Punjab Roadmap 2036

Clean Energy Transition

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Center for Study of Science, Technology and Policy (CSTEP)

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Foreword

In line with the broader national efforts for achieving net-zero emissions by 2070 and 500 GW of non-fossil-fuel-based capacity by 2030, Punjab is actively pursuing its clean energy initiatives. However, with over half of its power generation coming from thermal sources, the state faces the dual challenge of meeting the rising electricity demand and transitioning towards a clean energy future.

In this context, the Center for Study of Science, Technology and Policy (CSTEP) performed a data-driven assessment of Punjab's electricity demand-supply dynamics up to financial year 2035-36. On the basis of the key insights from the study, this report puts forth focused recommendations that can steer Punjab's power sector transformation over the next decade.

I hope that the insights from this study will not only help us visualise the long-term energy needs of Punjab but also empower the state utility, policymakers, and the relevant stakeholders to take strategic decisions for a greener, more resilient power sector.

Mr Ajoy Kumar Sinha, IAS,

Chairman and Managing Director

Punjab State Power Corporation Limited (PSPCL)

Foreword

Punjab's clean energy goals require strategic planning and bold interventions in its generation segment. With the state still significantly dependent on thermal power for its electricity needs, the role of this segment of Punjab State Power Corporation Limited (PSPCL) is critical for driving an effective shift to clean energy.

In this context, the Center for Study of Science, Technology and Policy (CSTEP) developed a forward-looking clean energy transition roadmap for the state till financial year 2035-36. The study provides a comprehensive assessment of Punjab's generation landscape and outlines the capacity additions to meet its rising demand.

The study recommendations would be particularly useful for increasing the share of clean energy (including nuclear capacity) and integrating energy storage systems, thereby improving the energy security of Punjab.

I appreciate CSTEP's analytical rigour and evidence-driven approach in preparing this roadmap. I hope that it will serve as a valuable tool to guide the state's generation strategy in the years ahead.

Er Harjit Singh

Director – Generation

Punjab State Power Corporation Limited (PSPCL)

Foreword

Punjab's growing energy demand—driven by agriculture, industry, and urbanisation—mandates a strategic shift for its power sector towards clean and sustainable energy sources. As the distribution utility of the state, Punjab State Power Corporation Limited (PSPCL) recognises the need to future-proof its planning processes in alignment with India's clean energy commitments.

This study undertaken by the Center for Study of Science, Technology and Policy (CSTEP) aimed to develop a comprehensive clean energy transition roadmap for Punjab till financial year 2035-36. The study took a data-driven approach to demand forecasting and resource planning, factoring in technological shifts and policy interventions.

The roadmap can guide the state to meet its Renewable Purchase Obligation (RPO) targets comfortably. It also provides critical insights that can aid the utility in ensuring reliable and cost-effective power delivery in the coming decade.

I look forward to operationalising the roadmap for advance Punjab steadily towards a clean energy future.

Er Inderpal Singh

Director – Distribution

Punjab State Power Corporation Limited (PSPCL)

Foreword

India is currently in a crucial phase of its energy transition. Aligning with the national clean energy aspirations, Punjab is striving to create a cleaner and resilient energy future. The state's strong commitment to achieving net-zero emissions by 2070 and securing 43% of its power generation capacity from renewable sources by 2030 is both ambitious and admirable.

In pursuit of these goals, the Center for Study of Science, Technology and Policy (CSTEP) has undertaken an in-depth study, examining the evolving dynamics of Punjab's energy sector upto FY 2035-36 and conducting a comprehensive analysis to provide a strategic roadmap that can advise effective policymaking.

The roadmap outlines the necessary initiatives, policy directions, and actionable measures that can enable the state to transition smoothly towards a future powered by renewables, while meeting the renewable purchase obligations laid out by the Ministry of Power. Given the rising electricity demand, the escalating impacts of climate change, and the need to reduce reliance on fossil fuels, this roadmap is both timely and essential.

I commend CSTEP and all contributing stakeholders for their diligent efforts in producing this valuable report. I am confident that it will serve as a guiding resource for policymakers, state utilities, and renewable energy developers in Punjab's journey toward a secure, affordable, and sustainable energy future.

