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Assessing key aspects of

Uttar Pradesh's Electricity Value Chain

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Suggested citation:

Saraswat, J., Mall, N., & Varun, B.R. (2022). Assessing Key Aspects of Uttar Pradesh's Electricity Value Chain. New Delhi: Vasudha Foundation

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Vasudha Foundation is a leading policy advocacy and clean energy market enabler with a, not for profit motive. It is India's pioneering organization promoting environment-friendly, socially just, and sustainable models of energy by focusing on renewable energy and energy-efficient technologies and lifestyle solutions.

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Introduction

Traditionally, electricity systems have been concerned with three core principles- to adequately meet demand, to improve the reliability of the electricity supply, and to provide electricity service. These systems today have evolved from these mandates. A shift in the design principles across the electricity value chain is observed, to incorporate an expanded set of societal and ecological values. Considerations of economic development that are mindful of climate change concerns, and carbon mitigation, have set the tone for the electricity landscape. The electricity value chain is advancing by keeping three core values at its centre- Interconnectedness; Bi-directionality; Data Analytics.

Figure 1 is a schematic representation of the modern electricity value chain. The electricity systems have broadly been segregated into three parts – Generation, Transmission, and Distribution. With a shift towards multi-directional value exchange where consumers have transformed into prosumers and influx of various private players in electricity generation, the presence of an astute power market becomes critical. Further, the integration of intermittent renewable energy sources, and call for energy efficiency interventions to achieve peak demand management, necessitates energy storage. Developments in digital technologies have pioneered smarter ways of grid management and have sealed their importance as a critical entity in the electricity value chain.

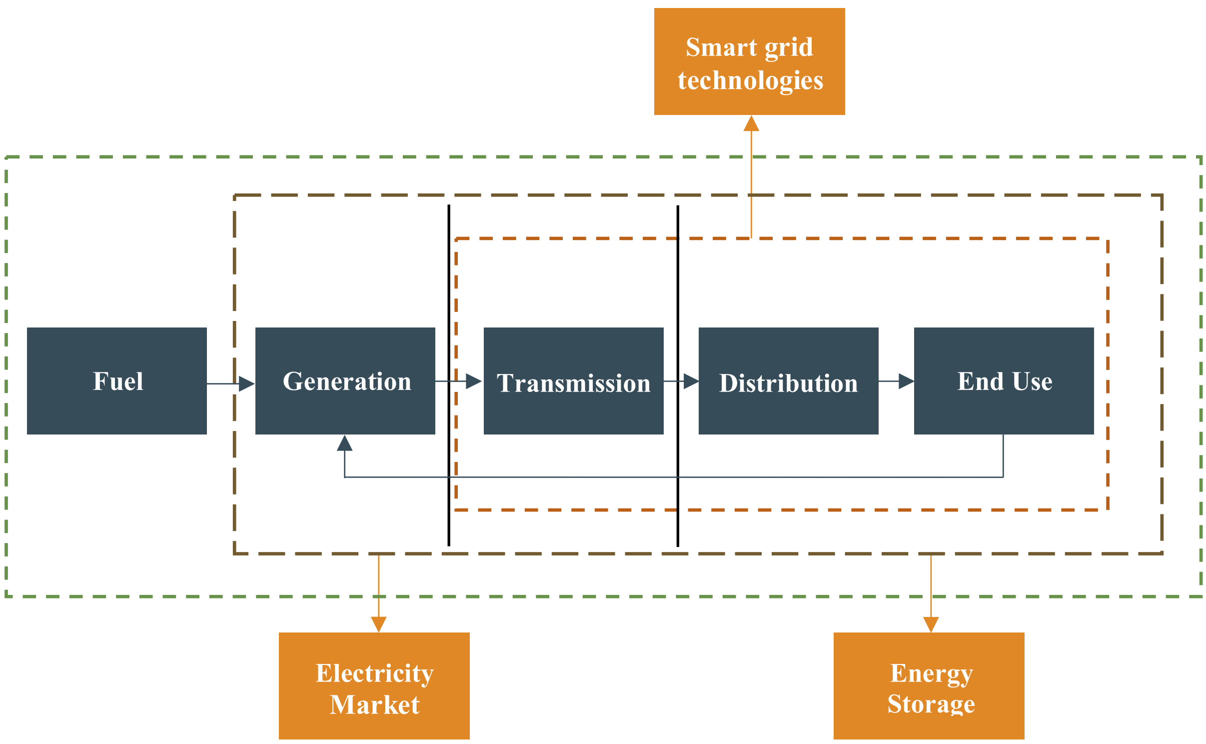


Figure 1: Schematic representation of the electricity value chain

The objective of this briefing paper is to study Uttar Pradesh's (UP) electricity sector, describe certain key aspects along its value chain, underscore accomplishments, and identify areas for improvement.

According to UP's energy policy, the goals of the power sector reform program are to provide cost-efficient good quality electricity to all categories of consumers for the economic development of the State, to make the energy sector commercially viable, and build investor confidence. Correspondingly, this briefing paper hopes to serve as a summary document for the State to aid in decision-making coherent with their power sector policies and goals.

The flow of this paper has been developed with Figure 1 serving as a guide. Traversing from Part-A to Part-C, this paper will describe key aspects of UP's electricity sector. Furthermore, this will be followed by the analysis of the three catalysts for clean electricity transition: Energy Storage, Smart Grid, and Electricity Market.

Brief background of UP's Electricity Sector

In UP, one of the first steps of reform and restructuring of the electricity sector was the institution of the UP Electricity Regulatory Commission (UPERC) under the aegis of the U.P. Electricity Reforms Act, 1999. Subsequent transfer schemes and the incoming of the Electricity Act, 2003, led to further reforms as illustrated in Figure 2. In view of the aforementioned goals, the Government of UP agreed upon the following key constituents of its electricity sector reform process:

- Restructuring of UP State Electricity Board (UPSEB) into autonomous and separately accountable entities.
- Creation of an Independent Regulatory Body to protect consumers as well as the long-term financial health of the Power Sector.
- Ultimate transfer of ownership of the assets to public corporate entities over a phased schedule.
- Rationalization of tariff.

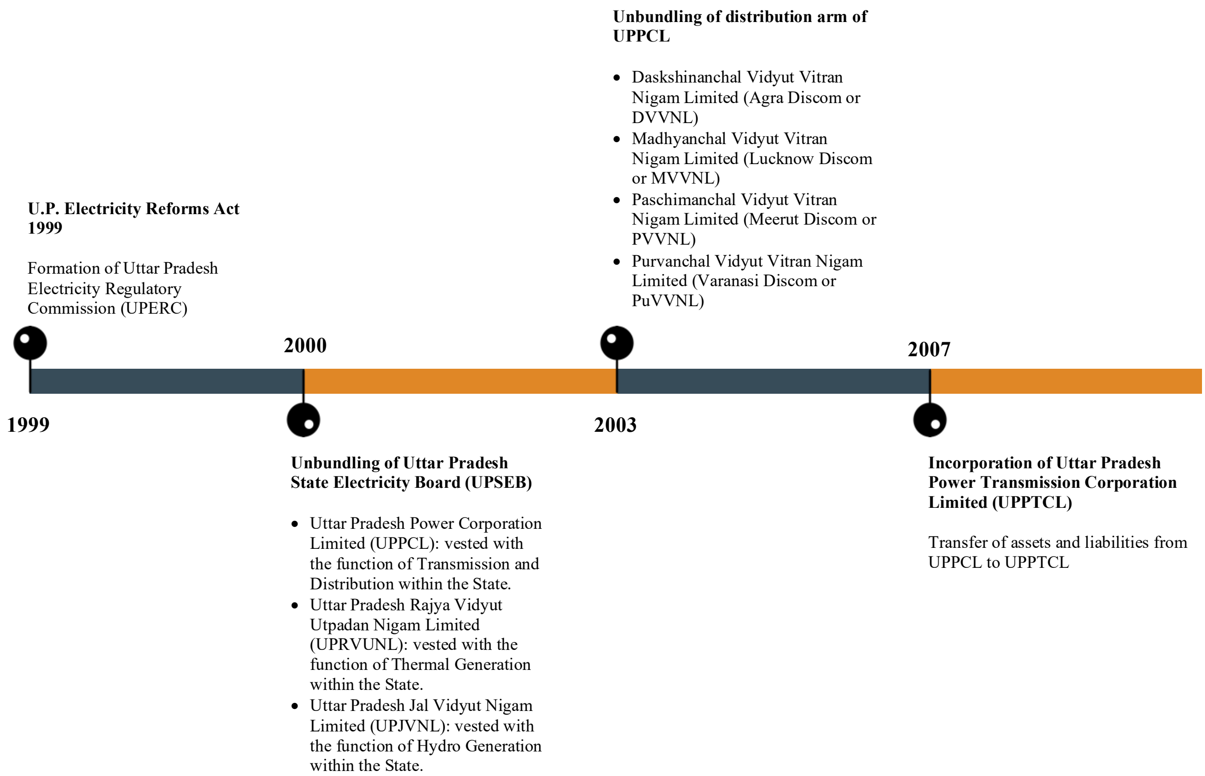


Figure 2: Major reforms in UP's electricity sector

Part A: Generation scenario of UP's electricity sector

Fuel sources and generation mix

With an objective to provide a 24x7 power supply, UP has seen a steady rise in its operational installed power capacity from the year 2015-16 to 2020-21. As illustrated in Figure 3 [2], the **primary fuel source is Coal which averages 82% of the total installed capacity in the last 5 years**. However, the share of coal has seen a slight drop over the years owing to the rise in renewable energy capacity. **Over the 5 year period, solar capacity has grown at a CAGR of 51%, rising by almost 12 times.**

