Report # 01

Energy Transition in Bihar

Progress, Challenges, and Policy Insights

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In December 2021, the Ministry of Science and Technology, Department of Science and Technology (Policy Research Programme) made an open call for the submission of Expressions of Interest in STI Policy Research towards the Establishment of the Centre for Policy Research (CPR) by the academic and research Institutes in India. After multiple rounds of consultations and review, the DST-CPR at NISER received the final sanction order from the Government of India, Ministry of Science & Technology, Department of Science & Technology, bearing the letter No DST/PRC/CPR/NISERBhubaneswar-2023 (G)(PCPM) dated 29/03/2023.

The primary focus of the DST-CPR at NISER is to study the Energy Transition and the secondary focus is to study the Tribal Education, and Innovations for Tribal Education in Eastern India covering Odisha, Bihar, Chhattisgarh, Jharkhand and West Bengal.

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DST-CPR, National Institute of science Education and Research, Bhubaneswar

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List of Abbreviations

BERC	Bihar Electricity Regulatory Commission
BREDA	Bihar Renewable Energy Development Agency
BSEB	Bihar State Electricity Board
BSHPC	Bihar State Hydroelectric Power Corporation
BSPGCL	Bihar State Power Generation Company Limited
BSPHCL	Bihar State Power Holding Company Limited
BSPTCL	Bihar State Power Transmission Company Limited
CAGR	Compound Annual Growth Rate
CEA	Central Electricity Authority
CFA	Central Financial Assistance
DDUGJY	Deendayal Upadhyaya Gram Jyoti Yojana
DISCOMs	Distribution Companies
EV	Electric Vehicle
GHG	Greenhouse Gas
GIS	Geographic Information System
GSDP	Gross State Domestic Product
GW	Gigawatt
GWh	Gigawatt-hour
KBUNL	Kanti Bijlee Utpadan Nigam Limited
MKVSY	Mukhyamantri Krishi Viduyt Sambandh Yojana
MNRE	Ministry of New and Renewable Energy
MU	Mega Unit
MW	Megawatt
NBP	National Biogas Programme
NBPDCL	North Bihar Power Distribution Company Limited
NPGCL	Nabinagar Power Generating Company Limited
NTPC	National Thermal Power Corporation
PEUM	Partial End Use Method
PGCIL	Power Grid Corporation of India Limited
PM-KUSUM	Pradhan Mantri Kisan Urja Suraksha Evam Utahan Mahabhiyan
PPAs	Power Purchase Agreements
RDSS	Revamped Distribution Sector Scheme
RPO	Renewable Purchase Obligation
RTS	Rooftop Solar
SBPDCL	South Bihar Power Distribution Company Limited
SHP	Small Hydro Power
SMEs	Small and Medium Enterprises
SMRs	Small Modular Reactors
T&D	Transmission and Distribution
UDAY	Ujwal Discom Assurance Yojana

Executive Summary

Bihar's energy transition marks a crucial move towards a more sustainable and diversified energy mix, essential for addressing the state's rising power demands and driving economic growth. Historically, Bihar has struggled with various challenges in its energy sector, such as limited power generation capacity, substantial transmission and distribution (T&D) losses, and a strong dependence on thermal power. However, in recent years, focused efforts have been made to overcome these constraints and promote renewable energy development.

The state's energy infrastructure is supported by both state-level and central agencies. The Bihar State Power Generation Company Limited (BSPGCL) operates major thermal power stations like the Barauni Thermal Power Station and Kanti Bijlee Utpadan Nigam Limited (KBUNL). On the renewable side, the Bihar Renewable Energy Development Agency (BREDA) has been instrumental in driving solar initiatives, including grid-connected solar parks and rooftop solar systems. Central government enterprises such as the National Thermal Power Corporation (NTPC) also contribute significantly, especially through ventures like the Nabinagar Power Generating Company Limited (NPGCL).

Expanding renewable energy, especially solar, has become a cornerstone of Bihar's energy strategy. BREDA has led numerous initiatives to scale up solar generation through large solar parks, rooftop systems, and off-grid solutions aimed at rural electrification. These projects are part of a broader effort to diversify the energy portfolio and reduce dependency on coal. Biomass energy is also gaining traction, particularly in rural areas where agricultural waste can be converted into energy. Small hydroelectric projects are being pursued as well, though their potential is limited due to geographical factors.

Bihar's energy transition is backed by a comprehensive policy and regulatory framework. The Bihar Renewable Energy Policy, 2017, plays a key role in promoting renewable energy investments and private sector participation. Other major schemes, such as the Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY) for rural electrification and the Ujwal Discom Assurance Yojana (UDAY) for strengthening the financial and operational performance of distribution companies (DISCOMs), support the broader transition agenda.

Nonetheless, several challenges continue to hinder progress. The gap between electricity demand and supply frequently leads to power shortages. High T&D losses persist despite ongoing infrastructure upgrades. The weak financial position of DISCOMs limits their ability to fund critical

improvements. Furthermore, integrating variable renewable energy sources into the existing grid infrastructure demands considerable technological and financial investments.

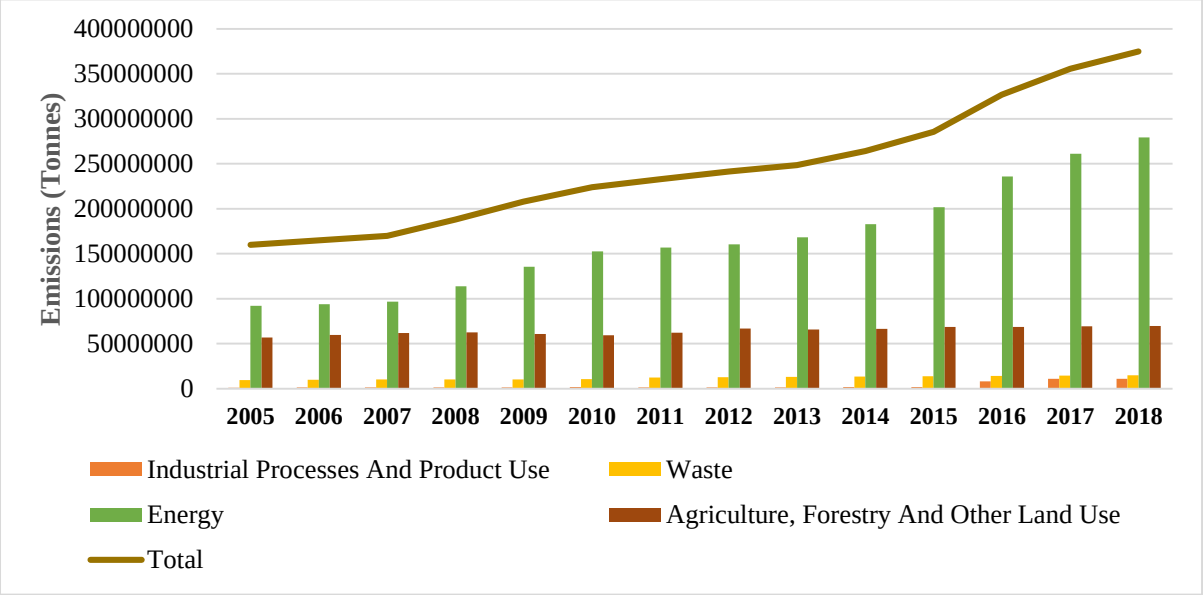
Looking forward, Bihar's energy future appears optimistic, with a range of current and planned initiatives addressing its pressing challenges. The state plans to significantly expand its renewable energy capacity, focusing on emerging areas such as floating solar plants and solar-powered agricultural pumps. Effective coordination between state and central agencies, bolstered by supportive policies and strategic investments in infrastructure, will be vital in ensuring a successful and inclusive energy transition in Bihar.

1. Introduction

India is undergoing a significant energy transition, aiming to move from traditional fossil fuels to a more sustainable and diverse energy mix. This transition is driven by the need to address climate change, enhance energy security, reduce pollution, and provide affordable and reliable energy to its growing population. India is committed to international agreements such as the Paris Agreement, which requires reducing greenhouse gas (GHG) emissions and increasing the share of renewable energy. The country targets achieving about 40% of its installed electric power capacity from non-fossil fuel-based energy resources by 2030, contingent on international finance and technology transfer availability (UNFCCC, 2022). India has set ambitious targets for solar power, including the goal of achieving 100 GW of solar capacity by 2022 and 280 GW by 2030 under the National Solar Mission (MNRE, 2023). As India continues to innovate and invest in clean energy solutions, it sets a powerful example for other developing countries striving for a sustainable energy future.

The state of Bihar, located in eastern India with its rich historical legacy and growing economic potential, is on a path of transformation. The state's focus on improving infrastructure, education, and healthcare, along with promoting sustainable development, positions it for significant growth and development. According to the 2011 census, Bihar has a population of over 104 million, which has grown significantly in the past decade. The population density is among the highest in India, with around 1,102 people per square kilometre. Bihar is also a state that is vulnerable to climate change and a growing population, which threatens to undermine its developmental efforts. Greenhouse gas (GHG) emissions are a critical concern for states like Bihar (86.59 Mt CO_{2e} i.e. 2.93 % of India's emissions), which is experiencing rapid economic growth and urbanization (GHG Platform India, 2022). The highest contribution to GHG emissions in Bihar is the energy sector (accounted for 65% of its total economy-wide emissions in 2018) followed by agriculture, forestry and other land use (27%) (**Fig. 1**). Electricity generation using conventional fuels such as coal is the major contributor to GHG emissions in the state. Biomass burning for cooking and heating in rural areas also contributes to CO_2 and methane emissions. In the agricultural sector, Bihar, with its extensive rice fields, sees significant methane emissions from paddy fields due to anaerobic decomposition in flooded fields. Besides this, enteric fermentation in the livestock sub-sector and manure management practices are the major contributors to emissions. Solid Waste Disposal, Domestic Wastewater and Industrial Wastewater are the key sources of GHG emissions in the Waste sector (5% of the total emissions) in Bihar. Domestic Wastewater has a share of 91% in the total Waste sector emissions of Bihar. Emissions from Domestic Wastewater from both rural and urban areas grew at a CAGR of 3.44% from 2.79 Mt CO2e in 2005 to 4.33 Mt CO2e in 2018.

Figure 1: Sector-wise GHG emissions in Bihar (2005-2018)



Source: GHG Platform India, 2022

The state is undergoing a significant transformation in its energy sector. Historically reliant on traditional energy sources such as coal and biomass, Bihar is now making strides towards embracing renewable energy and enhancing energy efficiency. The present report explores the current energy landscape, the drivers of energy transition, the challenges faced, the initiatives undertaken for renewable energy, and the prospects for Bihar.

2. Research Methodology

This report is based on a comprehensive review of secondary data to analyze the status, challenges, and policy landscape of energy transition in Bihar. The data sources include peer-reviewed research articles, annual reports of key government departments, and official policy documents that pertain to energy transition, renewable energy development, and sustainable energy practices in the state. This approach enables a holistic understanding of the evolving energy scenario in Bihar, focusing on both achievements and gaps in the implementation of clean energy initiatives. Key institutional sources such as the Central Electricity Authority (CEA), Bihar State Power Holding Company Limited (BSPHCL), and the Ministry of New and Renewable Energy (MNRE) were consulted for official statistics, policy updates, and performance assessments. These sources provide insights into the generation, transmission, and distribution capacities, as well as the financial health of power utilities and the progress of various renewable energy schemes in Bihar.

