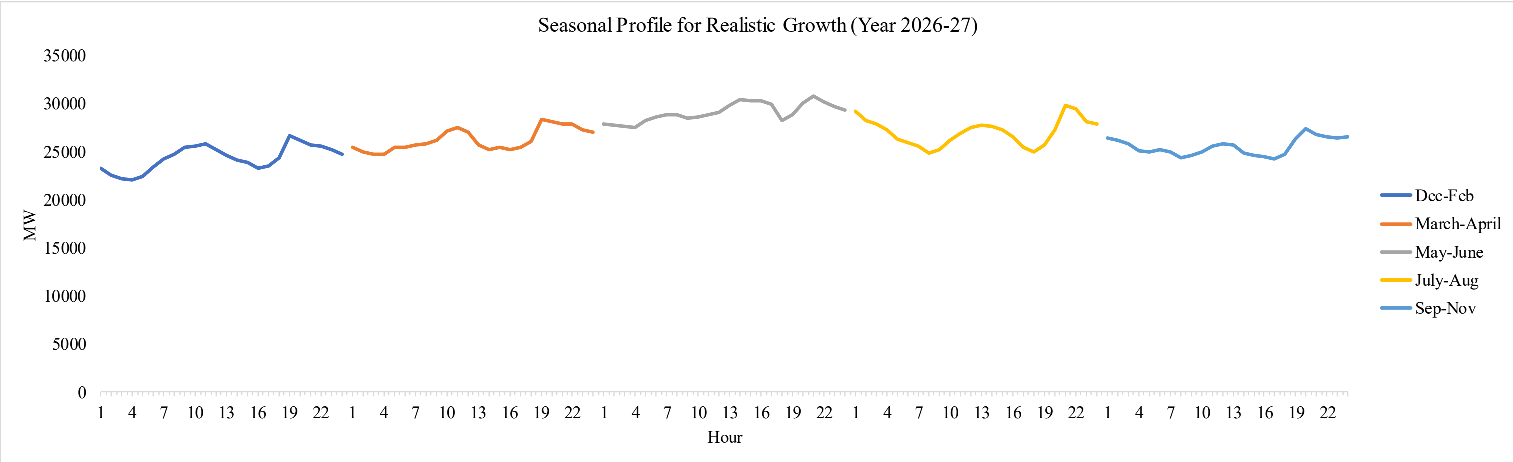
Annual Average Load Profile Data (Medium Growth Scenario)

↓Hour/Year→	2026-27	2025-26	2024-25	2023-24	2022-23	2021-22	2020-21	2019-20	2018-19	2017-18	2016-17	2015-16
1	22873	21525	20268	19095	17999	16976	16020	15081	14206	13389	12626	12222
2	22545	21217	19978	18821	17741	16732	15790	14865	14002	13197	12445	12046
3	22209	20901	19680	18540	17476	16482	15554	14643	13793	13000	12259	11866
4	21878	20589	19386	18264	17215	16236	15321	14424	13587	12805	12076	11689
5	21551	20281	19097	17991	16958	15993	15092	14208	13383	12613	11895	11514
6	21303	20047	18876	17783	16762	15808	14918	14044	13228	12467	11757	11381
7	21387	20126	18950	17853	16828	15871	14977	14099	13281	12517	11804	11426
8	21551	20281	19097	17991	16958	15993	15092	14208	13383	12613	11895	11514
9	22040	20741	19530	18399	17343	16357	15435	14531	13687	12900	12165	11776
10	22209	20901	19680	18540	17476	16482	15554	14643	13793	13000	12259	11866
11	22545	21217	19978	18821	17741	16732	15790	14865	14002	13197	12445	12046
12	22715	21376	20128	18963	17875	16858	15909	14977	14108	13296	12539	12137
13	23057	21699	20432	19249	18145	17113	16149	15203	14321	13498	12729	12321
14	23405	22026	20740	19540	18419	17371	16393	15433	14537	13702	12921	12507
15	23839	22435	21125	19902	18760	17694	16697	15720	14808	13956	13161	12740
16	23472	22089	20799	19595	18471	17421	16440	15477	14579	13741	12958	12543
17	22833	21488	20233	19062	17968	16946	15992	15055	14181	13366	12605	12201
18	22143	20838	19621	18485	17424	16433	15507	14599	13751	12961	12222	11831
19	22885	21537	20279	19105	18009	16985	16028	15090	14214	13397	12634	12229
20	24660	23208	21853	20588	19407	18304	17274	16262	15319	14438	13616	13180
21	25404	23909	22513	21211	19994	18858	17796	16754	15782	14875	14028	13579
22	25029	23556	22181	20897	19699	18579	17533	16507	15549	14655	13821	13378
23	24295	22864	21530	20283	19120	18033	17018	16021	15092	14224	13414	12984
24	23230	21862	20586	19394	18281	17242	16271	15318	14429	13599	12825	12414