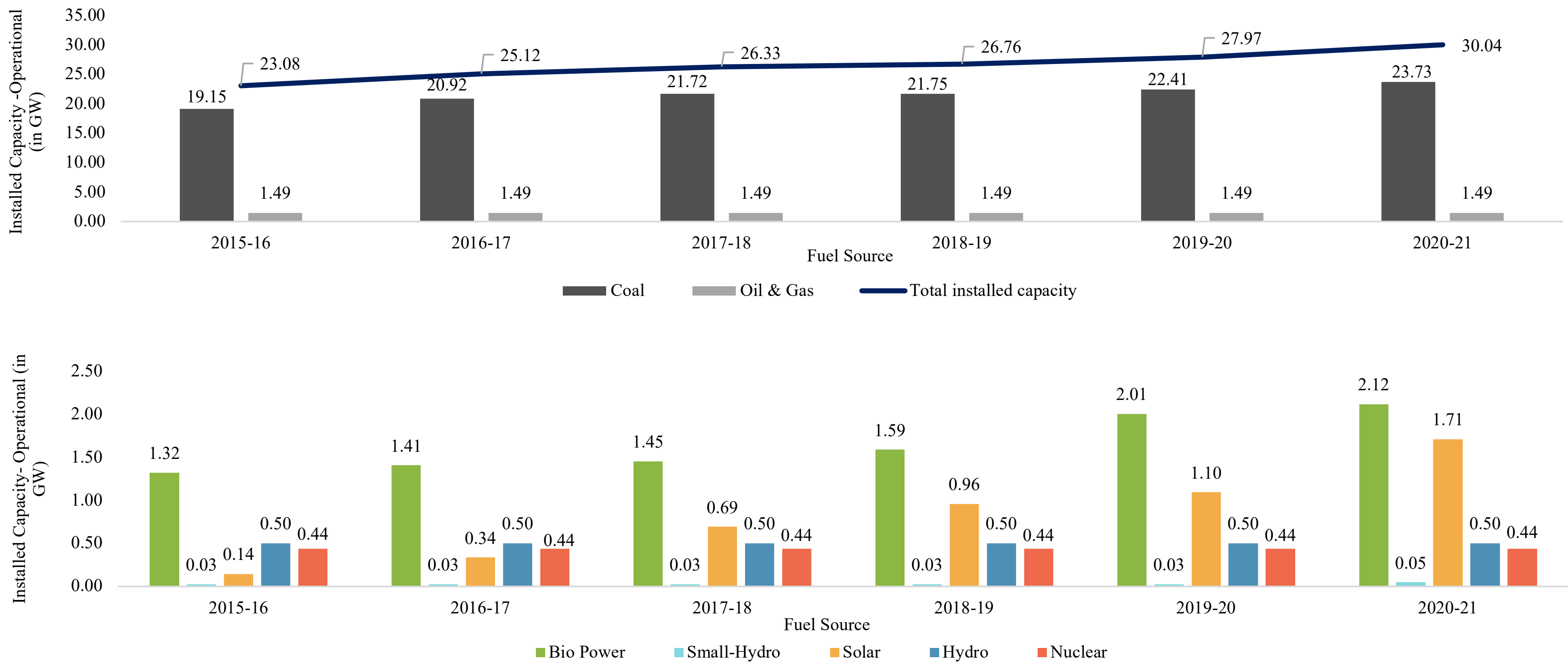


Figure 3: UP source-wise installed power capacity (in GW)

On similar lines, UP has seen electricity generation rising steadily over the period from 2015-16 to 2020-21, as seen in Figure 4 [2]. **An interesting observation is a shift in the share of generation from oil and gas sources to renewable sources of solar and biomass. Solar generation has grown at a CAGR of 57%** increasing by almost 15 times against the 2015-16 generation value.

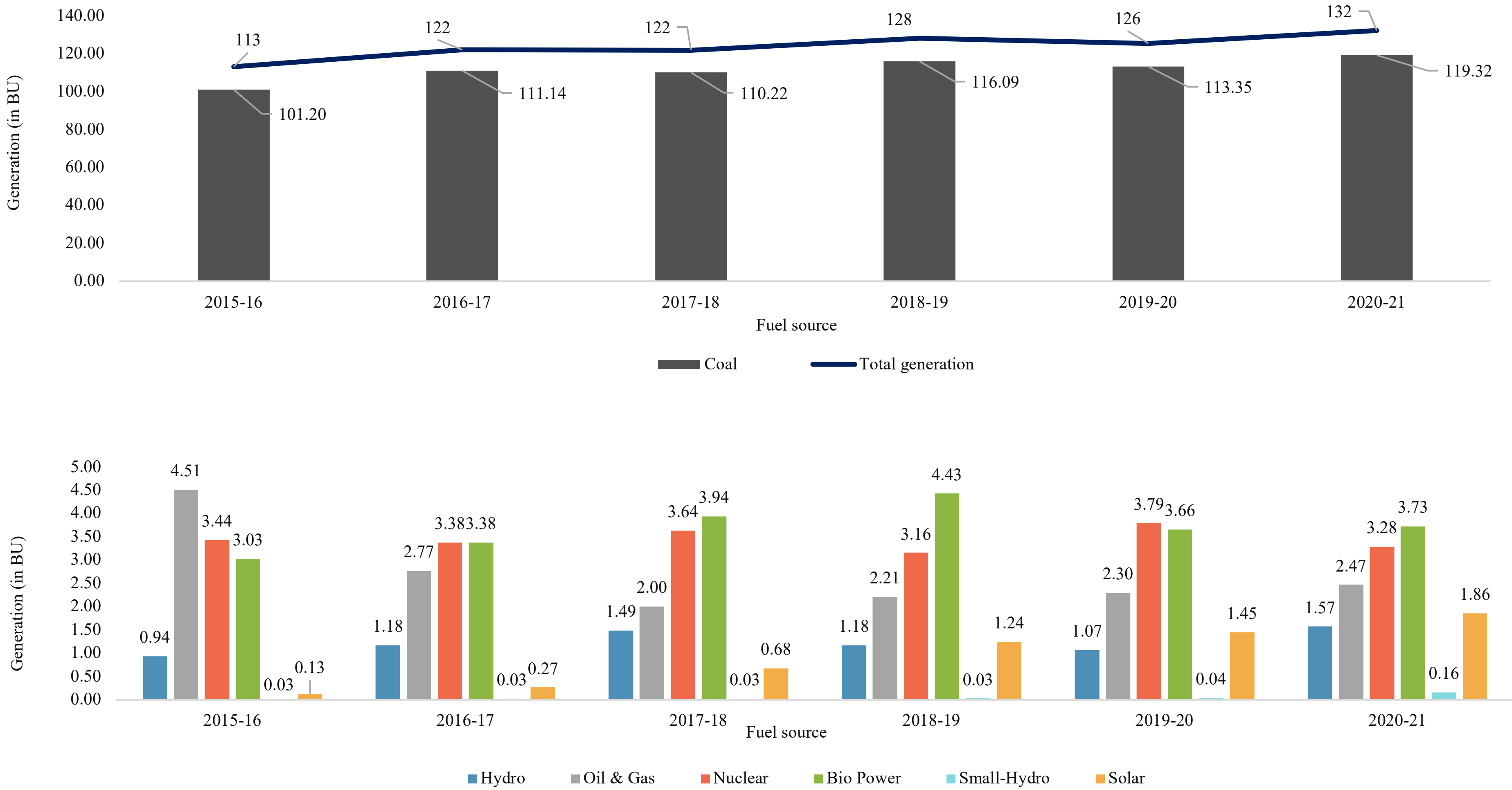


Figure 4: Generation share from fuel sources (in BUs)

Meeting energy demand: UP has seen a steady increase in its energy requirement and the State until 2016-17 was challenged with peak demand and energy deficit. However as illustrated in Figure 5, **the trend over the last 5 years indicates a scenario of energy sufficiency in the State.** It is expected that the increasing share of renewable energy will be catering to the energy projections indicating a rising demand.

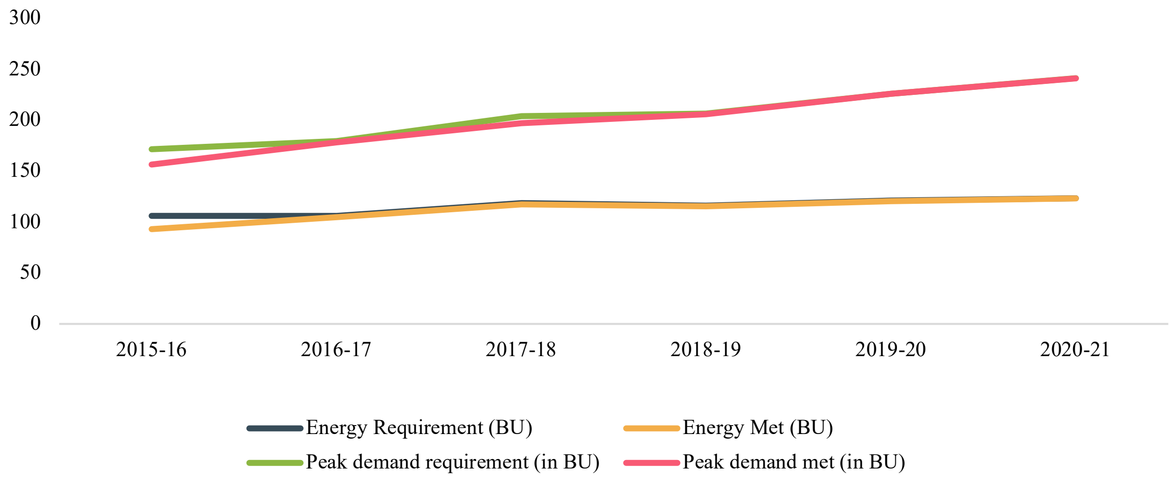


Figure 5: Energy sufficiency in UP

UP's carbon emission scenario

UP has the highest share of coal power units in the country. As seen in Figure 6, **the cumulative emissions from the 77 coal power units have seen a rise over the years 2015-16 to 2020-21**. A slight dip in emissions is observed for the year 2019-20 due to the drop in demand induced by the stringent lockdown in the initial stages of the pandemic.