In addition, secondary data helped trace the evolution of Bihar's energy policies, including the Bihar Renewable Energy Policy, 2017, and the role of centrally sponsored schemes such as the Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY) and Ujwal DISCOM Assurance Yojana (UDAY). This analysis is intended to inform evidence-based recommendations for a more inclusive, equitable, and sustainable energy transition in the state.

3. The Economy of Bihar

Bihar, situated in eastern India, is one of the country's most densely populated states, known for its rich cultural legacy and historical importance. The state's economy is predominantly agrarian, with agriculture serving as the primary livelihood for a majority of its residents, employing nearly 70% of the population. However, recent years have witnessed a gradual expansion in the industrial and service sectors, contributing to a more diversified economic landscape. Bihar has demonstrated impressive economic growth, often surpassing the national average. As per the Economic Survey of Bihar 2023–24, the state's Gross State Domestic Product (GSDP) at constant prices is estimated to have grown by approximately 10.6% during the financial year 2022–23, reflecting a strong post-pandemic recovery.

Table 1: GSDP at Constant and Current Prices from 2012-13 to 2022-23 FY.

Year	GSDP in Crore		Growth Rate in GSDP	
	Current Prices	Constant Prices	Constant Prices	Current Prices
2012-13	282368	256851	8.2	15.8
2013-14	317101	269650	1.6	4.9
2014-15	342951	279482	12.5	15.9
2015-16	371602	296488	8.3	6.0
2016-17	421051	318797	13.3	7.5
2017-18	468746	344028	9.0	14.2
2018-19	527976	381383	10.9	12.6
2019-20	581855	398329	4.4	10.2
2020-21	567263	368733	-7.4	-2.5
2021-22 (P.)	650302	399930	8.5	14.6
2022-23 (Pr.)	751396	442473	10.6	15.5

(P-Provisional, Pr. -Projection)
Source: Bihar Economic Survey, 2023-24, Govt. of Bihar.

The COVID-19 pandemic had a significant impact on economic activity, leading to a slowdown in 2020–21. During this period, Bihar's GSDP growth at constant and current prices dropped to 7.4% and 2.5% respectively. The GSDP at constant prices stood at ₹5,67,263 crore, while at current prices it was ₹3,68,733 crore. However, the economy rebounded swiftly, with real GSDP growth estimated

at 8.5% in FY 2021–22 and a projected 10.6% in FY 2022–23, reaching ₹4,42,473 crore at constant prices and ₹7,51,396 crore at current prices.

Similarly, the state's nominal and real per capita income from 2018-19 to 2022-23 has increased at an average annual rate of 7.6 per cent and 2.3 per cent respectively. The average annual percentage growth in real per capita income of Bihar was 2.3 per cent from 2018-19 to 2022-23.

Discussing the sectoral growth of the economy in Bihar from the years 2018-19 to 2022-23, Agriculture, forestry, and fishing form a significant part of Bihar's economy, supporting a large portion of the rural population. The sector includes crop production, livestock, forestry, and fishing. The growth rate of the service sector i.e. tertiary sector (Trade, Repair, Hotels and Restaurants', 'Transport, Storage and Communication', Financial Services and Real estate) has performed well compared to the primary and secondary sectors (**Table 2**).

Table 2 : Gross State Domestic Product (GSDP) of Bihar at Constant Prices from 2018-19 to 2022-23 FY

Sectors	2018-19	2019-20	2020-21	2021-22 (P.)	2022-23(Pr.)
Agriculture, Forestry and Fishing	114549	129136	150694	159741	182641
Mining and Quarrying	1902	6561	953	979	1247
Manufacturing	34364	37518	41533	50158	51592
Electricity, Gas, Water supply and Other Utilities	8627	9366	8606	9658	11239
Construction	44221	45828	42574	55892	65029
Trade, Repair, Hotels and Restaurants	95035	102043	88889	93723	118296
Transport, Storage and Communication	48251	54229	50256	68713	79013
Financial Services	22339	23286	25605	26276	29300
Real estate, dwelling and professional services	44017	44614	44105	48819	55354
Public administration	23525	25992	29165	35779	40755
Other services	73521	81231	69397	92591	105974

(P-Provisional, Pr. -Projection)

Source: Bihar Economic Survey, 2023-24, Govt. of Bihar.

4. The Energy Sector of Bihar

The energy sector in Bihar has been undergoing significant transformation to meet the growing demands of its population and economy. Historically reliant on traditional sources of energy, the state is now diversifying its energy mix to include renewable sources, modernizing its infrastructure,

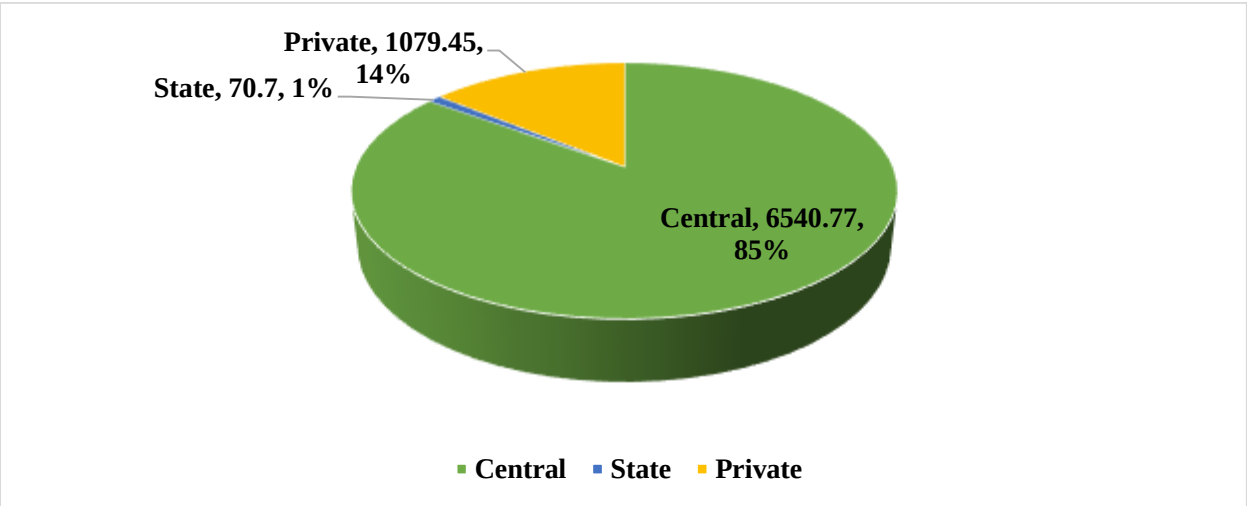
and enhancing its power generation capacity. The state's per capita energy consumption has traditionally been lower than the national average, reflecting both infrastructural deficiencies and lower levels of industrialization. Thermal power remains the backbone of Bihar's energy sector, with coal contributing the majority of the state's power.

4.1 Installed capacity

Bihar's installed power generation capacity highlights the state's ongoing efforts to address rising electricity demands and improve energy access. As per data from the Central Electricity Authority (CEA), the total installed capacity in Bihar stands at approximately 7690.92 MW, with thermal power plants constituting the dominant share, about 95% of the total. This heavy reliance on thermal energy underscores the state's continued dependence on conventional power sources. However, in recent years, Bihar has increasingly focused on diversifying its energy mix by investing in renewable energy, particularly solar power, which has shown considerable potential across the state. Additionally, small hydropower projects are under development, though their contribution remains modest due to the state's geographical limitations that restrict large-scale hydroelectric expansion.

The installed capacity is primarily owned and operated through a shared model between state and central entities, indicating a coordinated approach to energy development. Notably, central government-owned plants account for about 85% of the total installed capacity, while the state government's share is only around 1% (**Fig. 2**). This distribution reflects Bihar's reliance on centrally-supported infrastructure and underscores the need for increased state-level investment in power generation to achieve greater energy self-sufficiency and sustainability.

Figure 2: Sector-wise installed capacity (in MW) of power utilities in Bihar



Source: Central Electricity Authority (CEA) Report, as on 31st May, 2024

4.2 Production and Consumption of Power in Bihar

Bihar's power generation capacity has been steadily increasing over the years. The state has focused on expanding its infrastructure to meet the growing electricity demand. According to energy statistics, the availability of power has increased by 4034 MU at a rate of 9.8 per cent in the year 2022-23 (**Table 3**). It is revealed from the data that it accounts for the highest power availability. The per capita consumption of energy in Bihar state has increased from 145 kWh in 2012-13 to 329 kWh in 2021-22 indicating a growth rate of 12.68 per cent **(Fig. 3**).

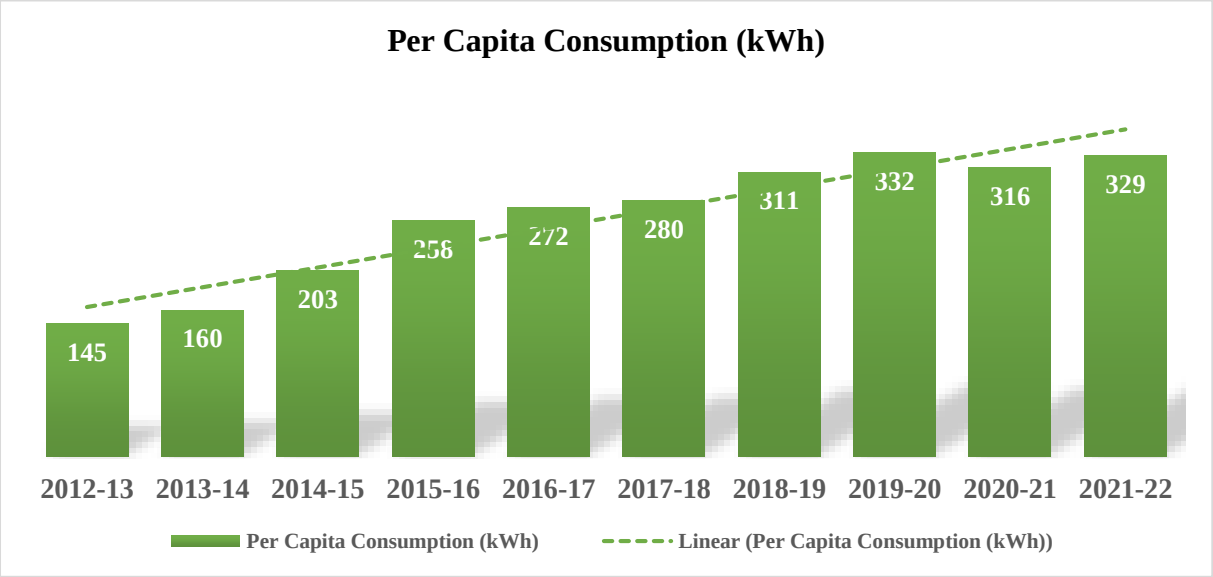
Table 3: Energy Statistics for Bihar from the year 2017-18 to 2022-23

Year	Energy Requirement Projection (MU)	Availability (MU)	Deficit/Surplus (MU)	Percentage of Deficit/Surplus
2017-18	30095	26788	(-) 3307	(-) 12.3
2018-19	32257	29472	(-) 2785	(-) 8.6
2019-20	32300	31540	(-) 760	(-) 2.4
2020-21	34171	34018	(-) 153	(-) 0.45
2021-22	36245	35857	(-) 388	(-) 1.1
2022-23	41102	45136	(+) 4034	(+) 9.8

Source: Bihar Economic Survey, 2023-24, Govt. of Bihar.

When we look into the sector-wise consumption, we have seen that domestic power consumption (56%) has been consistently high followed by industrial power consumption (28%) (**Fig.3**).