19 June 2025

Er. Hira Lal Goel
Director-Commercial
PSPCL

Executive Summary

Punjab has a considerable dependence on thermal sources for meeting its energy demand. In financial year (FY) 2025, Punjab's total installed generation capacity stood at 14,861 megawatts (MW), of which, thermal (including gas) constituted the largest share (56% or 8,370 MW), followed by hydro (23% or 3,398 MW), solar and wind (17.6% or 2,609 MW), other NCEs (1.9% or 287 MW), and nuclear (1.3% or 197 MW). While the state has been assigning an increasingly important role to renewable energy (RE)—especially solar—in its energy strategy, the consistent surge in energy consumption, driven by a high demand from industrial, agricultural, and residential sectors, makes clean energy transition challenging for the state.

The power sector of a state plays a crucial role in enabling its transition to clean energy. Therefore, Punjab must focus on strengthening its power sector for adequately supporting the agricultural, industrial, and urban energy needs through sustainable generation sources. For this, Punjab needs to craft an action plan that can propel it towards a greener energy future. This is particularly significant in view of India's goals of achieving net-zero emissions and installing 500 GW of RE capacity by 2030.

In this context, the Center for Study of Science, Technology and Policy (CSTEP) conducted a study for developing a clean energy transition roadmap for Punjab till FY 2036. The roadmap would aid the state in navigating the unique challenges posed by its relatively lower solar and wind potential, diversifying its energy mix, and reducing the dependency on thermal sources, while enabling a smooth shift towards a clean energy economy.

Understanding Punjab's existing power demand, supply, and the demand-supply gap was a prerequisite for the study. For this, we obtained the historical electricity consumption data for each consumer category over the past 8 years (FY 2016 to FY 2025) from Punjab State Power Corporation Limited (PSPCL). We projected the business-as-usual (BAU) demand forecast for each category, up to FY 2036. The BAU demand was then overlaid with policy levers influencing the consumer-category demand, such as electric vehicle (EV) adoption, penetration of rooftop solar (RTS), and energy efficiency initiatives/measures in the residential and commercial sectors. We also factored in the impact of deploying energy efficient pumps and solarising irrigation pump (IP) sets in the agricultural sector to arrive at the final energy demand.

We then performed a comprehensive supply planning analysis through two scenarios: 1) Conventional Scenario (which considered RE addition, along with thermal and nuclear energy sources); and 2) Clean Energy Scenario (which considered RE addition with only nuclear energy sources), to determine the generation capacity required by Punjab for meeting its projected demand, and the year-on-year (Y-o-Y) storage requirements for managing RE intermittency and providing round-the-clock power. The supply planning analysis was carried out for the BAU demand, as well as the final demand arrived at by incorporating key policy impacts.