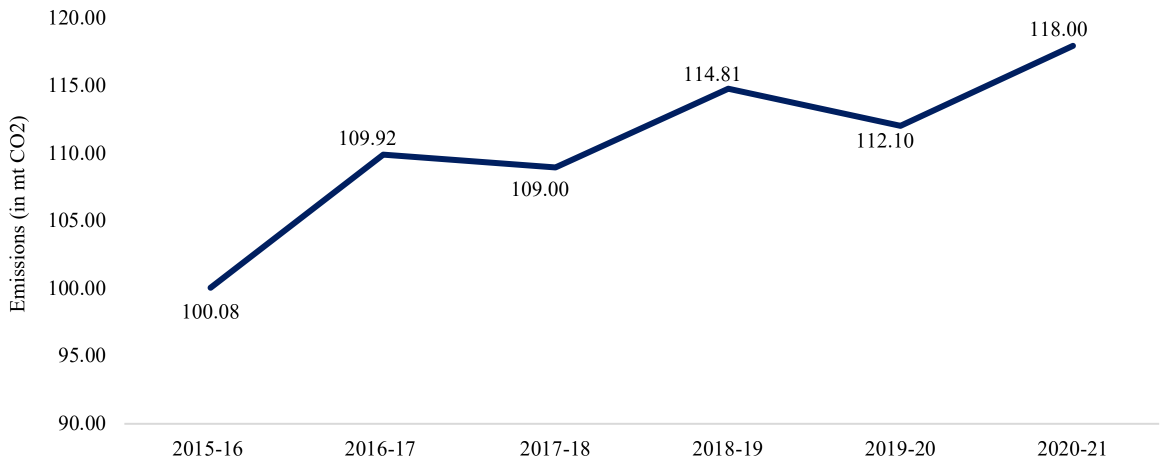


Figure 6: Emission trend in Uttar Pradesh

A generation to concomitant emission comparison of the coal power units for FY 2020-21 is illustrated in Figure 7. The figure captures a descending trend from plants with highest emissions to lowest. The grey data bars represent the percent share of generation for each of the 77 coal power units in UP. The blue curve is representative of the share of emissions contributed by the respective power generating unit. **The general observation is that the emissions from a coal power unit are commensurate to the power generated by it attributed to the increase in coal utilization.**

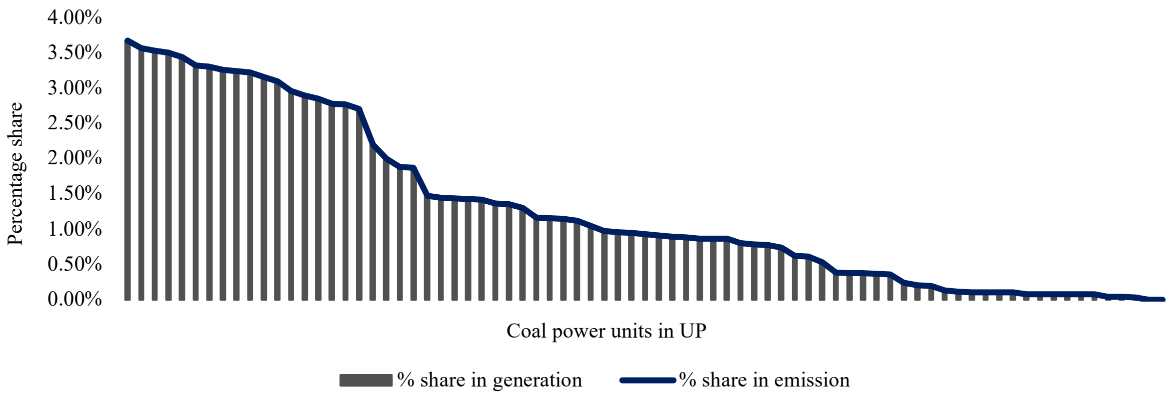


Figure 7: Generation to emission comparison of UP coal power units for FY 2020-21

Figure 8 represents the top 5 coal power units that have the highest share in emission. **These plants cumulatively contribute to about 18% of the emissions derived from coal power units in UP.** Thus, the State might benefit from prioritizing these units to undertake requisite decarbonization measures.

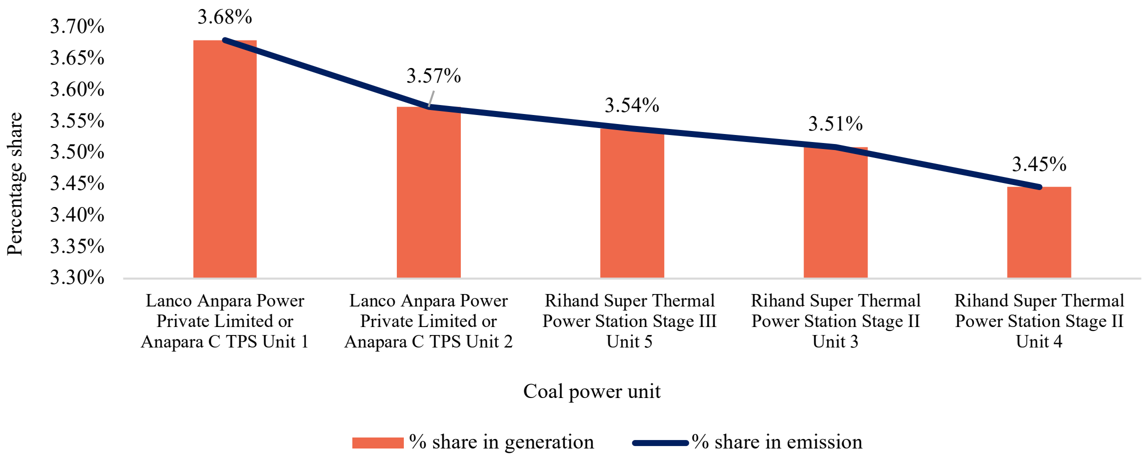


Figure 8: Top 5 emission-intensive coal power units (FY 2020-21)

Plant Load Factor (PLF)

Over the past decade, the plant load factor in the country for coal and lignite-based power plants has seen a decreasing trend. **The PLF in 2009-10 was 77.5% and as of 2020-21, the PLF has decreased by 31.1% and stands at 53.37%.** Among the 77 operating coal power units in UP, a similar trend is reflected as shown in **Table 1**.

Table 1: Descriptive statistics – Plant load factor of UP coal power units

Plant Load Factor (%)					
Year	Median	Mean	Standard Deviation	Skewness	Kurtosis
2015-16	64.47	54.69	32.25	-0.68	-0.87
2016-17	68.51	57.37	27.55	-0.79	-0.37
2017-18	63.88	52.34	26.49	-0.69	-0.81
2018-19	62.38	53.24	29.63	-0.45	-1.13
2019-20	56.71	49.02	27.95	-0.32	-1.07
2020-21	50.52	50.88	27.37	-0.11	-0.92

A descriptive statistical analysis of plant load factors across all the coal power units taken year-wise reveals a declining average PLF in the State. Progressing from 2015 to 2020, the commissioning of new coal power units has further exacerbated the decreasing plant load factor trend. This may be attributed to the asynchronous increase in the electricity demand. Moreover, the **PLF data is observed to be negatively skewed indicating that a majority of the PLFs were above the average value for the respective year**. However, progressing **towards 2020, we observe the skewness getting fairly symmetrical indicating an increase in the number of power generating units shifting to below-average PLF function.** The State government could benefit from reworking its power purchase portfolio. Low PLF for coal power units is transcending to be a pan-India issue and adequate State action can result in financial and environmental benefits.

Renewable Energy in UP

The UP New and Renewable Energy Development Agency (UPNEDA) has been instituted as the nodal agency for the implementation of various renewable energy schemes in the State. The agency is invested in developing capacity in sources such as solar energy, small-scale hydroelectricity, wind power, and biomass-based electricity production. Figure 9 illustrates the various focus areas in the State.

- 4 focus areas- Grid-connected solar, Off-grid solar, solar thermal and KUSUM scheme.
- Multiple schemes on-going such as solar pump, solar street light, solar city, water heater, among others.

- 2 tranches – bioenergy and biomass
- Biogas based power generation program; Biomass Based Gasifier Power Project; Biomass Based Co-Generation Power Project.

- Appointed authority in the State for projects up to 25 MW.
- Agency undertaking job of identification, surveying and preparation of feasibility of project reports.

- Wind Resource Assessment (WRA) by National Wind Energy Institute has been done to identify the wind energy programs in various districts of UP.
- Indicative Wind Power Density (WPD) in the order of 200-250 w/m2.

Figure 9: Snapshot of UPNEDA focus areas

UP was assigned renewable power capacity targets as part of India's cumulative RE target commitment of **175 GW by 2022– 10,967 MW of solar power, 25 MW of small hydro projects, and 3499 MW of biomass power.** Reflecting UP's commitment to renewable power installation, a total capacity of 1338.76 MW has been tendered primarily as solar energy projects. The projects comprise rooftop PV as well as ground-mounted installations in designated solar parks formalized by the government. A 150 MW floating solar project is in the pipeline to be implemented by the Solar Energy Corporation of India (SECI). Additionally, smaller projects based on waste to energy (8 MW) are also underway.