Figure 3: Per Capita Consumption



Source: Central Electricity Authority (CEA) Dashboard

The distribution of energy sales across various sectors in Bihar reflects the diverse energy needs of the state. When we look into the sector-wise energy sales, we have seen that energy sales to the domestic sector have been consistently high followed by industrial power consumption (**Table 4**). The energy sales for sectors reported have shown an increasing trend from the year 2012-13 to 2020-21. The energy sales to public lighting have decreased by 22.27 MU from 106.21 MU in FY 2019-20 to 83.94 MU in FY 2020-21. Similarly, in the traction sector, energy sales have also shown a decline in FY 2020-21.

Table 4: Sector wise Electrical Energy Sales (MU) of Bihar from the FY 2012-13 to FY 2020-21

Sectors	2012-13	2013-14	2014-15	2017-18	2018-19	2019-20	2020-21
Domestic	2858.03	3281.01	4033.87	9084.68	11505.49	13497.50	15045.49
Commercial	730.43	819.19	973.53	1742.03	2067.82	2126.53	2396.14
Industrial (Low & Med. Voltage)	251.12	281.01	306.17	510.25	553.88	654.09	807.96
Industrial (High Voltage)	1744.99	1914.74	1888.40	2602.52	2923.80	3158.47	3268.42
Public Lighting	56.35	45.70	21.72	57.55	62.15	106.21	83.94
Traction	448.64	523.95	545.50	700.02	1248.97	1442.74	1056.10
Agriculture	336.53	321.79	313.22	479.84	726.71	932.94	1149.30
Public Water Works and Sewage Pumping	53.30	58.52	65.35	107.39	104.77	130.99	216.22
Miscellaneous	581.44	1095.03	1999.61	3768.97	2004.21	1127.53	590.64
Total Energy Sold	7060.83	8340.94	10147.37	19053.26	21197.80	23177.00	24614.20

Source: Central Electricity Authority (CEA) Dashboard

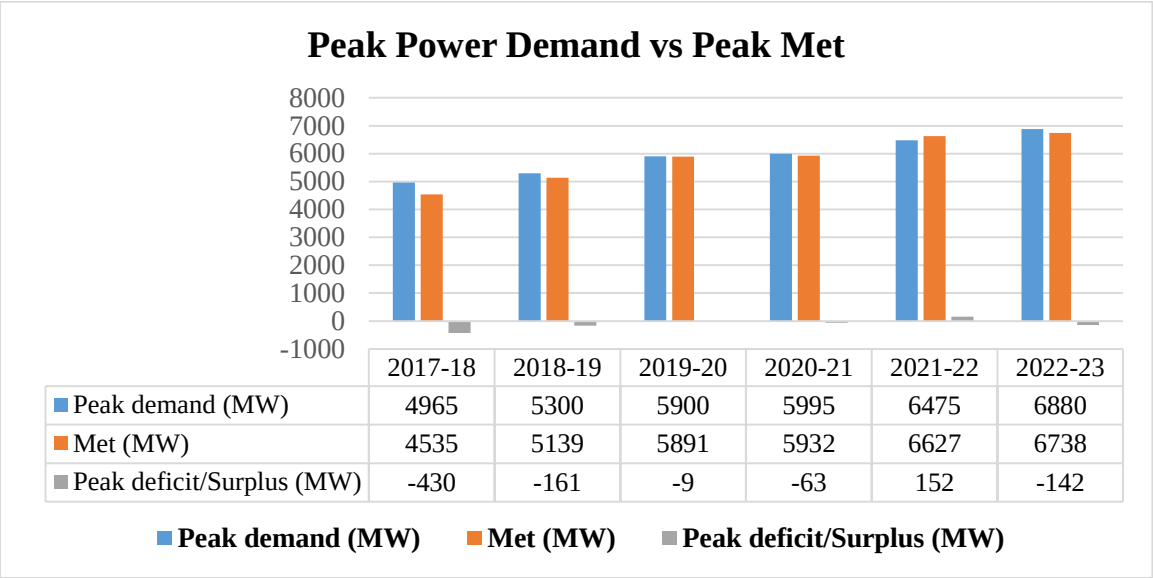
4.3 Demand and Supply of Electricity in Bihar

Bihar's economic growth in recent years has led to a notable rise in electricity consumption across industrial, commercial, and residential sectors. With a population exceeding 100 million, residential electricity demand alone constitutes a significant portion of the state's overall energy needs. The total power demand in Bihar has increased substantially, rising from 4965 MW in 2017–18 to 6880 MW in 2022–23, reflecting a growth of 38.6% over five years.

To meet this rising demand, Bihar has been actively expanding its power generation capacity by establishing new power plants and upgrading existing infrastructure. These efforts aim to ensure reliable electricity supply and support the state's development agenda. However, despite these initiatives, the state continues to experience an electricity shortfall.

As illustrated in **Figure 4**, the gap between peak demand and peak supply has been narrowing, indicating progress in addressing power shortages. Nevertheless, a peak deficit of 2.06% was recorded in 2022–23, highlighting that the state has not yet achieved complete demand-supply parity. Continued investment in generation capacity, grid infrastructure, and renewable energy integration will be essential for Bihar to bridge this gap and achieve long-term energy security.

Figure 4: Peak Power Demand and Supply (MW)

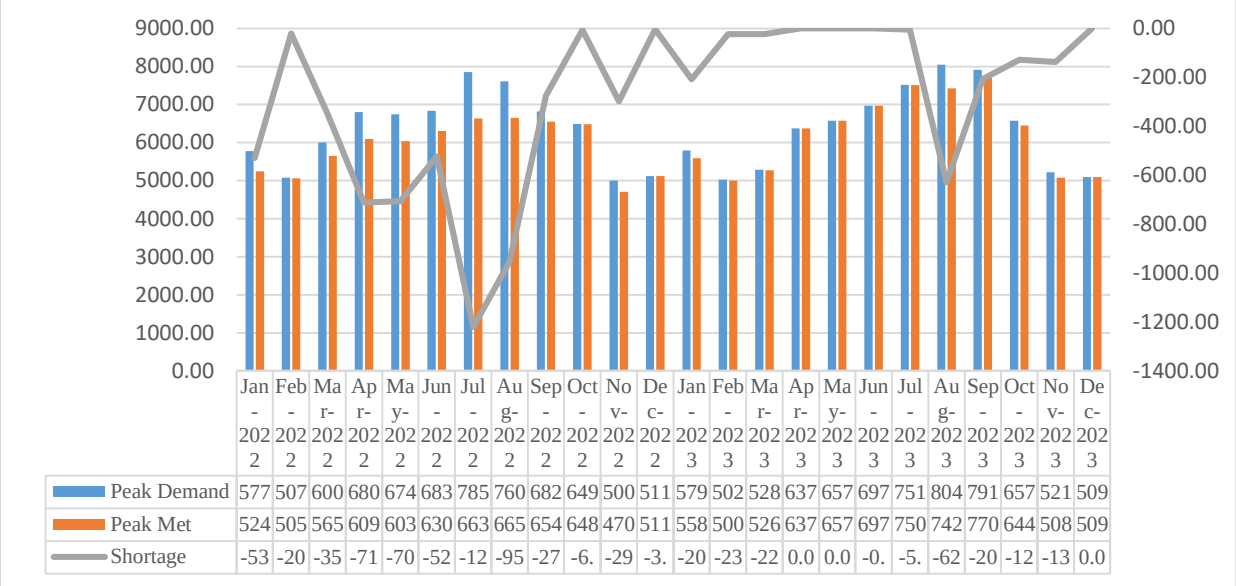


	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23
Peak demand (MW)	4965	5300	5900	5995	6475	6880
Met (MW)	4535	5139	5891	5932	6627	6738
Peak deficit/Surplus (MW)	-430	-161	-9	-63	152	-142

Source: Bihar Economic Survey, 2023-24, Govt. of Bihar.

The monthly status of power supply for the FY 2022- 23 and 2023-24 till December reveals that there is a recurring deficit in the supply of power for the stated demand. The maximum deficit was found in August 2022 (-953 MW) followed by May 2022 (-706 MW). The deficit was fully attained during April, May, June and December months 2023 (**Fig.5**). The figure indicates that the energy deficit is gradually declining in Bihar.

Figure 5: Peak Demand vs Peak met in Bihar in the financial years 2022-23 and 2023-24 (Up to December 2023)



	Jan-2022	Feb-2022	Mar-2022	Apr-2022	May-2022	Jun-2022	Jul-2022	Aug-2022	Sep-2022	Oct-2022	Nov-2022	Dec-2022	Jan-2023	Feb-2023	Mar-2023	Apr-2023	May-2023	Jun-2023	Jul-2023	Aug-2023	Sep-2023	Oct-2023	Nov-2023	Dec-2023
Peak Demand	577	507	600	680	674	683	785	760	682	649	500	511	579	502	528	637	657	697	751	804	791	657	521	509
Peak Met	524	505	565	609	603	630	663	665	654	648	470	511	558	500	526	637	657	697	750	742	770	644	508	509
Shortage	-53	-20	-35	-71	-70	-52	-12	-95	-27	-6.	-29	-3.	-20	-23	-22	0.0	0.0	-0.	-5.	-62	-20	-12	-13	0.0

Source: Central Electricity Authority (CEA) Dashboard

4.4 Transmission and Distribution (T&D) Loss in Energy

T&D losses are a significant concern for power utilities as they affect the efficiency of the energy supply chain and result in economic losses. These losses occur in the transmission lines, substations, and distribution networks. T&D losses are typically expressed as a percentage of the total energy generated or delivered. Reducing T&D losses is crucial for improving the efficiency of the power sector. By addressing both technical and non-technical losses through infrastructure upgrades, smart technologies, and stringent anti-theft measures, significant improvements can be achieved. The Distribution Companies' (DISCOMs) efficiency can be identified by analysing the energy losses encountered in a given period. Though there has been a decline in distribution losses from FY 2020-21 to 2022-23, the DISCOMs have failed to achieve the distribution loss targets stipulated by the Bihar Electricity Regulatory Commission (**Table 5**).