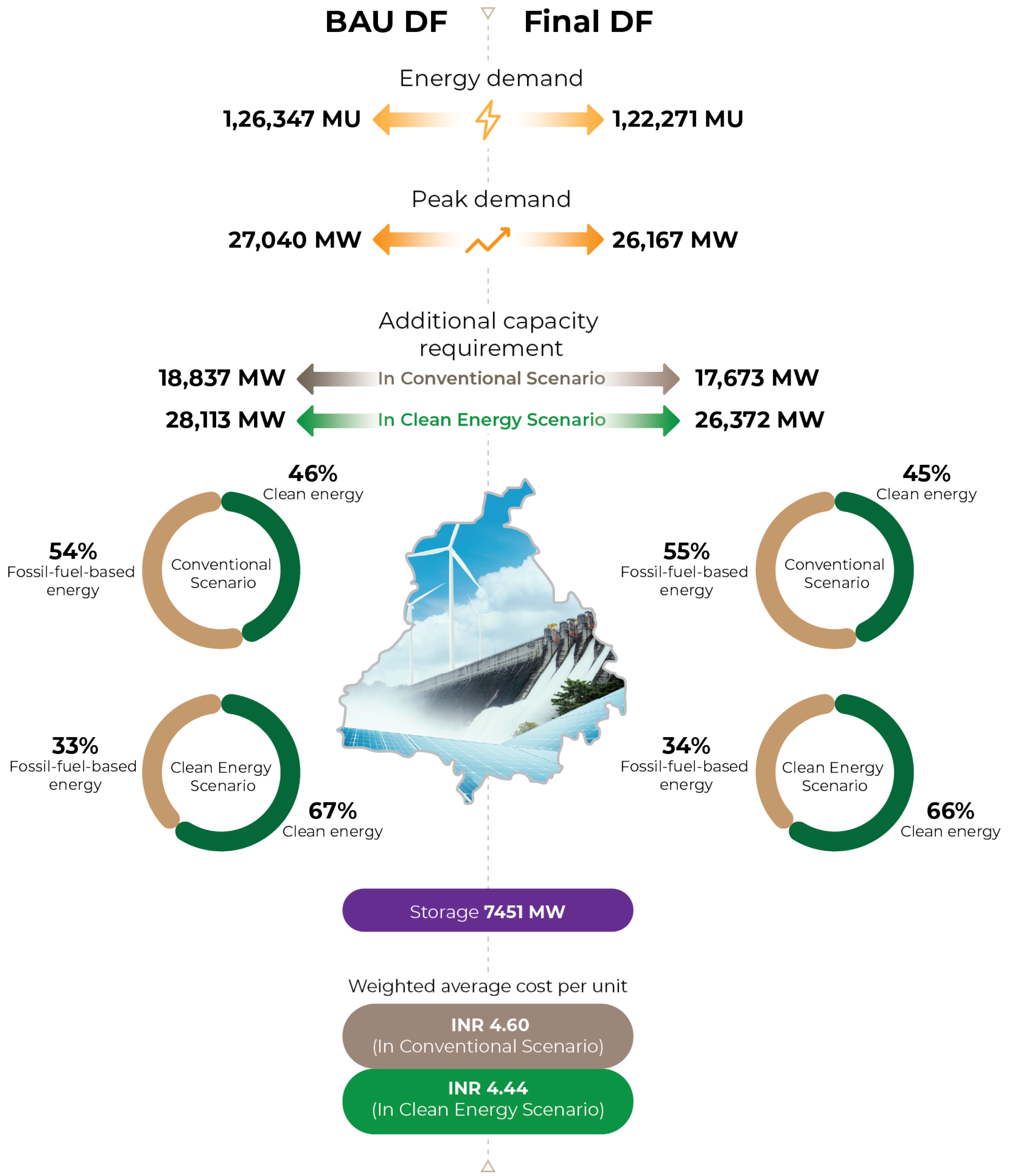
In addition, we assessed the impact of increasing the RE capacity (particularly solar and wind) on the power purchase cost of distribution companies (DISCOMs) and recommended suitable policy interventions for a smooth RE transition in the state.

Our study found that the state electricity demand would reach 1,26,347 MU by FY 2036 in a BAU scenario (from 75,316 MU in FY 2025), while the peak demand would increase from 16,058 MW to 27,040 MW during the same period. It is estimated that the penetration of 5.1 million EVs will increase the demand by 9,087 MU by FY 2036. On the other hand, the energy efficiency measures in residential, commercial, and agricultural sectors, and solarisation of agricultural and residential load are likely to bring down the demand by 12,726 MU by FY 2036. Thus, the state's final energy demand, arrived at after factoring in the impact of policy levers and distribution losses, would reduce to 1,22,271 MU by FY 2036. Consequently, the peak demand is expected to be 26,167 MW in FY 2036.

Considering the BAU demand forecast (DF) and the state's existing and planned supply availability, our study indicates an additional capacity requirement of 28,113 MW by FY 2036 to overcome the peak demand deficits and eventually achieve its RPO targets. With this proposed capacity, the state is expected to have a 46% clean energy share and a 54% fossil-fuel-based energy share in its energy mix in the 'Conventional Scenario', and a 67% clean energy share, along with a 33% fossil-fuel-based energy share in the 'Clean Energy Scenario' by FY 2036. To support this substantial RE integration, the state would need 7,451 MW of storage capacity by FY 2036, utilising both pumped-hydro energy storage (PHES) and battery energy storage systems (BESS). Based on the anticipated RE addition, our study estimates the average power purchase cost for the state utility to decrease by 4% and 7.3%, respectively, in the 'Conventional' and 'Clean Energy' scenarios.