Part B: UP's Transmission Network

The UP-Power Transmission Corporation Limited (UPPTCL) is bestowed with the responsibility to undertake the operation, maintenance, management of transmission lines and associated substations, equipment, cables, and wires, in the State. It also undertakes the functioning of the State Load Dispatch Centre (SLDC) and carries out schedule and dispatch generation of all units connected to the State power system including the centrally owned generating stations. Table 2 is a snapshot of the total installed transmission infrastructure in UP.

Table 2: Snapshot of UPPTCL transmission network

Voltage (in kV)	Length installed (C.KMS.)	Number of substations
765	1085.37	6000
400	6379.489	21720
220	13433.277	47420
132	25005.506	53787

Green Energy Corridor

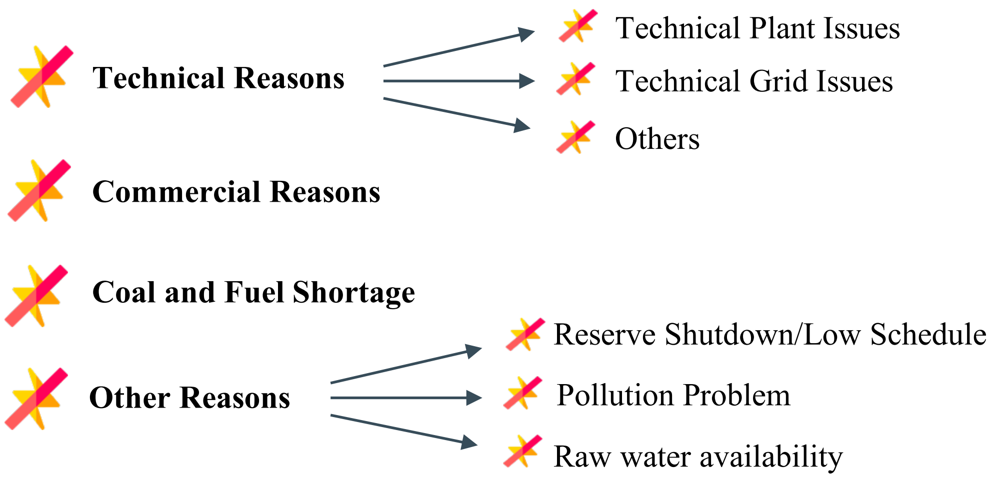
The Green Energy Corridor (GEC) is a comprehensive scheme for evacuation and integration of the renewable energy (RE) capacity addition underway in the country. UP as part of the second phase of the scheme (GEC-II) has accordingly undertaken infrastructure addition to supporting the national grid. **The projects underway as part of GEC-II are intra-state type. A total of 14 transmission line projects and 4 substation projects have been sanctioned.** 10 transmission line projects under construction are high-voltage level (66-132 kV) and 4 projects fall under the extremely high voltage level (220 kV). Table 3 is a snapshot of the projects under GEC-II that have achieved 100% completion status.

Table 3: Snapshot of completed GEC-II projects in UP

Substation Projects					
Project	Zone	Sector	Type	Implementing Agency	Voltage ratio (kV/kV)
Bhadrekhi (Urai) (Augmentation) (GEC-II)	Northern	State	Intra-State	UPPTCL	220/132
Transmission Lines					
Project	Zone	Sector	Type	Implementing Agency	Voltage Level kV
Bhadrekhi (Orai) - Jalaun line (GEC-II)	Northern	State	Intra-State	UPPTCL	132
Dakore (Solar plant) - Bhadrekhi (Orai) line (GEC-II)	Northern	State	Intra-State	UPPTCL	132
Jigna - Dadar Vijaypur (Solar plant) Mirzapur line (GEC-II)	Northern	State	Intra-State	UPPTCL	132
Meja - Kosda Kala (Solar plant) Meja line (GEC-II)	Northern	State	Intra-State	UPPTCL	132

Power outages: Dissecting transmission barriers in UP

Delivering reliable and stable electricity is a critical mandate of the modern electricity value chain. In this context, it is necessary to identify the reasons contributing to power outages in the State. This will deliver insights to help the State identify key problem areas and undertake measures to reduce the incidence of power outages. Power outages render coal power units to become non-operational resulting in allied outage days and generation loss. Given below are the major reasons recorded for power outages in UP.



In order to gauge the major reasons behind power outages in UP, the maximum generation losses, outage days, and the number of units affected were pitted against the corresponding cause of the outage. As Figure 10 illustrates, **technical reasons accounted for more than 50% of generation loss incurred per year.** While a decreasing trend was observed from 2015-16 to 2019-20, the percentage contribution of technical reason to generation loss, shot up to 67% in 2020-21.

Over the years from 2015-16 to 2020-21, Technical reason stood as the major contributing cause averaging 49% cumulative among the non-operational units. Similarly, the maximum **outage days recorded in the year were primarily due to two major causes - Technical reasons, and Reserve Shut Down. On average, these two major causes contributed 41% and 47% respectively** to the resulting outage days experienced from 2015-16 to 2020-21.

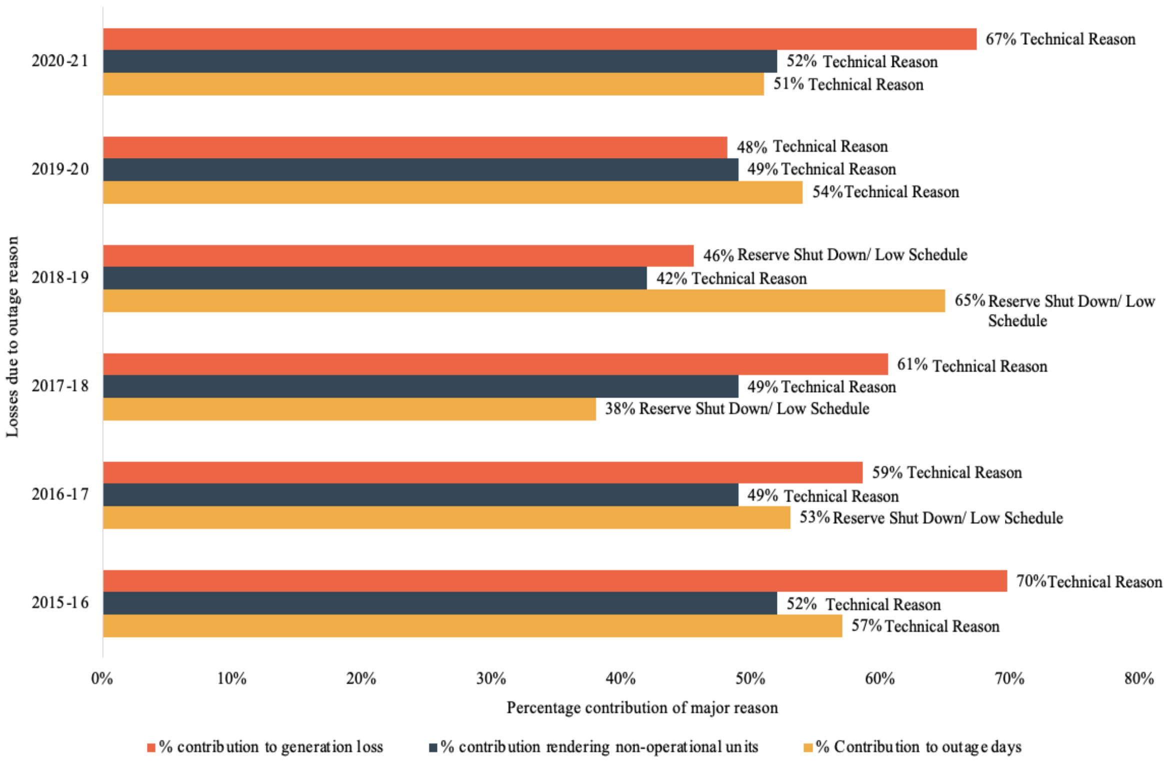


Figure 10: Reasons leading to power outrages

Part C: Key Aspects of UP's Distribution Sector

The modern electricity value chain has transformed into a multi-directional value exchange system. The emergence of prosumers, scope of Demand-Side Management (DSM) interventions for peak load management, grid stability applications required with increasing RE influx, and rise in end-use applications such as e-mobility, data centers, etc., have placed the distribution sector as a critical sphere in the evolution of electricity value chains. In this section, certain key aspects of UP's electricity distribution sector are probed.

Distribution

UP Consumer Profile

UP has a large domestic consumer base comprising 86% of all consumers on average, taken for the years 2015-16 to 2020-21. Post unbundling the distribution arm of UPPCL, the electricity consumers in the State are currently catered to through 6 companies - Dakshinanchal Vidyut Vitaran Nigam Limited (DVVNL), Madhyanchal Vidyut Vitaran Nigam Limited (MVVNL), Pashchimanchal Vidyut Vitaran Nigam Limited (PVVNL), Purvanchal Vidyut Vitaran Nigam Limited (PUVVNL), Kanpur Electricity Supply Company (KESCO), and Lucknow Electricity Supply Administration (LESA). Figure 11 represents the share of consumers under each Distribution Company's (DISCOM) jurisdiction.