Table 5: Year-wise Transmission and Distribution Loss of Energy

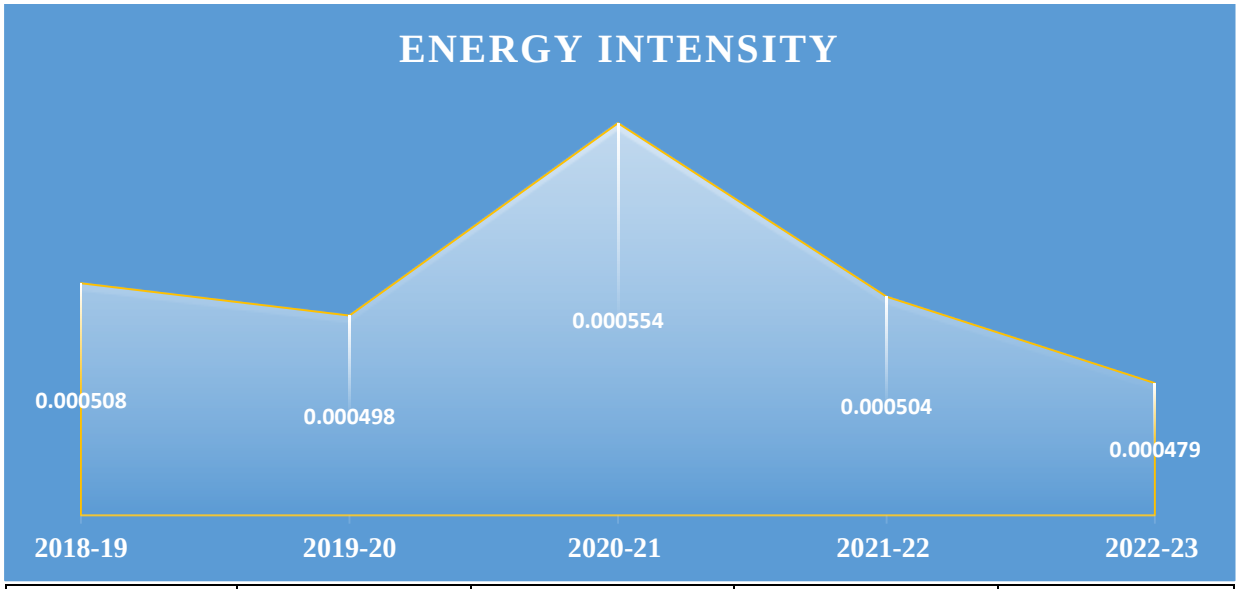
Year	T & D Loss (%)
2015-16	25.96
2016-17	25.35
2017-18	33.56
2018-19	26.21
2019-20	26.68
2020-21	20.19
2021-22	18.75
2022-23	19.53

Source: India Climate and Energy Dashboard, Niti Aayog

4.5 Energy Intensity

Energy intensity is a crucial indicator of economic energy efficiency. Reducing energy intensity is beneficial for both economic growth and environmental sustainability. Energy intensity is a measure of the energy efficiency of a nation's economy. It is calculated as the amount of energy consumed per unit of Gross State Domestic Product (GSDP). Lower energy intensity indicates a more energy-efficient economy, as less energy is required to produce a unit of economic output. High energy intensity implies that a large amount of energy is required to produce a given level of economic output, while low energy intensity indicates that less energy is needed for the same level of output (Hajiyev et al., 2023). **Fig. 6** indicates that the energy intensity in Bihar has decreased after the FY 2020-21 which signifies that Bihar state can be a more energy-efficient economy as less energy is required to produce the unit of economic output.

Figure 6: Energy Intensity in Bihar



Years	GSDP (in crore)	Consumption (in MU)	Consumption (in Crore)	Energy Intensity
2018-19	527976	26800	268.00	0.000508
2019-20	581855	28988	289.88	0.000498
2020-21	567263	31439	314.39	0.000554
2021-22	650302	32757	327.57	0.000504
2022-23	751396	35957	359.57	0.000479

Source: Computed by author

4.6 Forecasting of Electrical Energy Consumption in Bihar

Forecasting electricity demand is a complex but essential task for energy planning and policy-making. Accurately forecasting electricity demand is critical for ensuring a reliable and efficient energy supply. This process involves predicting future energy needs based on various factors such

as economic growth, population trends, technological advancements, and climate conditions. Effective forecasting helps in planning infrastructure, managing resources, and formulating energy policies.

The forecasting of electricity demand was calculated by Central Electricity Authority of India (CEA, 2022). To forecast the Energy Consumption of Jharkhand the Partial End Use Method (PEUM) was used. The PEUM is a technique used in energy demand forecasting to estimate electricity consumption by disaggregating the total electricity consumption into specific end-uses or applications. Unlike aggregate forecasting methods that consider total energy consumption for a region or sector, the PEUM provides a more detailed and granular analysis by breaking down consumption into various end-use categories.

Table 6: Forecasting of Energy Consumption (in MU)

Year	Consumption (in MU)
2021-22	27026
2022-23	31440
2023-24	34658
2024-25	37982
2025-26	41892
2026-27	45659
2027-28	49703
2028-29	53983
2029-30	58917
2030-31	63368
2031-32	67699

Source:20th Electric Power Survey of India, Central Electricity Authority, 2022

The first step in the PEUM is to identify the different end-use categories or applications of electricity consumption within the target area or sector. Common end-use categories include lighting, space heating and cooling, water heating, appliances, industrial processes, and commercial activities. The second step was to collect data on electricity consumption and relevant variables are collected for each end-use category. The data included historical consumption data, demographic information, economic indicators, building characteristics, weather data, and technological factors. Third, statistical regression techniques were used in the PEUM to establish relationships between electricity consumption and the variables that influence each end-use category. Regression models were developed for each end-use based on historical data and other relevant factors. The disaggregated end-use consumption estimates were then used to forecast future electricity demand for each category. **Table 6** shows the forecasting of energy consumption in Bihar from the FY 2021-22 to 2031-32. It is projected that Bihar will witness a steady growth in electricity consumption.

Bihar's Gross State Domestic Product (GSDP) has been growing steadily. Economic activities, particularly in agriculture, industry, and services, drive electricity demand. Industrialization and the rise of small and medium enterprises (SMEs) contribute significantly to this demand.

Table 7 depicts the Compound Annual Growth Rate (CAGR) of electrical energy sales in Bihar state from the FY 2012-13 to 2020-21. It indicates an increasing trend in electrical energy sales over the given period with a CAGR of 23. 14 per cent which started from 7060.83 GWh in the FY 2012-13 to 24614.20 GWh in the FY 2020-21.

Table 7: Compound Annual Growth Rate (CAGR) of Electrical Energy Sales

Year	Total Energy Sold (GWH)	CAGR (in %)
2012-13	7060.83	**23.14**
2013-14	8340.94	
2014-15	10147.37	
2017-18	19053.26	
2018-19	21197.80	
2019-20	23177.00	
2020-21	24614.20	

Source: Central Electricity Authority (CEA) Dashboard, from the FY 2012-13 to 2020-21

While calculating the CAGR of electrical energy sales sector-wise like domestic, industry, commercial, agriculture, and public sector, it was found that there is a growing trend in electrical energy sales in all sectors. The highest CAGR is found in the domestic sector (31.89 %) from the FY 2012-13 to 2020-21 followed by the service sector (public water works and sewage pumping) at 26.28 per cent and the agricultural sector at 22.71 per cent. The lowest pace of growth is found in the public lighting category (**Table 8**).

Table 8: Compound Annual Growth Rate of Electrical Energy Sales Sector-Wise in Bihar

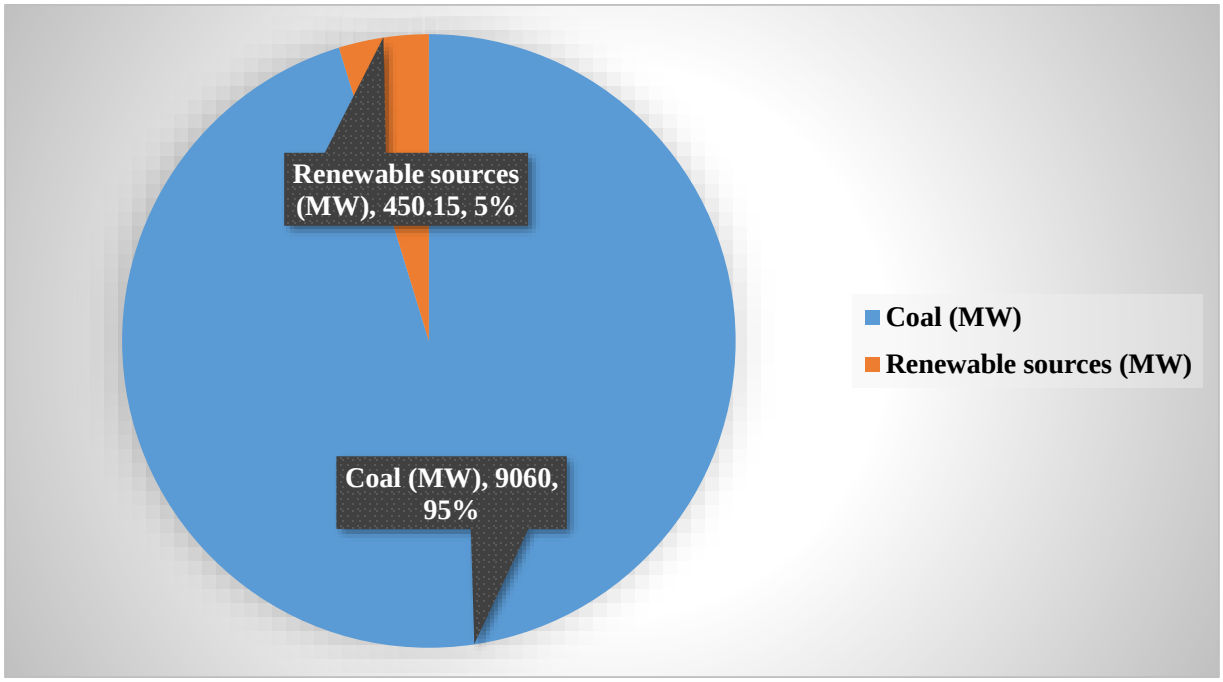
Category	CAGR (in %)
Domestic	31.89
Commercial	21.89
Industrial (Low & Med. Voltage)	21.50
Industrial (High Voltage)	11.02
Public Lighting	6.86
Traction	15.33
Agriculture	22.71
Public Water Works & Sewage Pumping	26.28
Miscellaneous	0.26

Source: Central Electricity Authority (CEA) Dashboard, from the FY 2012-13 to 2020-21

5. Energy Mix in Bihar

Bihar, one of the most populous states in India, has been on a path of significant transformation in its energy sector. The state's energy mix is diverse, encompassing both conventional and renewable energy sources. Thermal power remains the backbone of Bihar's energy supply, predominantly sourced from coal-based plants which is the major contributor to GHG emissions in the state. Despite this, Coal-based power generation has the highest share in the electricity mix of the state, as per recent data from the Central Electricity Authority on installed capacity. In the case of Bihar, the coal power-based installed capacity is around 95 per cent (CBGA, 2022) (**Fig.7**). Bihar has not been able to achieve its targets under the renewable energy policy. Only 15 per cent of the state's Renewable Energy policy, 2017 target has been achieved so far. Bihar needs to focus on the addition of clean energy in the electricity mix as its major strategy for a green economic recovery.

Figure 7: Resource Wise Installed Capacity of Energy in Bihar (as on March 2024)