Annual Average Load Profile Data (Low Growth Scenario)

↓Hour/Year→	2026-27	2025-26	2024-25	2023-24	2022-23	2021-22	2020-21	2019-20	2018-19	2017-18	2016-17	2015-16
1	19332	18537	17777	17050	16356	15691	15056	14405	13784	13192	12626	12222
2	19054	18271	17522	16805	16121	15466	14839	14198	13586	13002	12445	12046
3	18770	17998	17260	16554	15880	15235	14618	13986	13383	12808	12259	11866
4	18489	17729	17002	16307	15642	15007	14399	13777	13183	12617	12076	11689
5	18213	17463	16747	16063	15408	14782	14183	13570	12986	12428	11895	11514
6	18002	17261	16553	15877	15230	14611	14019	13413	12835	12284	11757	11381
7	18073	17330	16619	15940	15290	14669	14075	13466	12886	12332	11804	11426
8	18213	17463	16747	16063	15408	14782	14183	13570	12986	12428	11895	11514
9	18626	17860	17128	16428	15758	15118	14506	13879	13281	12710	12165	11776
10	18770	17998	17260	16554	15880	15235	14618	13986	13383	12808	12259	11866
11	19054	18271	17522	16805	16121	15466	14839	14198	13586	13002	12445	12046
12	19198	18408	17654	16932	16242	15582	14951	14305	13689	13100	12539	12137
13	19488	18687	17921	17188	16488	15818	15178	14522	13896	13299	12729	12321
14	19783	18969	18192	17448	16737	16057	15407	14741	14106	13500	12921	12507
15	20150	19322	18530	17773	17048	16356	15693	15015	14368	13751	13161	12740
16	19840	19024	18244	17498	16785	16103	15451	14784	14147	13539	12958	12543
17	19299	18505	17746	17021	16327	15664	15030	14380	13761	13169	12605	12201
18	18713	17944	17208	16505	15832	15189	14574	13944	13343	12770	12222	11831
19	19343	18547	17787	17060	16365	15700	15064	14413	13792	13199	12634	12229
20	20846	19989	19170	18386	17637	16921	16235	15534	14865	14226	13616	13180
21	21477	20594	19750	18943	18171	17433	16727	16004	15315	14657	14028	13579
22	21159	20289	19458	18663	17902	17175	16480	15768	15088	14440	13821	13378
23	20537	19693	18885	18114	17376	16670	15995	15304	14644	14015	13414	12984
24	19635	18828	18056	17318	16612	15937	15292	14631	14001	13399	12825	12414


Seasonal Profile for Realistic Growth (Year 2026-27)
MW
35000
30000
25000
20000
15000
10000
5000
0
Hour
Dec-Feb
March-April
May-June
July-Aug
Sep-Nov

Note: Candidate plant's name is referred with its initial alphabet character[†††]. Please see the list of all candidate plants in Appendix A.