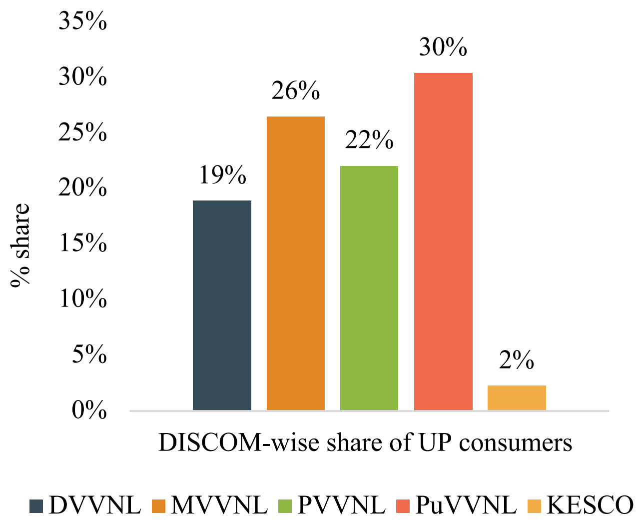


Figure 11: Percentage share of consumers under UP DISCOMs

Table 4 showcases the energy sales recorded for each consumer category in UP. It is observed that **Domestic consumers, followed by Agriculture consumers have the highest CAGR relatively among the categories**. The domestic category records a 7.4% CAGR increase. The energy sales of industrial consumers and other public services are observed to have decreased resulting in negative CAGR. **The Railway category records the lowest drop in the share of energy requirement, registering a 28% negative CAGR. Indian Railways have 220 MW of RE power and possess 3.45 GW RE capacity in their pipeline.** Owing to the sector's commitment to reduce its carbon footprint, the sector is seeing a shift from conventional grid electricity to RE sources.

Table 4: Snapshot of category-wise energy sales in UP

Consumer category	Energy Sales (in MUs)						CAGR
	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	
Agriculture	12681	15648	16545	16456	17259	18631	6.62%
Commercial	8864.6	10096	11538	11372	11399	9984.3	2.00%
Domestic	28235	32962	38286	39771	42961	43305	7.39%
Industrial	14165	14407	16443	16656	16336	13976	-0.22%
Others	2901.1	2912.7	2777.2	2815.5	2956	2711	-1.12%
Public Services	2485.9	2766.4	3110.3	2731.8	2530.8	2404	-0.56%
Railways	896.7	1016	1105	194.72	123.42	126.37	-27.86%

Figure 12 illustrates the percentage share of energy sales for the various consumer categories from the year 2015-16 to 2020-21. It is observed that the **percentage share of energy sales for domestic consumers has seen the largest increase**, thus indicative of the rising electricity demand in the State facilitated by the Saubhagya scheme (expounded in the next section).

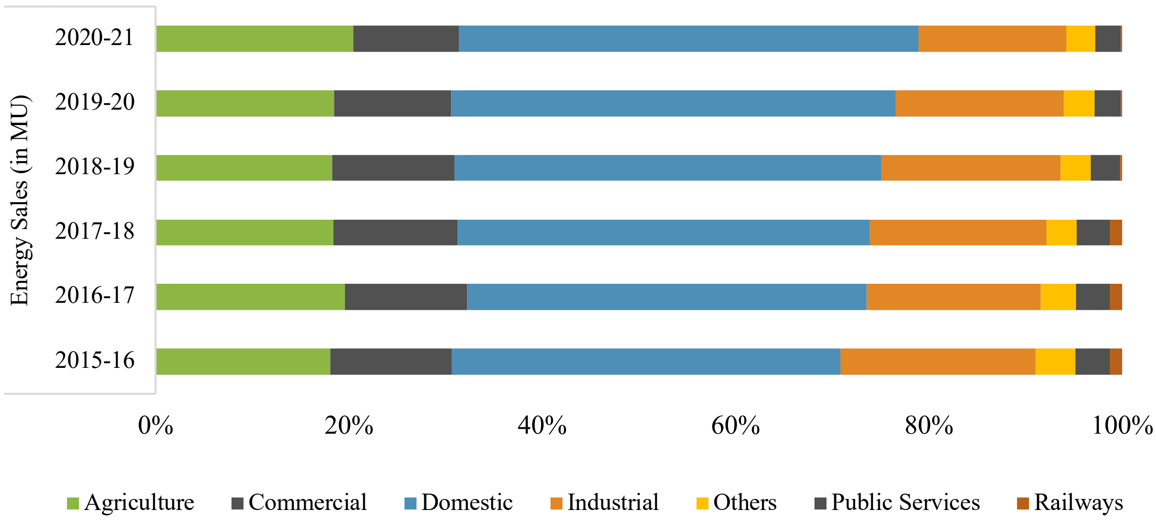


Figure 12: Percentage share of category-wise energy sales in UP

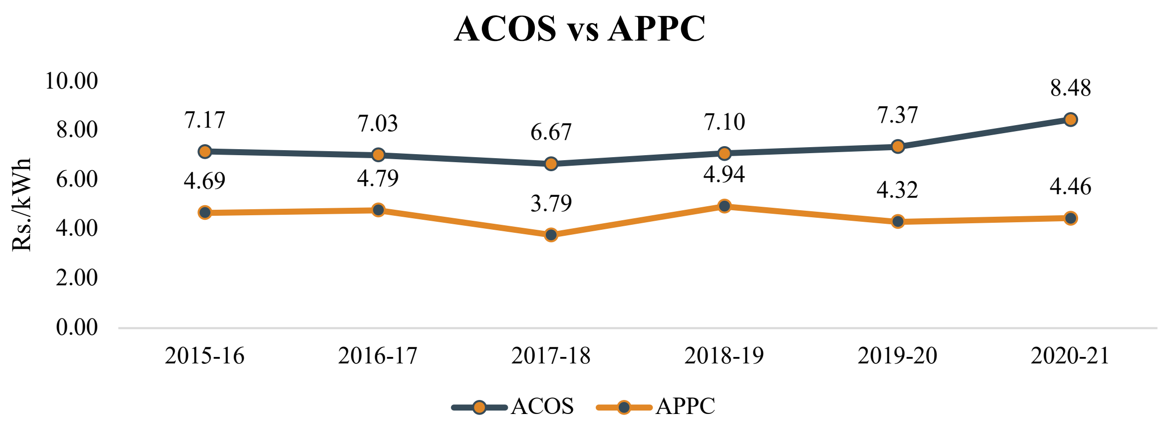
Analysis of UP DISCOMs' Operation

The Ministry of Power launched the Ujwal DISCOM Assurance Yojana (UDAY) in 2015 with a mandate to turn around the financial and operational performance of Power Distribution Utilities (DISCOMs) of the country. The improvements made by the distribution sector in the State are depicted through the key financial and operational parameters of UDAY. Table 5 is a summary of these parameters indicative of UP DISCOMs' performance. To address the shortfalls of UDAY, the Revamped Distribution Sector Scheme (RDSS) was launched in 2021, to introduce a performance evaluation framework for the DISCOMs subject to which their access to funds would be determined. The scheme nudges DISCOMs to improve their financial sustainability, the progress of infrastructure works, outcomes from these projects, and also mandate capacity-building measures including IT enablement within their scope.

Table 5: Financial and Operational data for UP

Financial Indicators	
Parameter	**Value**
Bonds issued (%)	₹ 49,510 crore (98.77% of target)
AT & C Loss (%)	27.92%
ACS-ARR Gap (₹/unit)	₹0.98
Operational Indicators	
Parameter	**Status of completion**
Feeder Metering (Urban)	100%
Feeder Metering (Rural)	100%
DT Metering (Urban)	100%
DT Metering (Rural)	10%
Electricity Access to Un-connected Households	100%
Smart Metering above 500 kWh	0%
Smart Metering between 200 and up to 500 kWh	100%
Feeder Segregation	70%
Rural Feeder Audit	100%
Distribution of LEDs under UJALA	100%

ACOS-APPC Gap: Low difference between the Average Cost of Supply (ACOS) and Average Power Purchase Cost (APPC), is an indicator of sound operational efficiencies in the State's electricity distribution. As illustrated in Figure 13, a **widening gap between ACOS and APPC in the State is observed**, indicating the need to adopt measures to improve the DISCOMs' operational efficiencies.



	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21
Gap (Rs/kWh)	2.48	2.23	2.88	2.15	3.04	4.02

Figure 13: ACOS-APPC gap in UP power sector

Cross-subsidy elimination: A key characteristic of tariff is that it must reflect the efficient and prudent cost of supply. As emphasized in Sections 39, 40, and 42 of the Electricity Act, 2003, and more recently the Tariff Policy, 2016, the elimination of cross-subsidization is a critical aspect. Figure 14 represents the average of cross-subsidy surcharges across the various supply sub-categories. A lower surcharge is observed for the year 2019-20 owing to the lockdown period in the pandemic. The figures indicate that the State is yet to achieve elimination of cross-subsidy thus expounding the importance of tariff rationalization.

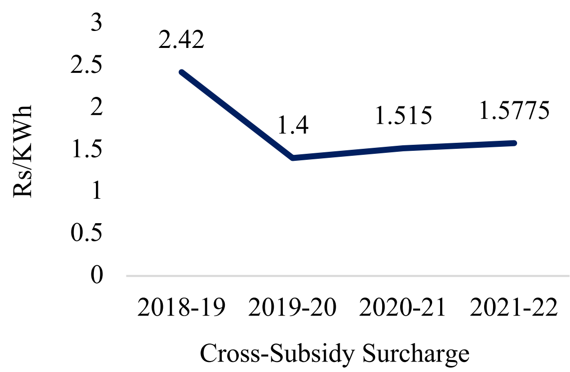


Figure 14: Cross-subsidy surcharge in UP

End-use

Overview of DSM Initiatives

DSM Initiatives undertaken in the State have primarily been municipal DSM programs, appliance efficiency-based projects, and agricultural DSM. A brief of the various programs implemented in the State has been described as follows-

Municipality Demand Side Management (Mu-DSM) scheme: The intervention was launched under the aegis of BEE to improve the overall energy efficiency of the Urban Local Bodies (ULBs). The program has an objective to facilitate substantial savings in electricity consumption, thereby resulting in cost reduction/savings for the ULBs [12]. One of the key initiatives under this scheme is the replacement of street lights with LEDs. **The Ghaziabad Development Authority has replaced 822 street lights with LEDs under this program.**

Domestic Efficient Lighting Program (DELP) scheme: The scheme more popularly known as the Unnat Jyoti by Affordable LEDs for All (UJALA) Scheme has key objectives of aggregating demand, reducing the high initial costs, and facilitating higher uptake of LED lights by residential users. Under the DELP scheme, each household having either a connected load of less than or equal to two kilowatts will be provided with up to five 7-watt high-quality LED bulbs. If the connected load is more than two kilowatts, households will be provided with up to ten 7-watt high-quality LED bulbs. The progress of this program in UP is as shown in Table 6.