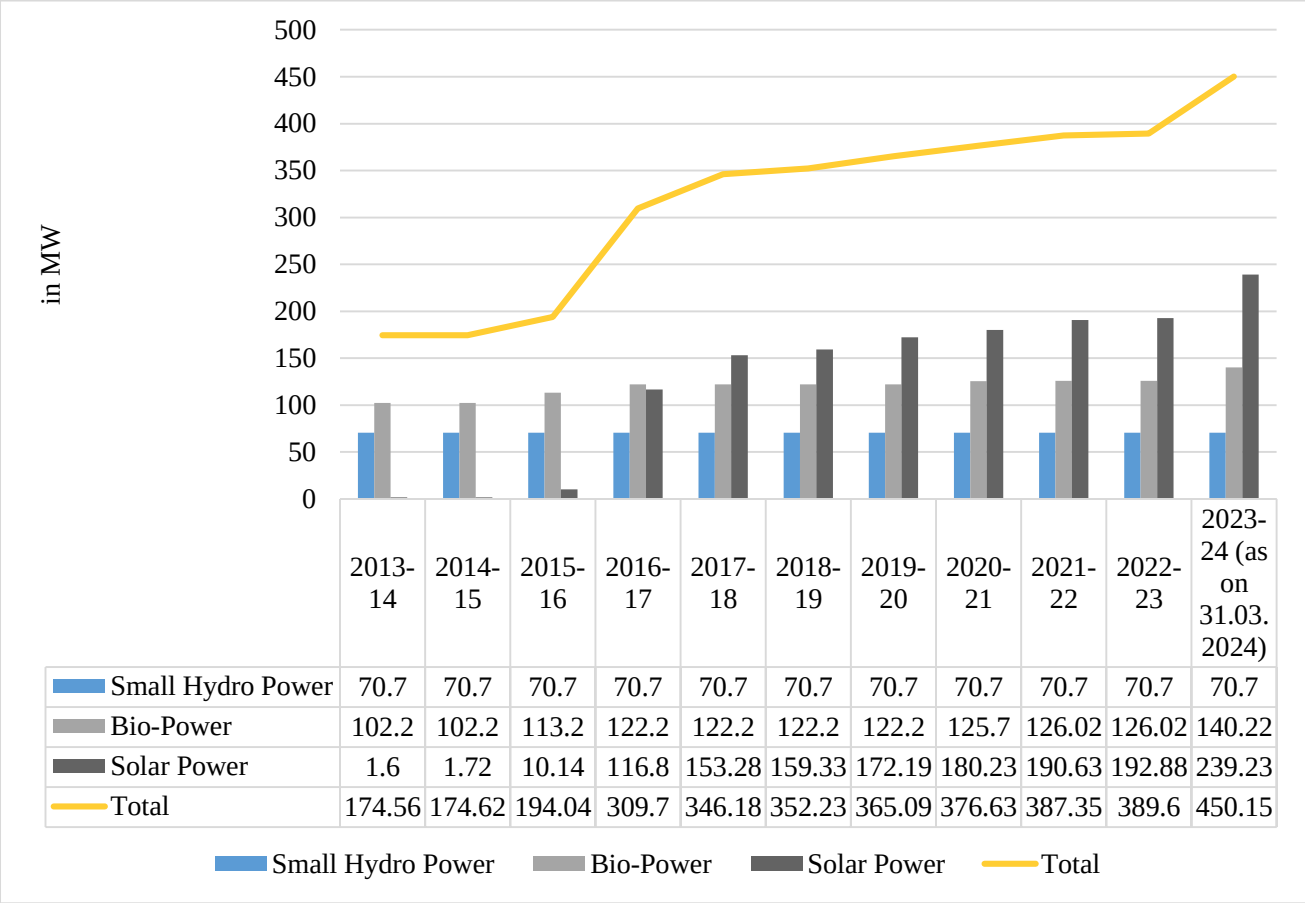


Source: Central Electricity Authority (CEA) Dashboard

According to the Central Electricity Authority, as of June 2024, the state's total power capacity reached 9510.15 MW. Of this, renewable energy accounted for just 450.15 MW. Solar power energy accounted for 239.23 MW followed by bio-energy (140.22 MW) and small hydropower (70.70 MW) (**Fig.8**). Bihar's geography and climatic conditions are not conducive to wind power generation. The state lacks significant wind speeds necessary for efficient and economically viable

wind power projects. Most wind energy potential in India is concentrated in coastal and hilly regions, which Bihar lacks. Also, Bihar's flat topography and the nature of its river systems limit the potential for large hydroelectric projects. The state lacks the steep gradients and large water reservoirs that are necessary for significant hydropower generation.

Figure 8: Source-wise installed capacity of Renewable Energy in Bihar from 2013-14 to 2023-24



	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24 (as on 31.03.2024)
Small Hydro Power	70.7	70.7	70.7	70.7	70.7	70.7	70.7	70.7	70.7	70.7	70.7
Bio-Power	102.2	102.2	113.2	122.2	122.2	122.2	122.2	125.7	126.02	126.02	140.22
Solar Power	1.6	1.72	10.14	116.8	153.28	159.33	172.19	180.23	190.63	192.88	239.23
Total	174.56	174.62	194.04	309.7	346.18	352.23	365.09	376.63	387.35	389.6	450.15

Source: MNRE progress achievement data, GOI (2024)

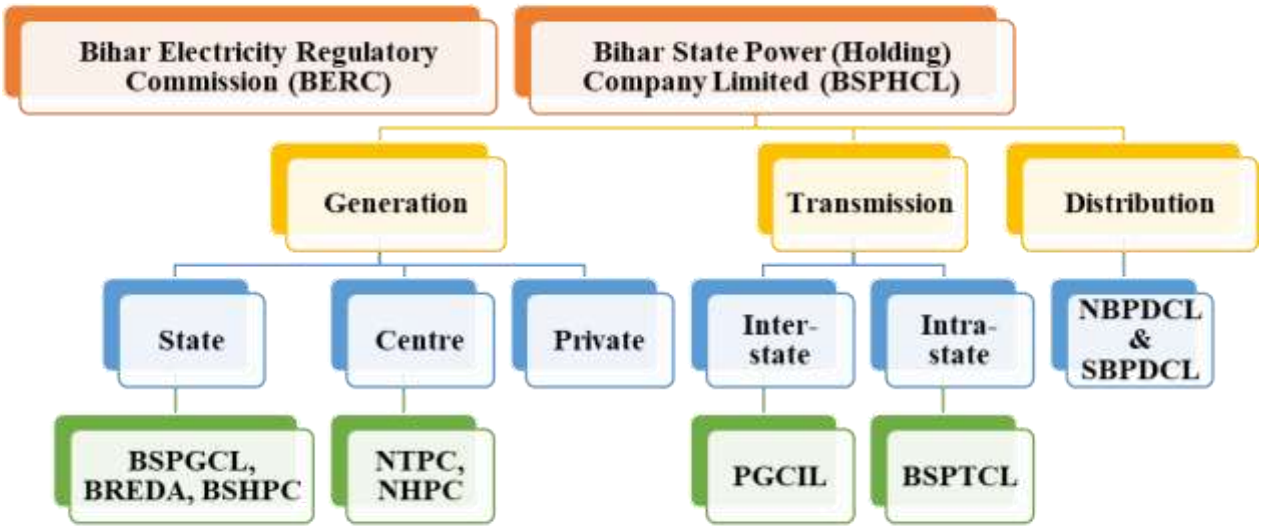
6. The Institutional and Administrative Structure of Bihar Power System

The power system in Bihar is organised through various entities responsible for generating, transmitting, and distributing electricity within the state. The state government, central agencies, and private players play a pivotal role in managing and developing the power infrastructure (**Fig.9**). The *Bihar Electricity Regulatory Commission (BERC)* is the regulatory authority responsible for overseeing the electricity sector in Bihar. Established under the Electricity Act of 2003, BERC aims

to ensure the efficient, transparent, and fair functioning of the power sector. It plays a crucial role in regulating electricity tariffs, ensuring compliance with regulatory standards, protecting consumer interests, and promoting sustainable energy practices within the state. BERC determines electricity tariffs for different categories of consumers, ensuring that the rates are fair and reflective of the cost of supply. It reviews and approves Power Purchase Agreements (PPAs) between distribution companies and power generators by ensuring that PPAs are fair, transparent, and beneficial for both parties and consumers.

Bihar State Power Holding Company Limited (BSPHCL) is the principal organization overseeing the electricity sector in Bihar. Established in November 2012 after the restructuring of the Bihar State Electricity Board (BSEB), BSPHCL manages and coordinates the activities of its subsidiaries, ensuring the efficient generation, transmission, and distribution of electricity throughout the state. The restructuring was aimed at improving operational efficiency, reducing losses, and enhancing customer service. BSPHCL operates through its subsidiaries, each responsible for different aspects of the power sector: Bihar State Power Generation Company Limited (BSPGCL), Bihar State Power Transmission Company Limited (BSPTCL), North Bihar Power Distribution Company Limited (NBPDCL) and South Bihar Power Distribution Company Limited (SBPDCL).

Figure 9: Bihar Power System Structure



6.1 Power Generators in Bihar

Bihar's power generation landscape encompasses a mix of thermal, hydroelectric, and renewable energy sources. The state government, in collaboration with central agencies and private players, is working towards enhancing its power generation capacity to meet the growing energy demand. The centre contributes the highest share in power generation (87 per cent), followed by the private sector (12 per cent) and the state (1 per cent) (**Table 9**).

Table 9: Power generation capacity in the Years 2022 and 2023

Ownership	2022				2023			
	Thermal (Coal) (MW)	Hydro (MW)	RES (MW)	Total (MW)	Thermal (Coal) (MW)	Hydro (MW)	RES (MW)	Total (MW)
Central	4675	754	1372	6801	6220	771	1609	8640
State	0	54	0	54	0	54	242	296
Private/IPPs	688	0	242	930	488	0	0	488
Total	**5363**	**808**	**1614**	**7785**	**6748**	**825**	**1851**	**9424**

Source: Bihar Economic Survey, 2023-24, Govt. of Bihar.

The *Bihar State Power Generation Company Limited (BSPGCL)* is a state-owned enterprise responsible for electricity generation in Bihar. It was established on November 1, 2012, after the unbundling of the Bihar State Electricity Board (BSEB) under the Bihar State Electricity Reforms Transfer Scheme, 2012. BSPGCL plays a crucial role in ensuring the supply of electricity to meet the state's growing energy demands. The main objective of BSPGCL is to increase the installed capacity of power generation to keep pace with demand growth, enhance operational efficiency and reduce generation costs. It coordinates with the power generating companies and also deals with the issues related to operation and maintenance (**Table 10**).

Table 10: Thermal Power Generating Companies in Bihar

Generating Units	Power plants	Type	BSPGCL share (MW)	Installed capacity (MW)
	Farakka Super Thermal Power Station, West Bengal (Farakka Stage I & II)	Thermal	488	1600
	Farakka Stage III	Thermal	97	500

National Thermal Power Corporation (NTPC)	Talcher Super Thermal Power Station (TSTPS), Odisha (Talcher Stage I)	Thermal	404	1000
	Kahalgaon Super Thermal Power Station (KSTPS), Bihar (Kahalgaon Stage I)	Thermal	345	840
	Kahalgaon Stage II	Thermal	64	1500
	Daripali Super Thermal Power Station (STPS)	Thermal	224	1600
	Barh Thermal Power Plant (Barh TPP Stage I)	Thermal	766	1980
	Barh TPP Stage II	Thermal	1144	1320
	North Karanpura TPP Unit 1	Thermal	297	660
***Kanti Bijlee Utpadan Nigam Limited (KBUNL) (a joint venture of NTPC and BSPGCL)**	Kanti Thermal Power Plant, Bihar	Thermal	284	390
***Nabinagar Power Generating Company Limited (NPGCL) (a joint venture of NTPC and BSPGCL)**	Nabinagar Thermal Power Plant (BRBCL)	Thermal	100	1000
***BSPGCL**	Barauni Thermal Power Plant (Barauni TPP)	Thermal	720	720
***Nabinagar Power Generating Company Limited (NPGCL) (a joint venture of NTPC and BSPGCL)**	Nabinagar Thermal Power Plant (NPGCL)	Thermal	1638	1980

*Transferred to NTPC completely

Source: Bihar Economic Survey, 2023-24, Govt. of Bihar

Besides conventional energy, BSPGCL is actively working to diversify Bihar's energy mix by incorporating renewable energy sources. As part of the state's strategy to enhance sustainable power generation, BSPGCL is involved in several renewable energy initiatives. It has embarked on developing solar power projects to harness solar energy, a key renewable resource. It has planned to build solar power plants of 400-450 MW capacity at Kajra (Lakhisarasi) and Pirpainti (Bhagalpur).

Bihar State Hydroelectric Power Corporation (BSHPC) is a state-owned enterprise established by the Government of Bihar to develop, operate, and manage hydroelectric power projects in the state.

The corporation plays a crucial role in harnessing the hydroelectric potential of Bihar's river systems to contribute to the state's power generation capacity. BSHPC is involved in 13 mini and small-sized hydroelectric projects operational across different river systems in Bihar with a total installed capacity of 54.3 MW (**Table 11).** Due to the changing course of rivers and flood-prone areas in North Bihar, Bihar doesn't have the rich hydel power potential.