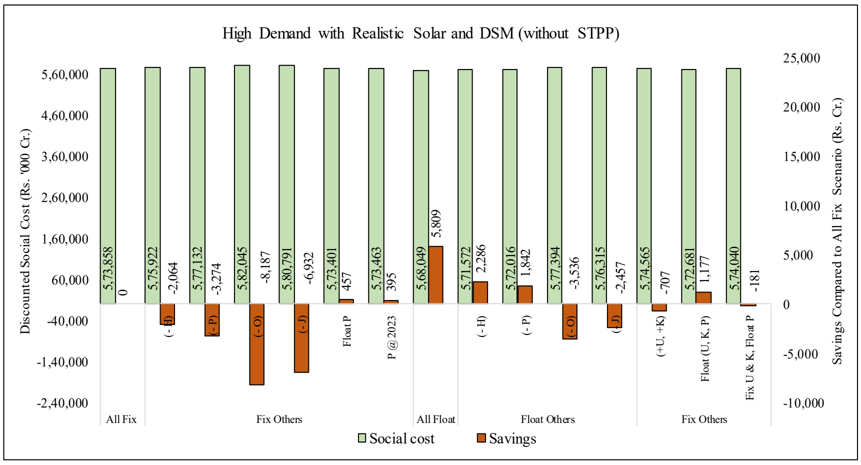


Figure 0.1: High Growth Scenario Social Cost Comparison without Short Term Contracts

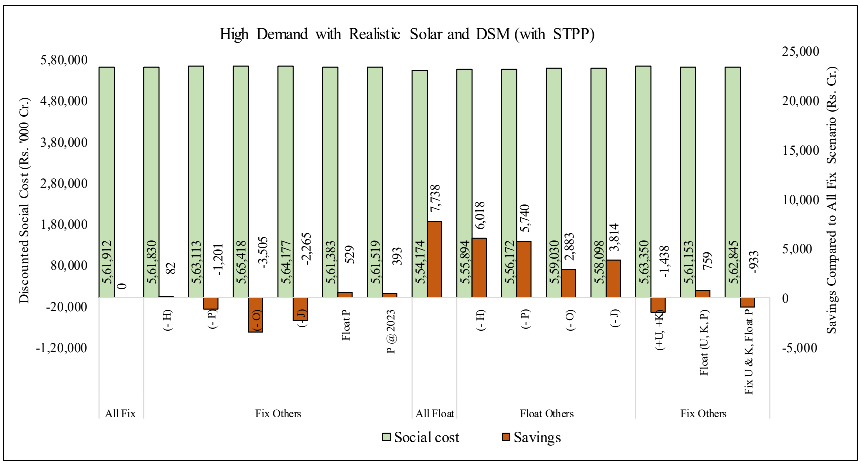


Figure 0.2: High Growth Scenario Social Cost Comparison with Short Term Contracts

[†††] Candidate plants names and their symbolic names. P – Panki, H – Harduaganj, O – Obra C, J – Jawaharpur, U – Upper Karnali, K – Kameng. In the charts given below, negative sign before the alphabets denoting a plant denotes a scenario considering exclusion/ cancellation of that plant/contract.

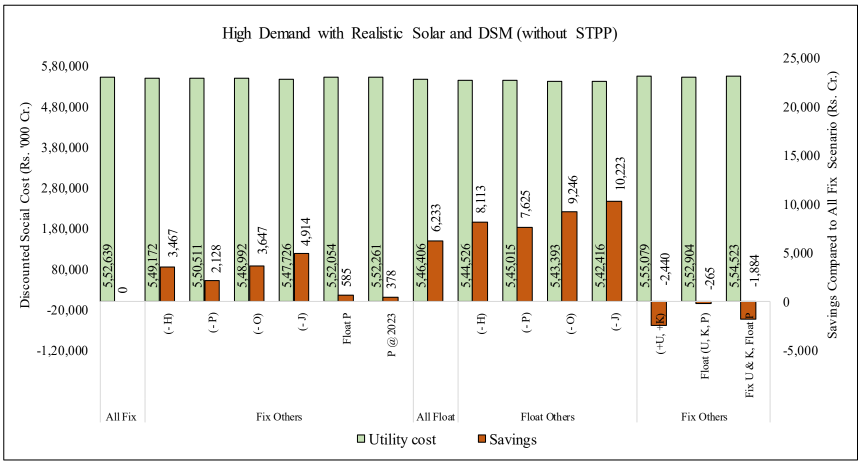


Figure 0.3: High Growth Scenario Utility Cost Comparison without Short Term Contracts