Table 6: Snapshot of UJALA Scheme in UP

Total LED Distributed	2,62,87,727
Energy Saved Per Year (in MWh)	34,13,908
Cost Savings per year (in Crore rupees)	1366
Avoided Peak demand (in MW)	683
CO2 Reduction per year (in tCO2)	27,65, 266

Agriculture DSM: The objective of this scheme is to create an appropriate framework for market-based interventions in the agriculture pumping sector. Pump-set efficiency upgradation projects were carried out through Public-Private Partnership (PPP) model. A total of **5945** old agriculture pumps have been replaced with Energy Efficient pumps and smart meters.

Demand Response interventions: Demand Response (DR) measures have been tested in various parts of the world owing to their ability to introduce flexibility on the demand side. In India, the concept is still at a nascent stage of deployment. **UP is among the pioneer states to conduct a DR pilot. A 3 MW DR pilot program under MVVNL's jurisdiction attempts to test DR's viability in the region and thereby exemplify the concept for adoption in other regions.**

PM-KUSUM: The scheme was launched in 2019 with the intent of increasing the non-fossil fuel installed capacity of electric power and aimed to ensure energy security for the farmers in India. The scheme consisted of 3 components focusing on setting up decentralized grid-connected RE power plants, installing solar agriculture pumps, and solarisation of grid-connected agriculture pumps. In UP, the scheme has made progress in the installation of solar agricultural pumps. **The State has successfully installed 32% of the total sanctioned solar pumps.**

Opportunity with E-mobility

The global push for Electric Vehicles (EV) is seeing a corresponding trend with India. The central government through the Faster Adoption and Manufacturing of Hybrid and Electric vehicles (FAME-II) scheme has incentivized EV adoption and manufacturing. 25+ states including UP have drafted their EV policy, with a majority of them already in effect. The measures have had a positive impact and a steady increase in EV sales is observed as shown in Figure 15.

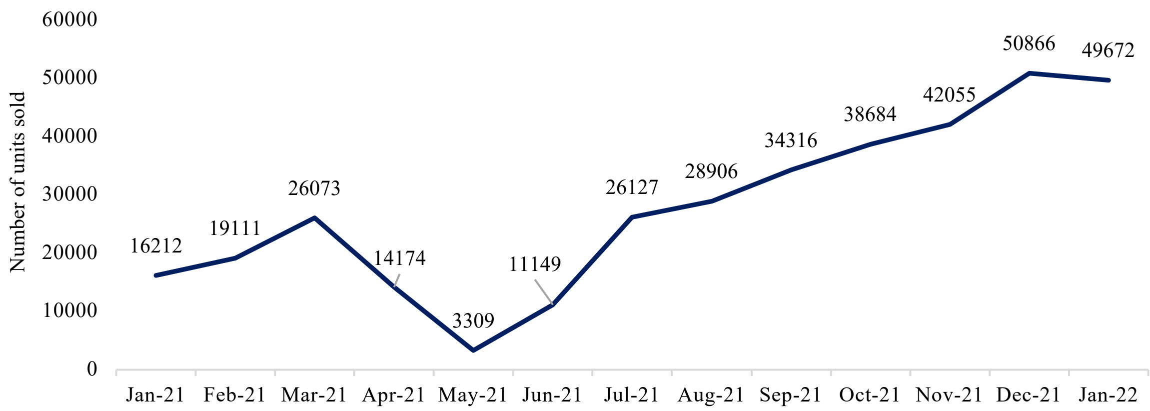


Figure 15: Pan-India EV sales registered month-wise

Increasing EV penetration implies that DISCOMs must prepare to manage the additional load from this upcoming sector. **A projection by the Central Electricity Authority (CEA) pegs the total electricity demand for India to be around 2325 TWh by 2030**. Projections for **EV electricity demand** under upper bound scenarios indicate that the demand **might not exceed 4% of the total electricity demand projection** which is deemed as a manageable demand figure. However, in light of grid stability and load balancing applications that EVs bring forth through vehicle-to-grid (V2G), and EV charging business opportunities, new revenue stream avenues have opened up for the DISCOMs.

In UP, the EV policy reflects the State's commitments to the e-mobility ecosystem. It aims to attract investments of over INR 40,000 Crore in the next 5 years across the EV sector and potentially generate 50,000 jobs. The State has set targets as illustrated below. **In the duration from January 2021 to January 2022, UP has consistently topped the EV sales averaging 22% share per month against sales figures for India. To date, UP has 254825 EV registrations in total and holds the top spot in the country.**

- To set up nearly 2 Lakh slow and fast charging, swapping stations by 2024
- To roll out nearly 10 Lakh EVS, combined across all segment of vehicles by 2024
- Launch 1000 Electric buses and achieve 70% EV Public transportation on identified green routes in identified 10 EV cities by 2030
- To bring in manufacturing units of high-density power storage of at least 5GWh capacity in next 5 years

Figure 16: UN EV Policy Targets

Catalyst in Electricity Transition

Energy Storage

In the power sector, as India is expected to ratchet up intermittent renewable energy deployment in this decade, the need for Energy Storage Systems (ESS) becomes paramount. This is attributed to the fact that the provision of '24X7 Power For All' can only be achieved by balancing the supply and demand of electricity that can be manifested with ESS. From a transport sector perspective, the advent of sustainable mobility can be supplanted by electrification where batteries (a form of ESS) power the vehicle. Concurrently, it has sundry applications in other sectors like Buildings, Industries, Cooling, etc. Given below is the summary of the applications of ESS.

GRID SUPPORT & APPLICATION

- Bulk Energy Services
- Ancillary Services
- Transmission Infrastructure Services
- Distribution Infrastructure Services
- Customer Energy Management Services

OTHER APPLICATIONS

- Distributed off-grid
- Industrial and Household Heating & Cooling
- Cold Storage
- Consumer Electronics

TRANSPORT ELECTRIFICATION

- Vehicle to Everything (V2X)
- Grid Services

Several studies have been conducted in India to assess the ESS requirement. As per Central Electricity Authority's Optimal Generation Mix report, **by 2030, India will require 34 GW/ 136GWh of stationary** ESS. **Cumulatively, the total ESS demand (including both mobile and stationary applications) will be around 2416 GWh by 2032**. There is a huge market for ESS in India and the collaboration of all the stakeholders in the value chain will assist in meeting this demand. Here, we examine a few technologies for UP.

Mechanical- Pumped Hydro Energy Storage (PHES):

Various types of ESS technologies are available in the market like mechanical, electrochemical, thermal, electrical, and chemical storage technologies. However, pumped hydro under the umbrella of mechanical storage has the largest installed capacity in India. **As of Feb 2021, a total of 3,305 MW of pumped hydro storage was operational in India**. Moreover, **around 1580 MW of pumped hydro projects are under construction phase and around 9730 MW of projects are under proposal development**. Of these, **no project belongs to UP.** Clearly, there is a need to examine the possibility of PHES in UP. As per a study conducted by Australian National University (ANU), there are several PHES sites available in UP as seen in Figure 17. There are **250 lower** sites, and **190 upper** sites located in the **Bijnour, Chitrakoot, Shrawasti, Bahraich, and Sonbhadra districts**. More than **70% of the potential PHES sites are present in the Sonbhadra district. A detailed study of these sites can assist in quantifying the capacity of PHES in the state.**