Table 11: Mini and Small Hydel Projects in Bihar

Hydroelectric Projects	Installed capacity (MW)
1. Kosi Hydel Power Station	19.2
2. Eastern Gandak Canal Hydroelectric (HE) Project	15.0
3. Sone Western Link Canal HE Project	6.6
4. Sone Eastern Link Canal HE Project	3.3
5. Agnoor HE Project	1.0
6. Dhelabagh HE Project	1.0
7. Triveni Link Canal HE Project	3.0
8. Nasriganj HE Project	1.0
9. Sebari HE Project	1.0
10. Jainagra HE Project	1.0
11. Shirkhinda HE Project	0.7
12. Belsar HE Project	1.0
13. Arwal HE Project	0.5
Total	**54.3**

Source: Bihar Economic Survey, 2023-24, Govt. of Bihar

Bihar Renewable Energy Development Agency (BREDA) is the principal state-level agency established by the Government of Bihar to promote and facilitate the development of renewable energy sources in the state. BREDA plays a crucial role in implementing renewable energy policies, coordinating projects, and supporting the growth of clean energy technologies in Bihar. Its primary objective is to increase the share of renewable energy in the state's energy mix, reduce dependence on fossil fuels, and support environmental sustainability. The agency operates under the guidance of the Bihar State Government and collaborates with central agencies, private sector entities, and non-governmental organizations. BREDA has been instrumental in developing Grid-connected Rooftop solar power plants, floating solar power plants, ground-mounted solar power plants, off-grid hybrid rooftop solar power plants, solar street lights and promoting rooftop solar photovoltaic

(PV) installations. These projects are designed to harness the state's solar potential and increase the share of solar power in the energy mix (**Table 12**).

Table 12: Achievements of Bihar Renewable Energy Development Agency (BREDA)

Sl. No.	Component/Scheme	Unit	Achievement	Capacity	Cost
1	Grid-connected Rooftop solar power plants at Government buildings	No's	2479	20.70 MW	100 cr
2	Grid-connected Rooftop solar power plants at private/ residential buildings	No's	113	583 KWp	3.08 cr
3	Floating Solar Power Plants (Supaul and Darbhanga districts)	No's	2	525 KWp (Supaul) 1600 KWp (Darbhanga)	11.55 cr
4	Solar water pumps	No's	2771	NA	77.16 cr
5	Grid-connected Rooftop solar power plants at Government buildings under Jal-Jeevan-Hariyali Mission Phase-II	No's	1032	16.25 MW	NA
6	Solar Street Lights (under Shyama Prasad Mukherji Urban Mission)	No's	1050	--	1.66 cr
6	Solar Street Lights (under Mukhyamantri Gramin Solar Street Light Yojana)	No's	60,000	--	NA
7	Hybrid (Off-Grid) Rooftop Solar Power Plant at Government Buildings	KWp	--	409 KWp	3.96 cr

Source: Bihar Economic Survey, 2023-24, Govt. of Bihar

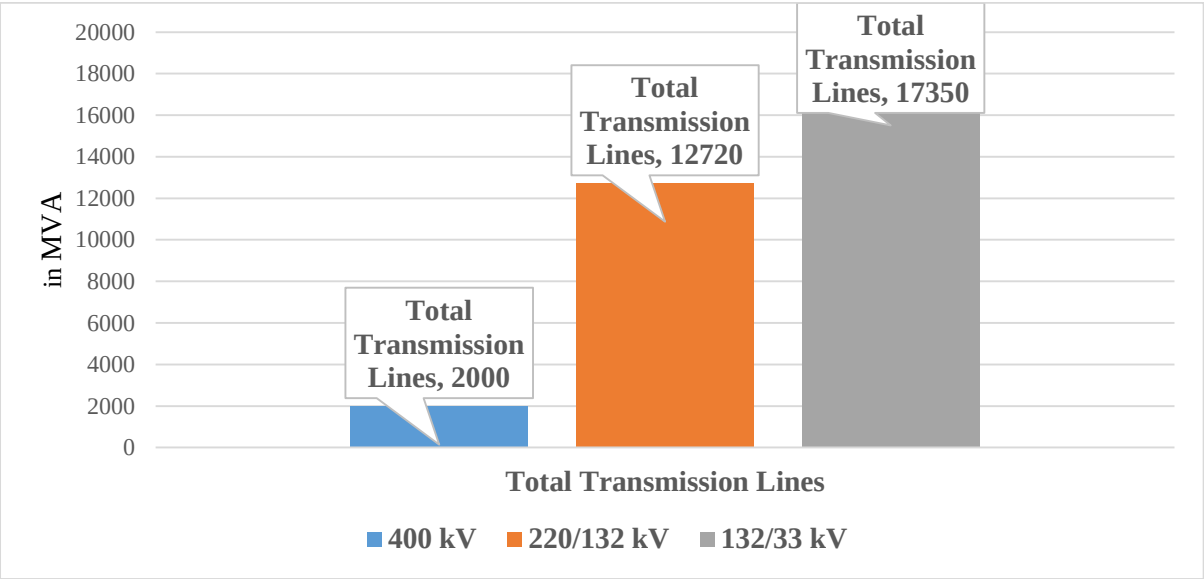
6.2 Power Transmission in Bihar

Power transmission in Bihar involves transporting electrical energy from power generation facilities to distribution networks, ensuring that electricity reaches end-users reliably and efficiently. The power transmission infrastructure in Bihar is managed by the state entity, which works to develop, operate, and maintain the transmission network. This infrastructure is crucial for maintaining a stable and efficient power supply across the state.

The *Bihar State Power Transmission Company Limited (BSPTCL)* is the state-owned entity responsible for electricity transmission within Bihar. It operates and maintains the state's high-voltage transmission network. BSPTCL is involved in the planning, developing, and expanding the transmission network to meet the growing electricity demand. The company ensures that the

transmission system is reliable, efficient, and capable of supporting the state's energy needs. The transmission network in Bihar consists of various high-voltage lines, including 400 kV, 220 kV, and 132 kV lines (**Fig.10**). These lines are used to transport electricity over long distances with minimal losses.

Figure 10: Total Transmission Lines in Bihar (Up to 2022-2023)



Source: Bihar Economic Survey, 2023-24, Govt. of Bihar

Power Grid Corporation of India Limited (PGCIL) also known as Power Grid, is a central government-owned entity that operates the national transmission network. It plays a significant role in the inter-state transmission of electricity. PGCIL's responsibilities include the construction, operation, and maintenance of high-voltage transmission lines that connect Bihar to the national grid. This connectivity is crucial for the import and export of electricity between Bihar and other states.

6.3 Distribution Companies (DISCOMs) in Bihar

Two distribution Companies (DISCOMs) in Bihar, namely **North Bihar Power Distribution Company Limited (NBPDCL)** and **South Bihar Power Distribution Company Limited (SBPDCL),** operational in Bihar, play a critical role in ensuring the delivery of electricity to end-users. In Bihar, the distribution network is managed by two key state-owned DISCOMs under the Bihar State Power Holding Company Limited (BSPHCL). These DISCOMs play a critical role in ensuring the reliable delivery of electricity, managing the distribution infrastructure, and addressing consumer needs. NBPDCL is responsible for the distribution of electricity in the 21 districts of the northern regions of Bihar including Saran, Muzaffarpur, Darbhanga and Gopalgunj and SBPDCL

distributes electricity in 17 districts of Bihar. As of March 2023, the two DISCOMs served 189.54 lakh consumers in Bihar (**Table 13**).

Table 13: Existing Distribution Structures of DISCOMs as on 31st March 2023

Sl. No	Particulars	Unit	SBPDCL	NBPDCL
1	No. of electrified villages	Nos.	18521	20552
2	No. of Consumers	Nos.	70.05 lakh	119.49 lakh
3	No. and capacity of 33/11kV substations	Nos/MVA	608/--	625/9742.40
4	No and capacity of 11/0.4kV 3 phase Transformers	Nos/MVA	141233/--	192712/11477
5	Length of 33kV Line	CKM	8878	9631
6	Length of 11kV Line	CKM	60991.50	77365
7	Length of LT Line	CKM	147179	195031

Source: Tariff Order of DISCOMs, Bihar Electricity Regulatory Commission

The two DISCOMs handle the distribution of electricity to various consumer categories, including residential, commercial, industrial, and agricultural users. They offer comprehensive customer service, including billing, metering, and addressing consumer grievances. The major challenge they face is to reduce high distribution losses caused by technical issues and unauthorized connections. **Table 14** presents the financial and operational status of the two DISCOMs. The generation and purchase of power has increased from 32,071 MU in 2020-21 to 36,253 MU in 2022-23. One of the major challenges for DISCOMs in Bihar has been high AT&C losses, which include technical losses, theft, and inefficiencies in billing and collection which has reduced from 27.1 per cent in 2020-21 to 18.9 per cent in 2022-23 which signifies the efficiency in collection and billing. The financial loss has also decreased from 11.9 per cent to -0.7 in 2022-23 which brings the DISCOMs in profit (**Table 14)**.

Table 14: Financial Status of DISCOMs (2020-21 to 2022-23)

Items	2020-21			2021-22			2022-23		
	NBPDCL	SBPDCL	Total	NBPDCL	SBPDCL	Total	NBPDCL	SBPDCL	Total
Generation and purchase (Available for sale) MU	14435	17636	32071	15308	18080	33388	16123	20130	36253
Sales (MU)	10614	12767	23381	12355	14092	26448	13675	15719	29393
Loss (%)	26.5	27.6	27.1	19.3	22.1	20.8	15.2	21.9	18.9
Average Revenue (Rs/Unit)	6.74	6.88	6.82	6.91	7.08	7.0	7.01	7.02	7.01
Sale of power (in cr)	7155	8788	15943	8536	9971	18508	9581	11032	20612

Total income (including subsidies) (in cr)	8411	10342	18753	11193	12756	23949	14302	17982	32284
Toral cost (in cr)	9622	11653	21275	12123	14044	26167	14510	17560	32069
Financial loss (%)	12.6	11.2	11.9	7.7	9.2	8.5	1.4	-2.4	-0.7

Source: Bihar Economic Survey, 2023-24, Govt. of Bihar

7. Energy Transition in Bihar: Policy Actions and Achievements

Bihar has undertaken several policy actions and achieved notable milestones in its journey towards a cleaner and more resilient energy future. These policies encompass various aspects of the energy sector, including renewable energy promotion, rural electrification, energy efficiency, and regulatory frameworks. The Electricity Act, of 2003 is a comprehensive legislation aimed at consolidating laws relating to the generation, transmission, distribution, trading, and use of electricity. It promotes competition, protects consumer interests, and provides a regulatory framework for the electricity sector in India, including Bihar. Besides that, Tariff Policy 2016 was implemented to ensure the availability of electricity at reasonable and competitive rates, improve the quality of supply, and promote the financial viability of the power sector. The key feature of this policy is to set tariffs that reflect efficient costs of service provision and renewable purchase obligation (RPO) to purchase a certain percentage of their power from renewable sources.

7.1 Energy Sector Schemes in Bihar

The Central Government and the state of Bihar have undertaken several schemes to enhance the power infrastructure, promote energy access, and ensure sustainable development in Bihar. These schemes aim to address various challenges in the power sector, such as inadequate infrastructure, high transmission and distribution losses, and low electrification rates in rural areas (**Table 15**).