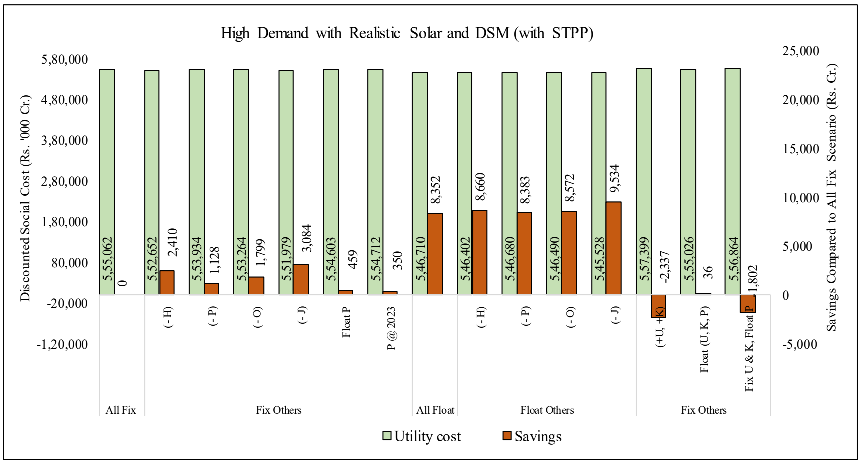


Figure 0.4: High Growth Scenario Utility Cost Comparison with Short Term Contracts

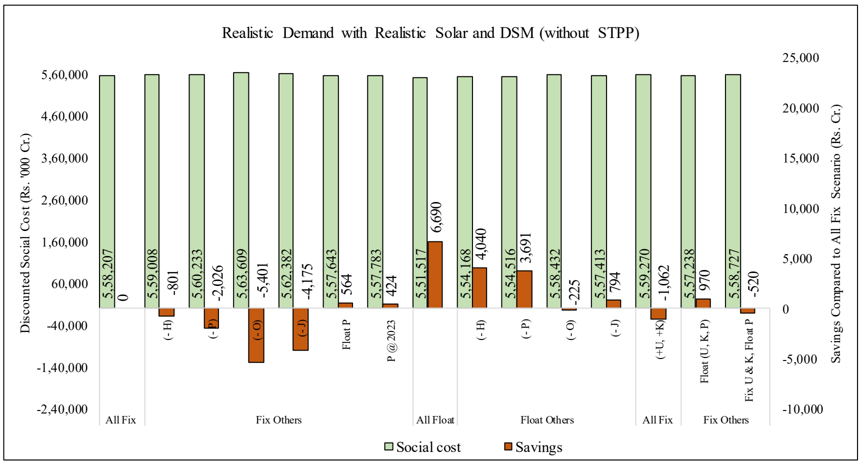


Figure 0.5: Realistic Growth Scenario Social Cost Comparison without Short Term Contracts

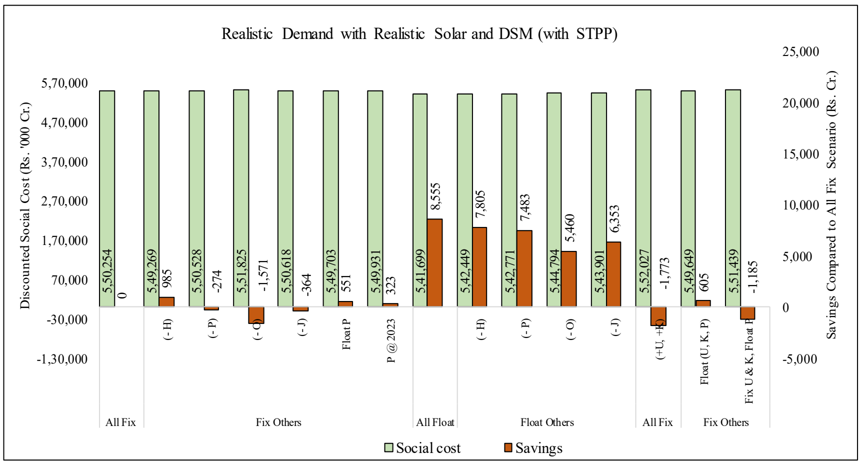


Figure 0.6: Realistic Growth Scenario Social Cost Comparison with Short Term Contracts