In the context of the final energy demand of Punjab (which incorporates the impact of policy levers), our study indicates an additional capacity requirement of 26,372 MW by FY 2036 to overcome the state's peak demand deficits and achieve its RPO targets comfortably. With this proposed capacity, the state is expected to have a 46% clean energy share and a 54% fossil-fuel-based energy share in its energy mix in the 'Conventional Scenario', and a 66% clean energy share, along with a 34% fossil-fuel-based energy share in the 'Clean Energy Scenario' by FY 2036. To support this substantial RE integration, the state would need 7,451 MW of storage capacity by FY 2036, utilising both pumped-hydro energy storage (PHES) and battery energy storage systems (BESS). Based on the anticipated RE addition, our study estimates the average power purchase cost for the state utility to decrease by 4.3% and 7.7%, respectively, in the 'Conventional' and 'Clean Energy' scenarios.

The study estimates also have significant implications for Punjab's carbon emissions, indicating a decrease from 47 metric tons of carbon dioxide equivalent (MtCO2) in FY 2025 to 30 MtCO2 by FY 2036, at a negative compound annual growth rate (CAGR) of 4%. Without RE addition, the state's emissions are expected to rise by 93%—from 47 MtCO2 in FY 2025 to 91 MtCO2 by FY 2036.



Given the impact of key policy developments considered in this study, the state needs to focus on expediting the implementation of these policy levers to optimise the energy demand in Punjab. This can help in reducing the capacity addition requirement by 7% (from 28 GW to 26 GW by FY 2036).

On the basis of the overall findings, our study makes focussed recommendations to enable Punjab to progress towards its RE goals, while ensuring a reliable energy supply. For this, we put forth area-specific interventions, identifying the challenges in implementing them and suggesting key actions to overcome them.

Intervention	Challenges	Recommended Action	Responsibility
Energy-efficiency and solarisation measures in agriculture sector	Unavailability of land parcels	• Develop a land-use tool for identification of non-fertile land parcels.	• State Government • PSPCL • Financial Institutions • Agriculture Department • Revenue Department • Department of Industry • Punjab Energy Development Agency (PEDA) • Bureau of Energy Efficiency (BEE)
	Inefficient pumps and lack of awareness on energy-efficient pumps	• Introduce buy-back scheme for older and inefficient pumps and provide energy-efficient star-rated pumps at subsidised cost, starting with pilot projects for large-scale deployment.	
Integrating a higher RE capacity	Inadequate land availability	• Identify suitable land parcels by creating a land-aggregation tool for solar parks and conduct techno-commercial feasibility studies within the state.	• State Government • PEDA • Punjab State Electricity Regulatory Commission (PSERC) • Revenue Department • Agriculture Department • Punjab State Power Corporation Limited (PSPCL)
	High capital expenditure for biomass developers and high energy tariffs	• Capitalise on biomass potential through viability gap funding for flexible supply and reduced emissions.	
Integration of storage systems	Meeting the evening peak load when there is insufficient RE availability.	• Devise a comprehensive storage policy to promote energy storage development by both public and private sectors. • Develop 1,000 MW of storage by FY 2027, and increase it to 7,451 MW by FY 2036, to manage the intermittency in RE generation and meet the evening peak demand.	• State Government • PSPCL
Nuclear capacity addition	Insufficient base-load generators in the future and low contracted nuclear capacity	• Procure additional 2,637 MW of nuclear capacity by FY 2036 to support base-load requirements for the grid and handle RE-intermittency issues through upcoming plants like: o Mahi-Banaswara (in Rajasthan) o Gorakhpur (in Haryana)	• State Government • PSPCL
Smoother and faster adoption of electric vehicles	Inadequate charging infrastructure	• Create a single-window platform (including the power and transport departments) to plan for an efficient charging infrastructure and the associated distribution infrastructure. • Conduct 11kV feeder-level feasibility studies for EV integration.	• State Government • Department of Power • Transport Department • Department of Industries and Commerce • Manufacturing Units • R&D Institutes