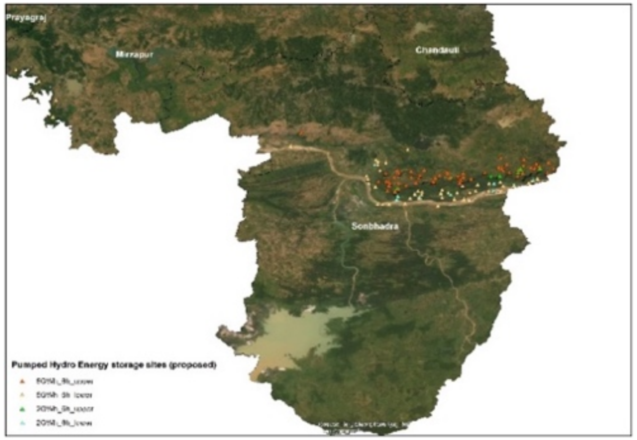
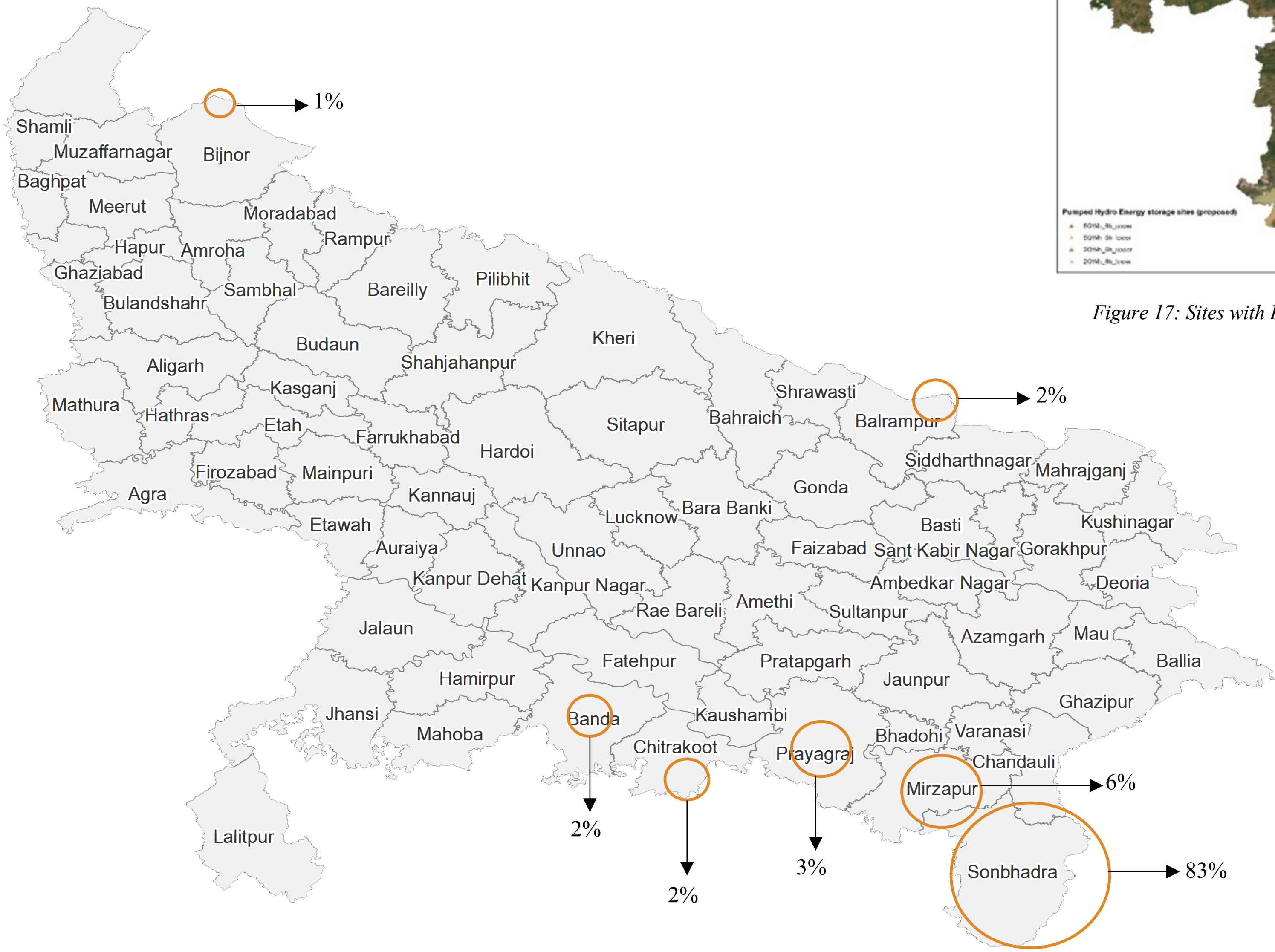


Figure 17: Sites with PHES potential in Sonbhadra, UP

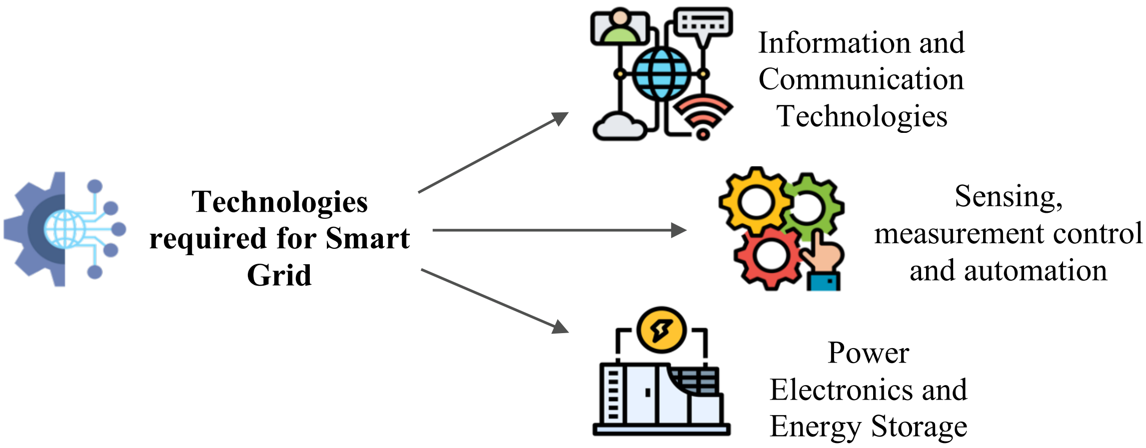


Electrochemical-Lithium-ion Batteries

Electrification of the transport sector is a vital intervention to decarbonize the sector. As per ICCT, the **Electric Vehicle industry in India is forecasted to consume over 824 GWh of batteries in the Business As Usual (BAU) scenario and 1114 GWh in the Ambitious scenario** [24]**.** To meet this mammoth demand, the giga factories of lithium-ion batteries have been announced in India facilitated by the INR 18,100 crore Production Linked Incentive (PLI) scheme for Advanced Chemistry Cell (ACC) launched by the Government of India (GOI). UP has seen enhanced interest from manufacturers in setting up lithium-ion manufacturing plants in the state. In July 2021, the Lohum group announced setting up a **3GWh Lithium-ion battery manufacturing and recycling facility in Greater Noida, UP**. In the same year, a US-based clean energy products manufacturer has unveiled plans **to invest USD 25 million to set up a 1 GWh lithium-ion battery manufacturing facility in Greater Noida as well.**

Smart Grid

Traditional electrical grids are characterized by a one-way flow of power and electricity, as well as human monitoring. The power is generated centrally and distributed to a huge number of load centers. The Smart Grid, on the other hand, is distinguished by distributed generation, two-way information and power flow, and self-monitoring capabilities as seen below.



Smart Metering

Smart metering consists of 4 main components- smart meters, a two-way communication network, a Meter Data Management System (MDM), and HAN. Smart meters are advanced meters that can collect energy usage & production, status, and diagnostic data in detail. This data is often used for billing, user appliance control, monitoring, and troubleshooting. **Under the Smart Meter National Program, the GOI intends to replace 250 million conventional meters with smart meters. In December 2020, around 2.14 million smart meters were deployed in India and around 7.02 million meters were in the deployment phase.** Figure 18 provides more details on the state of smart meter deployment in India. Of the total smart meters deployed by 2020, **UP's share is the largest with around 1.1 million.**

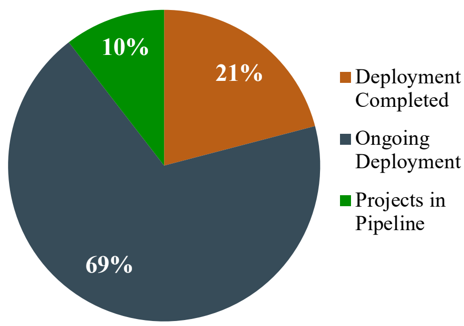


Figure 18: Smart Meter Deployment in India

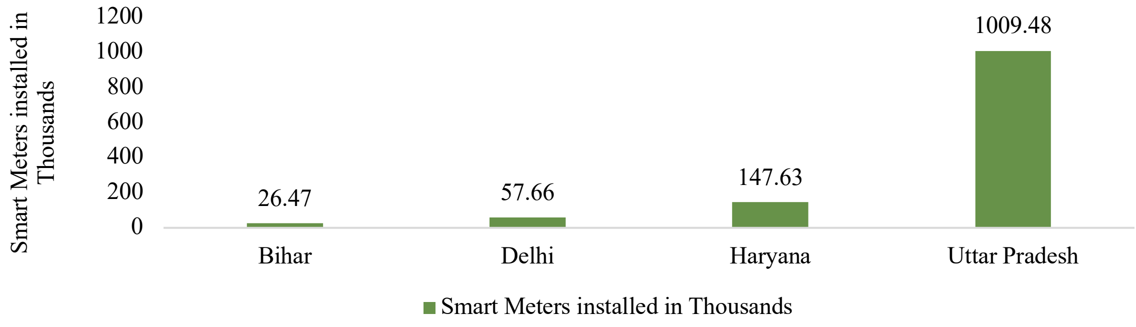


Figure 19: Smart meter deployment - State-wise share

This large uptake of smart meters was facilitated by the Memorandum of Understanding (MoU) signed between UP Power Corporation Limited (UPPCL) and Energy Efficiency Services Limited (EESL) in 2018 to roll out 4 million smart meters. This will result in a cumulative **savings of INR 8000 crores over eight years**. **In the 13 cities of Lucknow, Kanpur, Varanasi, Allahabad, Gorakhpur, Meerut, Moradabad, Aligarh, Saharanpur, Jhansi, Mathura, Bareilly, and Faizabad, smart meters have been deployed since 2018.** Table 7 showcases a sample of the project benefit derivation for the Smart Meter installation by EESL for the city of Lucknow.