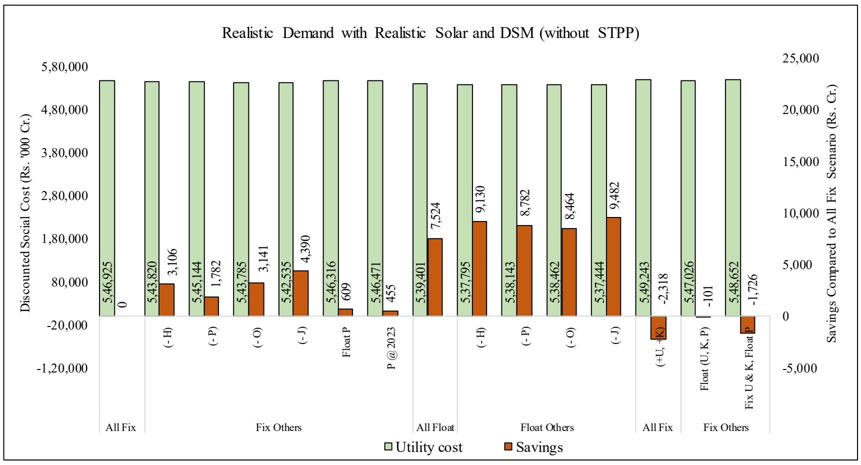


Figure 0.7: Realistic Growth Scenario Utility Cost Comparison without Short Term Contracts

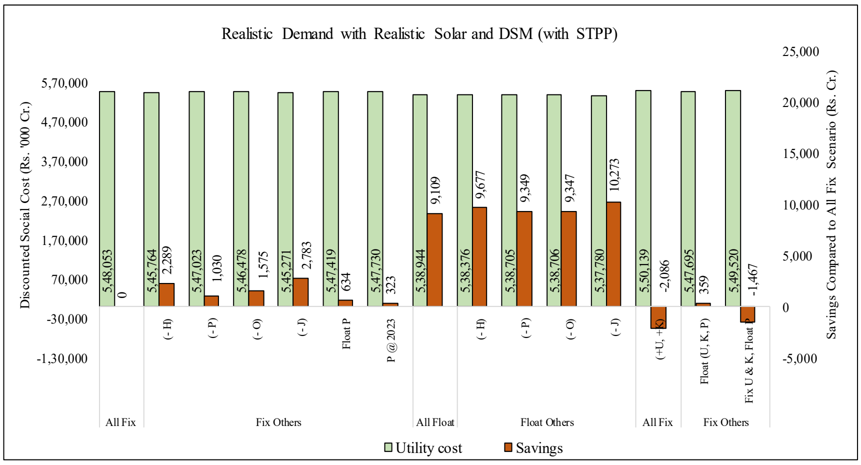


Figure 0.8: Realistic Growth Scenario Utility Cost Comparison with Short Term Contracts

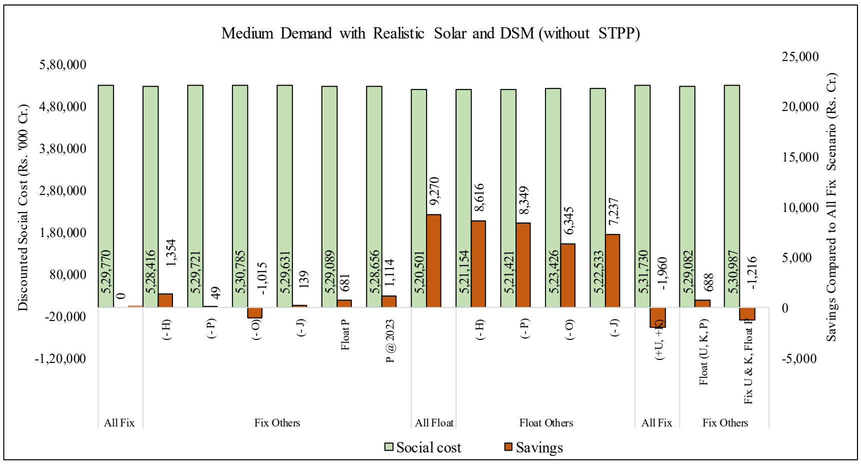


Figure 0.9: Medium Growth Scenario Social Cost Comparison without Short Term Contracts