Intervention	Challenges	Recommended Action	Responsibility
	Lack of policy push for electrification of vehicles used in agriculture	• State government to include manufacturing and adoption of e-tractors and e-lorries under the state EV policy. • Provide support for R&D for electrification of vehicles in agriculture sector.	
Integration of RTPV into the distribution grid	Low adoption of RTPV systems	• Use drone-based aerial photogrammetry to identify RTPV installation sites on: o Government buildings o Municipal/local body premises o Schools and hospitals o Major commercial spaces • Pilot execution for peer-to-peer energy trading to encourage consumers in the decentralised energy markets.	• State Government, in consultation with: o PSPCL o Department of Power o Department of Housing and Urban Development; and o Local Bodies.
Energy-efficient initiatives in residential and commercial sectors	Limited enforcement of the Energy Conservation Building Code (ECBC) - Residential	• Ensure strict compliance with 'Eco-Niwas Samhita 2018' for new residential buildings through building by-laws and approvals by municipalities/urban bodies.	• State Government should offer rebates/subsidies in collaboration with: o Department. of Housing and Urban Development o Department of Finance o PSPCL o Local Bodies (Municipalities/ Panchayats)
	Low incentives for ECBC - Commercial	• Support building construction/retrofitting at low interest rates through green finance.	
	Inefficient energy monitoring and management	• Deploy smart meters and energy management systems to track Energy Performance Index (EPI) scores for improving consumption patterns and highlighting economic benefits.	

These recommended interventions, when complemented by adequate policy support, capacity additions, and technological advancements, will be instrumental in enabling Punjab to smoothly achieve a clean energy transition that is sustainable. Their effective implementation will not only boost Punjab's energy security but can also position it as a frontrunner in India's green energy endeavour.

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1. Introduction

Punjab’s power sector plays a pivotal role in sustaining the state’s agricultural, industrial, and urban energy needs. Managed primarily by the Punjab State Power Corporation Limited (PSPCL) and regulated by the Punjab State Electricity Regulatory Commission (PSERC), the sector has evolved through various reforms over the years to strengthen its power generation, transmission, and distribution functions and capabilities.

The state’s energy consumption has seen a significant rise post the COVID pandemic, driven by increased demand from the industrial and agricultural sectors, as well as from the residential sector that benefitted from subsidised power supply (PSPCL, 2022). Although the state remains heavily reliant on thermal power (which forms 80% of its total energy mix), renewable energy (RE) sources—especially solar—are playing an increasingly important role in Punjab's evolving energy landscape.

In view of India’s goals of attaining net-zero emissions and installing 500 gigawatts (GW) of RE capacity by 2030 (PIB, 2022), Punjab needs to tweak its energy policies. Importantly, the state needs to craft a strategic roadmap to facilitate its transition to a greener and more sustainable energy future. This roadmap will be critical in navigating the unique challenges posed by Punjab’s limited solar and wind potential, diversifying its energy mix, and reducing the dependency on thermal sources, thus enabling a smooth clean energy transition.

1.1 Objective

The objective of this study was to develop an actionable roadmap for accommodating a higher share of RE in Punjab’s generation mix by financial year (FY) 2036, with tailored strategies for transitioning from fossil fuels to sustainable alternatives for power generation. The study provides targeted recommendations to ensure that Punjab's energy supply meets its future demand, with due consideration to affordability, accessibility, and availability. It also emphasises the importance of aligning the future capacity plans with environmental and economic sustainability considerations to support the state's overall growth.