Table 7: Project Benefit Derivation Sample (Lucknow) for the Smart Meter installation by EESL

Project Benefit Plan		
Description	Pre-Smart Metering	Post-Smart Metering
Total Number of consumers	365089	365089
Energy Input (MU)	2614.28	2614.28
Energy Billed (MU)	2027.91	2222.14
Billing Efficiency	77.57%	85%
Revenue Assessed (in Cr.)	1226.42	1343.89
Revenue Realised (in Cr.)	1207.62	1343.89
Minimum ABR	6.05	6.05
Thru Rate	4.62	5.14 (11.2% increase)

Blockchain for Peer-to-Peer Energy Trading

Blockchain is a decentralized, distributed, and shared collection of data. The tenets that make blockchain novel and at the same time transformative are its decentralization and transparency attributes, promoting trust amongst the entire value chain as seen in Figure 20. The potential for blockchain to unleash an energy revolution in which both distribution *utilities and consumers produce and sell electricity has piqued the interest of the power industry. The surge in demand for Distributed Energy Resources (DER) like solar photovoltaic (PV) systems, batteries, microgrids, electric car charging, and embedded networks has shifted the power balance away from centralized agencies and toward the grid's margins.*

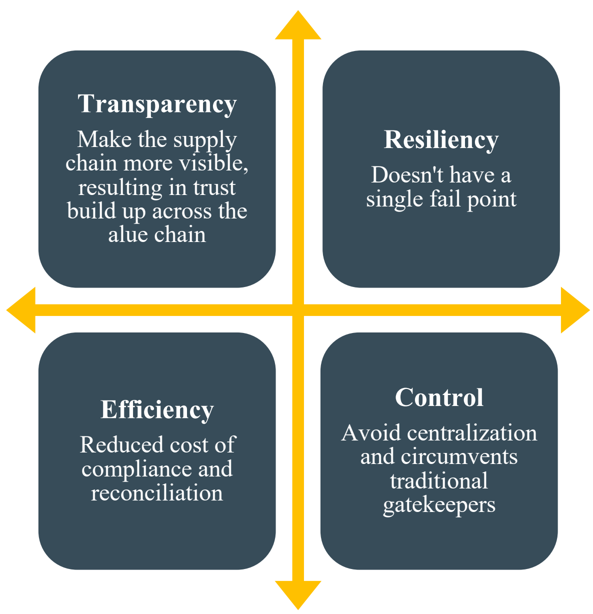
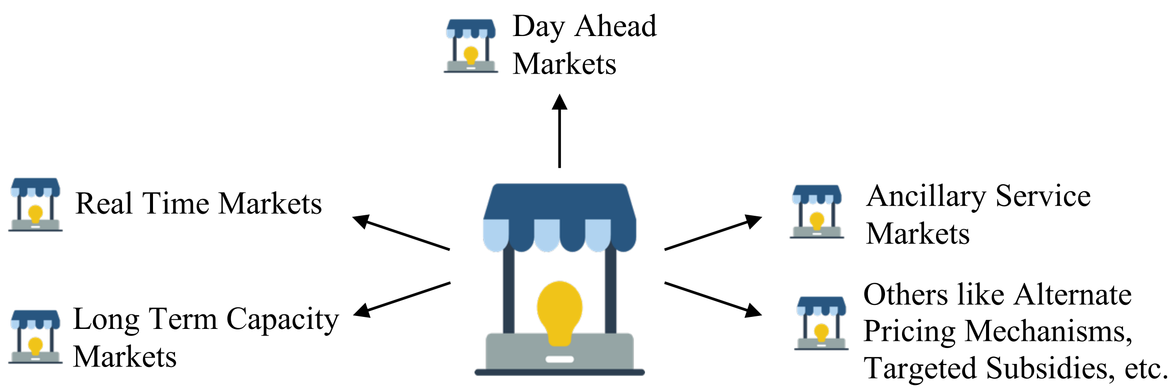


Figure 20: Characteristics of Blockchain

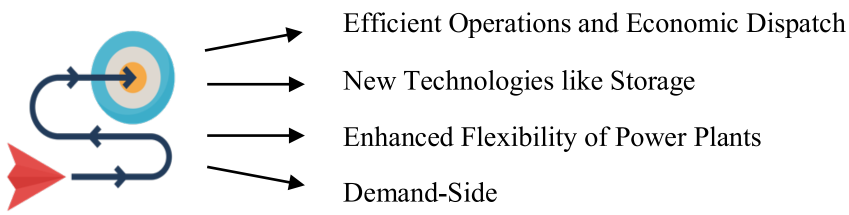
In this regard, UP leads the way in piloting this novel idea. **It has become the first state in India and South Asia to implement blockchain-enabled solar power trading**. The first-of-its-kind pilot project involving peer-to-peer (P2P) trading of energy generated from solar rooftop systems installed on buildings in Lucknow will be hosted by UP Power Corporation Limited (UPPCL) and the subsidiary Madhyanchal Vidyut Vitran Nigam Limited (MVVNL). Moreover, the blockchain platform was integrated with UPPCL's billing system with the help of Abajyon Inc, a system integrator. The P2P trading platform comprises 12 players, including nine customers who have rooftop solar (prosumers) and three customers who do not have rooftop solar (net purchasers).

Electricity Markets

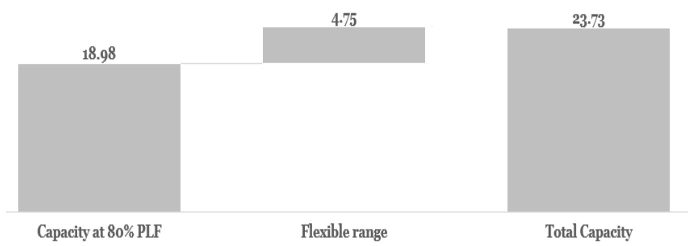
UP is well placed to meet its energy needs over the next decade thanks to its rapid deployment of renewables as part of India's ambitious decarbonization program. However, capacity additions independently will not suffice to have an economical energy-efficient electricity value chain that reduces carbon emissions at low costs. Today, there are several markets mechanisms with varied application and effectiveness, given below are some examples:



The confluence of various market mechanisms and other measures must increase the flexibility of both the supply and demand sides. UP, in consonance with the nation, is at an inflection point with respect to the design and structure of electricity markets. These market mechanisms can be made effective with strategies like:



With around 23 GW of coal thermal power plants in UP, utilizing the flexibility of power plants gains precedence. As per our analysis, keeping in view that around 80% of PLF is to be maintained by the coal thermal power plants, the remaining capacity can be unlocked by the State for flexibility options as seen in the figure below. However, ensuring this requires technical changes at the plant level as well as addressing contractual limitations.



*Minimum PLF of Thermal Power Plant – 50%

Figure 21: Unlocking the capital of thermal power plant flexibility

Key Suggestions

Based on the inferences gathered from the various aspects assessed in UP's electricity value chain, this section presents key suggestions. These suggestions are intended to highlight certain key areas for the State's immediate intervention to further improve the electricity sector:

Market Interventions

- The DSM initiatives active in the State, albeit targeting critical areas for energy conservation, have limited scope in their application. To achieve the broader goal of a zero-carbon grid, a confluence of demand-side measures and integration of RE is necessary. The State could look into actionable market interventions for energy conservation such as trading megawatt-hours which potentially reduce the financial burden for energy conservation programs in the State.
- Understanding the local and regional differences in the electricity value chain is of paramount importance. There is a need to evaluate options and plans at the State level to incorporate various market mechanisms as an integral part to decarbonize the grid efficiently.
- Power purchase costs for oil and gas plants value more than double the costs of purchasing solar power. Thus, in line with the State's trend of decreasing electricity purchase from oil and gas sources, and increased RE capacity addition commitments made at COP-26, additional interventions are necessary to promote RE-based projects.

Regulatory Interventions

- UP has recorded the highest monthly EV sales in the country for over a year. While the State does possess a competitive EV policy, certain gaps warrant attention to support this fast-growing sector. Battery swapping regulations and skill development to develop a sound EV ecosystem workforce must be incorporated in the policy for action by the State.
- UP being the leader in EV sales, battery requirement is set to soar in the coming years. To meet this demand, the State government should come up with additional incentives and subsidies to attract global Li-ion battery manufacturers to set up a base in the State.
- It is commendable that UP has tested the waters in blockchain-based P2P trading. This calls for an urgent need to frame related policy and regulations. This in turn will facilitate and scale similar programs.

Action for measurement and Audit

- Monitor the Emissions/kWh for coal thermal power plants in the State and take course corrective measures for the ones that have values higher than the State's average.
- In UP, the technical reason is the leading cause of power outages. An assessment of the technical reasons reveals that the majority of cases are attributed to Plant issues. This indicates that the majority of the outage reasons can be avoided, and the State can reduce the incidences of power outages. An audit of power plant machinery and operations could determine the key areas leading to frequent outages, and enable subsequent corrective action.
- Presence of energy storage for intermittent renewable energy is of paramount importance and with several pumped hydro energy sites, UP can meet its requirement. Thus, a detailed study to quantify the PHES potential in the State will aid in the capacity addition of energy storage.

Improving operational efficiencies

- As observed, the PLFs for coal thermal power plants are facing a downward trend. Explore ways of meeting electricity demand from existing operational thermal power plants instead of creating a pipeline of new power plants.
- As the operational indicators of UDAY suggest, the State has delivered the targets set under the scheme on most fronts. Metering at the Distribution Transformer (DT) level is crucial from an energy audit perspective. Gauging network health by comparing DT energy with consumer energy can help analyse the losses incurred and enable better planning of electricity supply. The success of the Saubhagya scheme in UP, saw the electrification of 2, 86, 75,462 households covering 100% of the scheme's State target. Thus, catering to these added electricity consumers warrants priority for DT metering in rural areas.
- A widening ACOS-APPC gap is observed, indicating the need to adopt measures to improve the DISCOMs' operational efficiencies.
- With respect to smart metering, the focus should shift from urban areas to the rural side where operational inefficiencies creep into the distribution system.

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