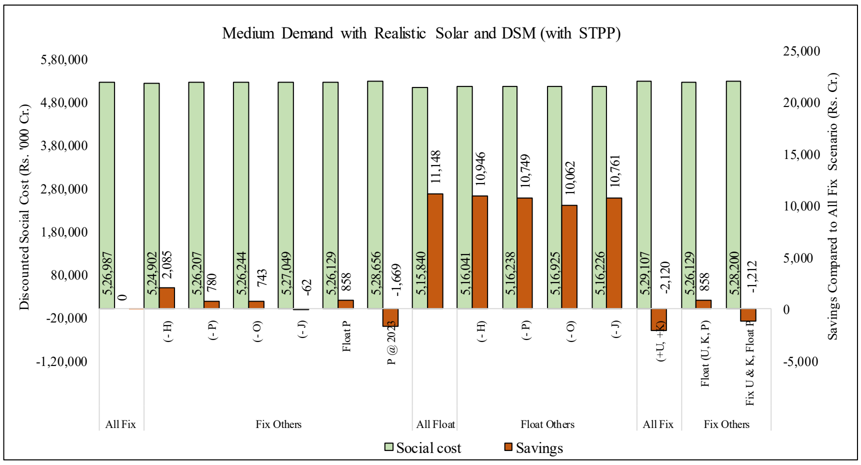


Figure 0.10: Medium Growth Scenario Social Cost Comparison with Short Term Contracts

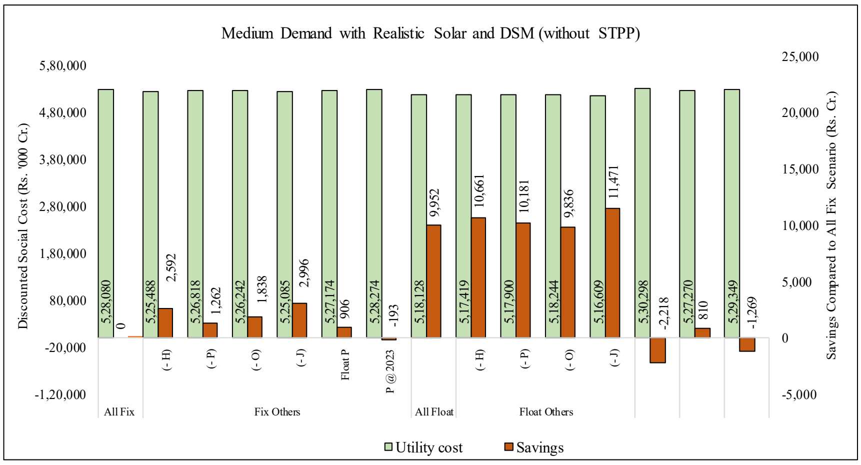


Figure 0.11: Medium Growth Scenario Utility Cost Comparison without Short Term Contracts

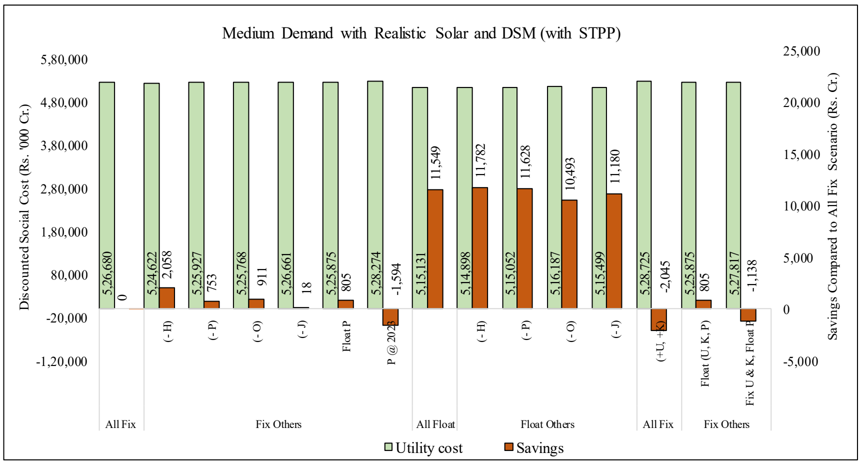


Figure 0.12: Medium Growth Scenario Utility Cost Comparison with Short Term Contracts