Table 15: Objectives and Achievements of Energy Sector Schemes in Bihar

Schemes	Central/ State	Objectives	Achievements
1. Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY)	Central	To strengthen the rural electrification infrastructure and ensure reliable power supply to rural areas.	291 Power substations and 1354 Dedicated Agriculture Feeders were constructed with a total cost of Rs. 7489 crores
2. Re-DDUGJY	Central	Full-scale electrification of villages and habitations in all 38 districts	The work is completed with a total cost of Rs.10643 crore

3. Integrated Power Development Scheme	Central	To strengthen the sub-transmission and distribution network to address the distribution constraints in urban areas and provision of solar panels in government buildings.	The work is completed with a total cost of Rs. 2715.19 crores
4. Pradhan Mantri Sahaj Bijli Har Ghar Yojana (SAUBHAGYA)	Central	To achieve universal household electrification by providing electricity connections to all willing households in rural and urban areas.	32,59,041 electricity connections to the households in rural areas with a total cost of Rs. 1183 crores
5. Revamped Distribution Sector Scheme (RDSS)	Central	To improve the operational efficiency and financial sustainability of DISCOMs	Construction of agricultural feeders, High voltage distribution system, IT/OT information, and Installation of smart meters in urban areas. These works are presently in progress.
6. Renovation and Modernization (R&M) of Distribution Lines	State	To improve the reliability and efficiency of the state's power distribution network.	2730 circuit Km of 33 KV line, 36860 CKm 11 KV line and 47744 CKm LT lines were connected.
7. Mukhyamantri Krishi Viduyt Sambandh Yojana (MKVSY)	State	To provide reliable and uninterrupted power supply to agricultural operations and to address power shortages in rural and agricultural areas.	10576 11 kV line, 15212 nos of distribution transformers, 16815 CKm LT Line on AB cable and 105172 nos of New agricultural connections were established.

Source: Bihar Economic Survey, 2023-24, Govt. of Bihar

7.2 Renewable Energy Policies and Schemes in Bihar

The state of Bihar has been actively promoting renewable energy to address its growing energy needs while ensuring sustainability. Bihar is primarily a flat, floodplain state, with limited elevation changes required for effective hydropower generation. Most of its rivers flow slowly across the plains, making them less suitable for traditional large-scale hydroelectric projects, though there is potential for small-scale hydro. Also, Bihar does not have favourable conditions for wind energy. The state lacks high wind speeds and consistent wind patterns necessary for efficient wind energy generation, which are more prevalent in coastal and hilly regions. The state, despite its various geographical and infrastructural challenges, holds significant potential for solar energy development. The state's commitment to harnessing this potential is reflected in its ambitious policies and programs aimed at promoting solar energy. Therefore, several policies and schemes have been initiated to harness renewable energy sources like solar, biomass, and small hydropower,

aimed at reducing dependency on conventional energy sources, decreasing carbon emissions, and providing reliable power to underserved areas.

Bihar Policy for Promotion of Bihar New and Renewable Energy Sources, 2017 marks a cornerstone in the state's commitment to a sustainable and diversified energy future. By focusing on renewable energy development, energy security, and environmental sustainability, the policy aims to transform Bihar's energy landscape. A significant component of Bihar's renewable energy strategy is its focus on solar power. This policy targeted to establish the 2969 MW installed capacity of solar, 244 MW Biomass and bagasse cogeneration and 220 MW small hydropower by 2022. However, the state has achieved only 15 per cent of the set target which is only 450.15 MW of total renewable energy when compared to other eastern states like West Bengal (583 MW) and Odisha (590 MW). The policy also ensures that solar power projects receive grid connectivity, which is crucial for the seamless transmission of generated power. The emphasis on solar energy is further reflected in schemes like the Mukhyamantri Solar Pump Yojana, which provides financial support to farmers for the installation of solar-powered irrigation pumps. This not only reduces their dependency on diesel and grid electricity but also promotes sustainable agricultural practices.

The ***Jal Jeevan Hariyali Mission*** is a comprehensive initiative launched by the Bihar government to address water scarcity, increase green coverage, and promote sustainable development. A significant component of this mission is the promotion of solar energy, which aligns with the goals of reducing dependence on conventional energy sources, mitigating climate change, and supporting sustainable agricultural practices. Under this scheme, all government buildings such as PHC, Block offices, schools and panchayat sarkar Bhawan will have Grid Connected Rooftop solar panels with a target of 150-200 MW solar power, of which 50 MW has been established. A total of 2479 solar power plants have been installed under this scheme. ***Mukhyamantri Navin Evam Navikarniya Saur Adhisthapan Yojana*** is part of the broader efforts under the Jal Jeevan Hariyali Mission to promote renewable energy, enhance energy security, and support sustainable development which encourages widespread adoption of solar energy systems in government and private buildings. A total of 113 solar power plants are established at private residential buildings with a capacity of 583 KWp.

The state government has initiated the installation of floating solar power plants in Supaul and Darbhanga districts under the ***Niche Machhli Upar Bijli*** **('Fish below, energy above')** concept. The floating solar plants of capacity 525 KWp have been installed under the state plan at Supaul

and 1600 KWp at Darbhanga. The generated power is purchased by BSPHCL at the rate of 4.15 paise/unit through a PPA effective for 25 years.

Another initiative, '***Mukhyamantri Navin Evam Navikarniya Saur Pump Yojana'*** is a flagship initiative by the Government of Bihar aimed at promoting the use of solar-powered irrigation pumps. This scheme is designed to provide a sustainable and cost-effective solution for the agricultural sector, reducing the dependence on conventional energy sources and enhancing agricultural productivity. Under this scheme, 2771 solar water pumps have been installed at the cost of Rs. 77.16 crore. Under '***Shyama Prasad Mukherji Rurban Mission'*** 1050 solar street light systems were installed and under '***Mukhyamantri Gramin Solar Street Light Yojana***', approximately 60,000 solar street lights have been installed in rural districts of Bihar.

The ***Grid Connected Rooftop and Small Solar Power Plants Programme*** is a significant initiative under the National Solar Mission in India. This program aims to promote the installation of solar panels on rooftops and small solar power plants, encouraging the use of renewable energy sources. The Phase II programme was launched in 2019 by the Ministry of New and Renewable Energy (MNRE), Government of India, to promote the installation of rooftop solar systems and small solar power plants across the country with a capacity of 40,000 MW by 2022. Due to the COVID-19 pandemic, the programme period has been extended till 2026. In Bihar, this program has been implemented in two phases, focusing on enhancing solar energy capacity and reducing reliance on conventional power sources. The main objectives of this programme are to promote the use of solar energy in residential, commercial, industrial, and institutional sectors and to provide financial assistance and subsidies to encourage the adoption of rooftop solar systems. The net allocated capacity under phase II of the rooftop solar programme for the year 2022-23 was 25 MW. As of December 2023, 22.07 MW capacity of the Rooftop Solar (RTS) system was installed in Bihar in all sectors with and without Central Financial Assistance (CFA) (MNRE, 2023).

The ***Off-grid and Decentralised Solar PV Applications Programme*** is a crucial component of India's renewable energy strategy, aimed at providing reliable and sustainable energy solutions to areas that are not connected to the national grid. The key components of the program are the installation of solar street lighting, solar pumps, community solar systems, and distribution of solar lanterns. Under the off-grid SPV phase-I programme, 12303 solar home lights, 1735227 solar pumps, 54147 solar street lights, 2813 solar pumps, and 6905 kW capacity of solar power plants were installed in Bihar state till December 2022.

Pradhan Mantri Kisan Urja Suraksha Evam Utahan Mahabhiyan (PM-KUSUM)

The Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahabhiyan (PM-KUSUM) is a flagship scheme launched by the Government of India in the year 2019 aimed at promoting the use of solar energy among farmers, reducing their dependence on diesel for irrigation, and increasing their income through the sale of surplus solar power generated on their lands. Under the PM-KUSUM scheme, the government provides financial assistance to farmers for installing solar-powered agricultural pumps. These solar pumps replace traditional diesel or electric pumps, reducing farmers' energy costs and ensuring reliable irrigation facilities, especially in remote and off-grid areas. The scheme also promotes the solarization of existing grid-connected agricultural pumps by installing solar panels on pump sets. This helps in reducing the electricity bills of farmers and contributes to the green energy transition by harnessing solar power for agricultural purposes. According to the Annual Report 2022-23, Ministry of New and Renewable Energy (MNRE), 160000 feeder level solarization (FLS) was sanctioned under component C of the programme, but unfortunately, only 21.28 MW capacity was installed under this KUSUM programme (MNRE, 2024).

Suryamitras Programme

The Suryamitras Programme is an initiative by the Ministry of New and Renewable Energy (MNRE) in India to develop skilled technicians (Suryamitras) to support the solar power sector, focusing on the installation, operation, and maintenance of solar energy projects. The programme provides specialized training to unemployed youth, particularly from rural areas, to equip them with the skills needed for the solar industry. Training covers various aspects of solar energy systems, including photovoltaic (PV) systems, solar thermal systems, and hybrid systems. The programme is implemented through various training institutions, including the National Institute of Solar Energy (NISE) and other affiliated institutes. Under this program, 1886 suryamitras were trained in Bihar from 2015-16 to 2021-22 (MNRE, 2023).

The ***Small Hydro Power (SHP) Programme*** is a key initiative by the Ministry of New and Renewable Energy (MNRE), which aims to promote the development and utilization of small hydro resources to provide clean and renewable energy. This programme is particularly significant for states like Bihar, which have abundant hydro potential but face challenges in harnessing it effectively. The primary objective of the SHP Programme is to promote the development of micro, mini and small hydroelectric projects with capacities typically ranging from 0.1 megawatts to 25

megawatts. **Table 16** provides the list of potential sites, installed projects and ongoing projects under SHP in Bihar state.

Table 16: List of potential sites, installed projects, and on-going projects in the SHP (as of 31/12/2022)

Sl. No.	Components		Quantity
1	Total potential	Nos. (Total capacity in MW)	139 (526.98 MW)
2	Projects installed up to 2022-23	Nos. (Total capacity in MW)	29 (70.7 MW)
3	Projects under implementation	Nos. (Total capacity in MW)	0

Source: Annual Report 2022-23, MNRE, Govt. of India

Programme on Energy from Urban, Industrial and Agricultural Waste/Residues" (Waste to Energy Programme)

The Programme on Energy from Urban, Industrial, and Agricultural Waste/Residues, commonly known as the Waste to Energy Programme, is an initiative by the Government of India that aims to support the setting up of waste-to-energy projects for the generation of biogas. The Waste to Energy Programme holds particular relevance for states like Bihar, where waste management and energy access are critical issues.

The ***GEF-MNRE-UNIDO Project*** is a collaborative initiative between the Global Environment Facility (GEF), the Ministry of New and Renewable Energy (MNRE) of India, and the United Nations Industrial Development Organization (UNIDO). The project aims to address the industrial waste management challenges by promoting sustainable practices and renewable energy solutions. One of the key components of the GEF-MNRE-UNIDO Project involves promoting the use of decentralized biogas plants for organic waste management. The project supports waste-to-energy initiatives that utilize advanced technologies to convert various types of waste, including municipal solid waste (MSW), industrial waste, and agricultural residues, into energy. By turning waste into energy, these projects contribute to both waste management and renewable energy objectives. The project includes capacity-building initiatives aimed at enhancing the technical skills and knowledge of stakeholders, including government officials, industry professionals, and community members, in the areas of renewable energy and energy efficiency. Under this project, a Geographic Information System (GIS) waste-mapping tool has been launched.

Table 17: Waste Generation, Bio CNG Potential, and Energy Potential Estimate of Selected Sectors in Bihar (as of December 2022)

Sl. No.	Components	Quantity
1	PRESS MUD (000 TPA)	347
2	POULTRY (000 TPA)	241
3	Cattle Waste Generation (000 TPA)	38877
4	Urban Liquid Waste Sewage Generation (MLD)	1636
5	Urban Solid Waste Generation (000 TPA)	1852
6	Total Solid Waste Generation (000 TPA)	43683
7	Total Liquid Waste Generation (MLD)	1639
8	Total Energy Potential (MW)	394
9	Total Bio-CNG Potential (TPD)	1894

Source: GIS Waste Mapping Tool, GEF-MNREUNIDO (https://bio-energy.isid4india.org/

National Biogas Programme

The primary objective of the National Biogas Programme (NBP) is to promote the adoption of biogas technology for decentralized energy generation, primarily in rural and semi-urban areas for the period of 2021-26. The state government, in collaboration with MNRE, has been promoting biogas plants to provide a reliable source of energy in rural areas, improve agricultural productivity, and manage waste sustainably. Under this NBP program, 130072 small biogas plants were installed in Bihar till December 2022.

8. Challenges to Energy Transition in Bihar

Energy transition refers to the global energy sector's shift from fossil-based systems of energy production and consumption such as oil, natural gas, and coal, to renewable energy sources like hydro, wind and solar, as well as energy efficiency initiatives. This transition is crucial for reducing greenhouse gas emissions and mitigating climate change. However, in a developing state like Bihar, this shift presents numerous challenges. Bihar's unique socio-economic landscape, coupled with its existing infrastructural deficits, makes the energy transition particularly complex. Bihar has been able to achieve the installation of only 450.15 MW of renewable energy, which is only around 15 per cent of the stipulated target by June 2024. Unlike other states, Bihar has not seen much private investment from big renewable energy players for large-scale clean energy projects (Centre for Budget and Governance Accountability, 2022). This could be the reason for the low achievement of RE targets to date. The multifaceted challenges Bihar faces in its journey towards a just transition encompasses economic, social, environmental, and governance aspects.

8.1 Economic Challenges

Bihar is one of India's poorest states, with a high dependency on central government funds. The state's financial limitations restrict its ability to invest in expensive renewable energy infrastructure and technologies. Transitioning to a green energy economy requires significant upfront investments, which Bihar struggles to secure due to its budget constraints. The initial costs associated with renewable energy projects, such as solar panels and hydropower, are significantly higher compared to traditional fossil fuel-based power generation. Despite the long-term economic benefits and lower operational costs of renewables, the high capital expenditure poses a substantial barrier for Bihar.

8.2 Infrastructural Challenges

Bihar's existing power grid infrastructure is outdated and insufficient to handle the integration of large-scale renewable energy. The state faces frequent power outages and technical losses, which undermine the reliability of electricity supply. Upgrading the grid to accommodate renewable energy sources is a significant challenge that requires substantial investment and planning. The transmission and distribution network in Bihar is fraught with inefficiencies and high loss rates. These technical and non-technical losses make the distribution of power, particularly from intermittent renewable sources, a complex task. Enhancing the efficiency and capacity of this network is crucial for a successful energy transition. The infrastructure for renewable energy generation, such as wind farms and solar parks, is still in its nascent stages in Bihar. Developing this infrastructure requires land acquisition, regulatory approvals, and substantial capital, all of which present considerable hurdles.

8.3 Technological Challenges

Bihar faces a shortage of skilled professionals and technical expertise in the field of renewable energy. This skills gap hinders the deployment, operation, and maintenance of renewable energy projects. Building a skilled workforce is essential for the sustainable development of the renewable energy sector. Access to advanced renewable energy technologies is limited in Bihar due to high costs and a lack of local manufacturing capabilities. Reliance on imported technologies increases costs and dependency, making the transition process slower and more expensive.

One of the critical challenges in integrating renewable energy is the lack of efficient energy storage solutions. Solar and hydro energy are intermittent, and without reliable storage systems, managing supply and demand becomes difficult. Developing and deploying affordable energy storage technologies is vital for ensuring a stable energy supply.

8.4 Social Challenges

With a significant portion of Bihar's population living below the poverty line, the socio-economic conditions present a substantial challenge to the energy transition. Poor households often lack the

financial capacity to invest in renewable energy solutions, such as solar home systems, which limits the adoption of clean energy at the grassroots level. Despite improvements, many rural areas in Bihar still lack reliable access to electricity. Extending renewable energy solutions to these remote and underserved regions requires targeted policies and substantial investment, which are challenging given the state's financial constraints.

There is a lack of awareness and acceptance of renewable energy among the general population in Bihar. Misconceptions about the reliability and cost-effectiveness of renewable energy sources can hinder their adoption. Effective awareness campaigns and education programs are necessary to promote the benefits of renewable energy.

8.5 Environmental challenges

Bihar is highly vulnerable to climate change impacts, such as flooding and extreme weather events. These environmental challenges can damage renewable energy infrastructure and disrupt energy supply. Building climate-resilient infrastructure and integrating disaster risk management into energy planning is vital for a sustainable energy transition. Land availability is an important challenge for the energy transition in Bihar. Renewable energy projects, particularly solar and wind farms, require significant land area. In a densely populated state like Bihar, land availability is a critical issue. Competing demands for land for agriculture, housing, and industry make it challenging to allocate space for renewable energy projects.

8.6 Policy and Regulatory Challenges

The energy transition in Bihar faces numerous policy and regulatory challenges that need to be addressed to achieve a sustainable and inclusive energy future. Inconsistent policy implementation, regulatory barriers, fossil fuel subsidies, tariff structure issues, inadequate incentives, weak institutional capacity, and political and social challenges are significant hurdles that require a multifaceted approach. Addressing these challenges requires coordinated efforts from government agencies, private sector stakeholders, and civil society. By streamlining regulatory processes, reforming tariff structures, enhancing financial incentives, building institutional capacity, and fostering political and public support, Bihar can overcome these barriers and successfully transition to a renewable energy-driven economy.

9. Policy Recommendations

To successfully navigate the complex landscape of energy transition, Bihar must adopt a holistic and strategic approach. The following are key recommendations to facilitate this transition:

- ***Phase Out Fossil Fuel Subsidies***: The Bihar Government increased the diesel subsidy for farmers due to the delay in the launch of the solar irrigation pump scheme PM-KUSUM, which the Centre announced in 2019-20. The Bihar government provides a subsidy of Rs 50 a litre and a farmer with an acre of land gets a subsidy for 10 litres of diesel for each round of irrigation. Therefore, gradually subsidies for fossil fuels should be phased out and redirect these funds towards supporting renewable energy projects. This will create a level playing field and incentivize the adoption of clean energy.
- ***Strengthen policy implementation for the promotion of renewable energy***: The Bihar Renewable Energy Development Agency (BREDA) is the state's nodal agency to undertake renewable energy projects and formulate policies to support the growth of clean energy. Robust monitoring and evaluation mechanisms should be developed and implemented to track the progress of renewable energy policies and projects. This will ensure accountability and facilitate timely adjustments to policies.
- ***Reform Regulatory Framework*:** There should be improvement in the regulatory framework to ensure easy and reliable grid connectivity for renewable energy projects. This includes developing standards and protocols for integrating decentralized energy sources into the grid. Land acquisition procedures for renewable energy projects should be streamlined by reducing bureaucratic hurdles and ensuring fair compensation for landowners. This can be achieved through clear guidelines and faster processing times.
- ***Rooftop Solar Systems: Solving Land Availability Problems in Bihar***: The state of Bihar, with its growing population and development needs, faces challenges in allocating land for large-scale solar farms. Rooftop solar systems make use of existing building infrastructure, turning otherwise unused rooftop space into productive energy-generating areas. This approach mitigates the need for acquiring new land, preserving agricultural and forested areas.
- ***Need for Grid Modernization and Energy Storage Solutions***: The state government should accelerate efforts to harness new investment opportunities to install RE capacities. There should be investment in modernizing the power grid to enhance its capacity and reliability. This includes upgrading transmission and distribution infrastructure to support the integration of renewable energy sources. Energy storage technologies should be promoted to address the intermittency of renewable energy sources.

- ***Cost-Reflective Tariffs***: There should be implementation of cost-reflective tariff structures that accurately reflect the long-term benefits and lower operational costs of renewable energy. This will make renewable energy more attractive to consumers and investors.
- ***Integrating small modular reactors (SMRs) into Bihar's energy infrastructure*:** Bihar's reliance on coal and other fossil fuels contributes to high levels of pollution, adversely affecting air quality and public health. Nuclear energy, particularly through SMRs, offers a cleaner alternative with minimal greenhouse gas emissions. Integrating SMRs can significantly reduce the state's carbon footprint and contribute to national and global climate goals. Bihar's energy security is a pressing concern. The state largely depends on energy imports from other regions, making it vulnerable to supply disruptions and price fluctuations. By investing in SMRs, Bihar can enhance its energy independence, ensuring a stable and reliable power supply for its population and industries.
- ***Need to design a long-term strategy for EV adoption***: The state needs to carefully design a plan for a long-term shift towards an electric vehicle (EV)-based transport system. This strategy should encompass several critical elements to ensure a successful transition. Firstly, the installation of EV charging stations from solar energy across urban and rural areas is essential to address range anxiety and promote widespread adoption. Additionally, offering financial incentives such as subsidies, tax breaks, and low-interest loans for EV purchases can make these vehicles more accessible to consumers.
- ***Promotion of Green Hydrogen Production***: Green hydrogen can present a promising solution for Bihar's energy and environmental challenges. By harnessing its renewable energy potential and developing a robust green hydrogen infrastructure, Bihar can achieve energy security, economic growth, and environmental sustainability. Policies and initiatives such as the National Hydrogen Mission, launched by the Government of India aim to support the development of a green hydrogen ecosystem. Bihar can leverage these national initiatives and align its state policies to promote green hydrogen adoption.
- ***Integrate Climate Resilience into Energy Policies***: Renewable energy infrastructure should be designed and built to withstand the impacts of climate change, such as extreme weather events and flooding. This will enhance the resilience and reliability of energy systems. There should be the integration of disaster risk management into energy planning to mitigate the impacts of climate-related disasters on renewable energy projects.
- ***Promote Public Awareness and Acceptance of Renewable Energy***: Extensive awareness campaigns should be conducted to educate the public about the benefits of renewable energy

and the importance of energy conservation. Renewable energy education into school curriculums and vocational training programs should be integrated which will help build a future workforce equipped with the knowledge and skills needed for the renewable energy sector.

10. Conclusion

The energy transition in Bihar faces a complex array of challenges spanning economic, infrastructural, technological, social, policy, and environmental domains. Overcoming these hurdles demands a comprehensive and integrated strategy that combines sustained investment, effective policy reforms, capacity enhancement, and active community participation. Infrastructure development, particularly in transmission, distribution, and renewable energy integration, must be prioritized alongside institutional strengthening to ensure efficient implementation and governance of energy initiatives. Raising public awareness and encouraging stakeholder engagement are equally critical to building acceptance for clean energy technologies such as solar, biomass, and small hydropower. Bihar possesses considerable potential in renewable energy, particularly solar power, which can be harnessed to diversify the energy mix, reduce dependence on fossil fuels, and minimize environmental degradation. Transitioning to a green energy economy offers the opportunity not only to mitigate climate risks but also to spur inclusive economic development, generate employment, and improve overall living standards. By capitalizing on its natural resources, demographic dividend, and emerging innovation landscape, Bihar can create a resilient and sustainable energy ecosystem. Ensuring equity and social justice, fostering strong public-private partnerships, and implementing transparent and accountable governance mechanisms will be key to driving a just and inclusive energy transition and positioning Bihar as a leader among developing regions.

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