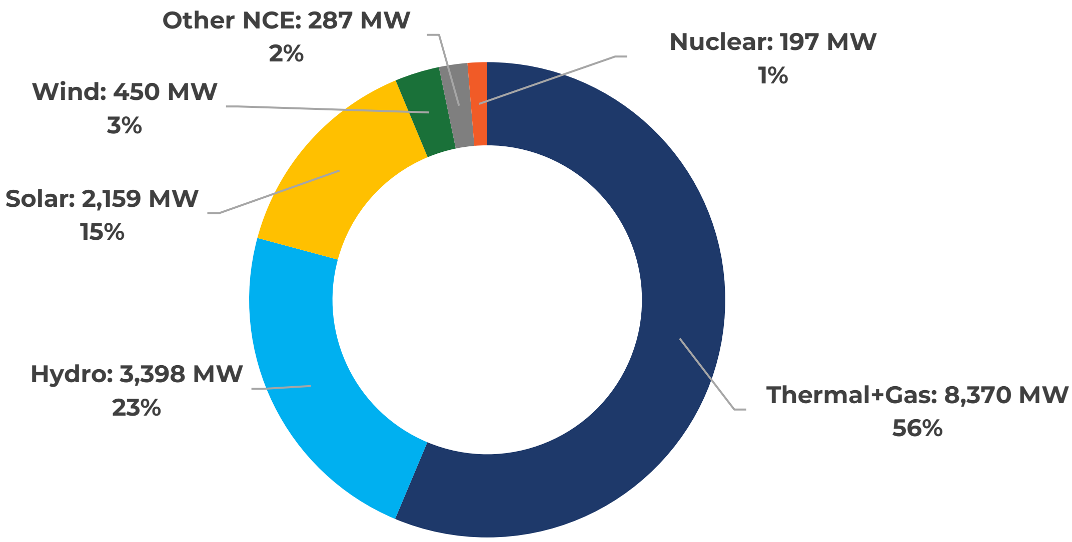
Given Punjab's commitment to achieve 100% RE in its energy mix by 2040 as part of the national goal of 50% non-fossil-based generation, this study aims to guide the state in making critical decisions for a smooth and sustainable energy transition, thereby building a resilient energy system by FY 2036.

2. Punjab Power Sector Overview 2025

2.1 Generation segment

In FY 2025, Punjab's total installed generation capacity stood at 14,861 megawatts (MW). Of this, thermal (including gas) had the largest share of 56% (8,370 MW), followed by hydro with 23% (3,398 MW). Solar and wind contributed 18% (2,609 MW), while nuclear made up 2% (197 MW). Other non-conventional sources, such as small hydro, cogeneration, and bio-power collectively contributed 2% (287 MW). The fuel-wise breakup is shown in Figure 1.

Figure 1: Installed capacity in FY 2025

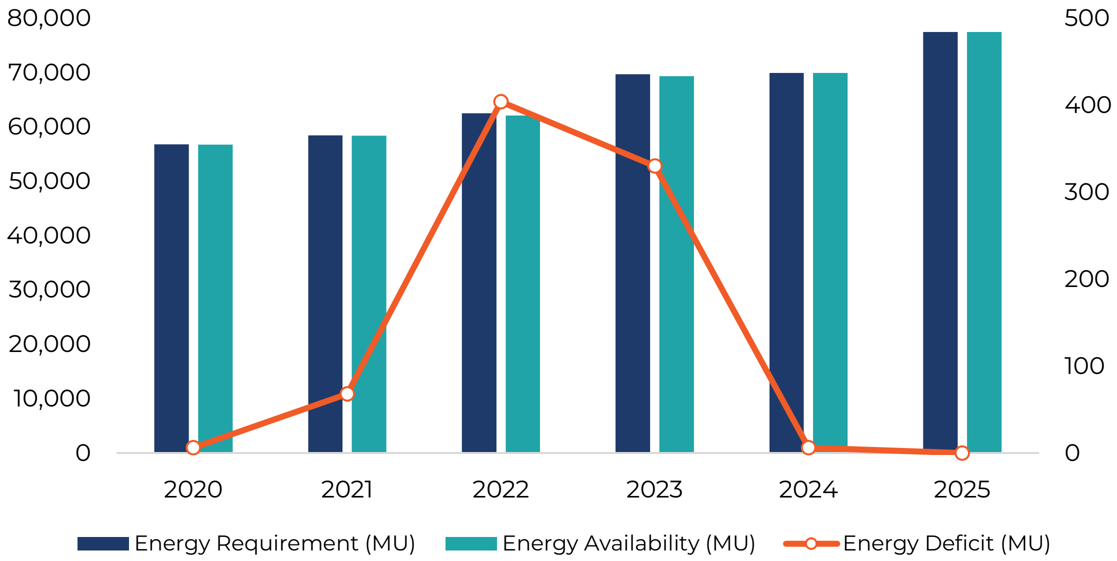


Source: Punjab State Power Corporation Limited (PSPCL)

2.2 Peak demand and supply

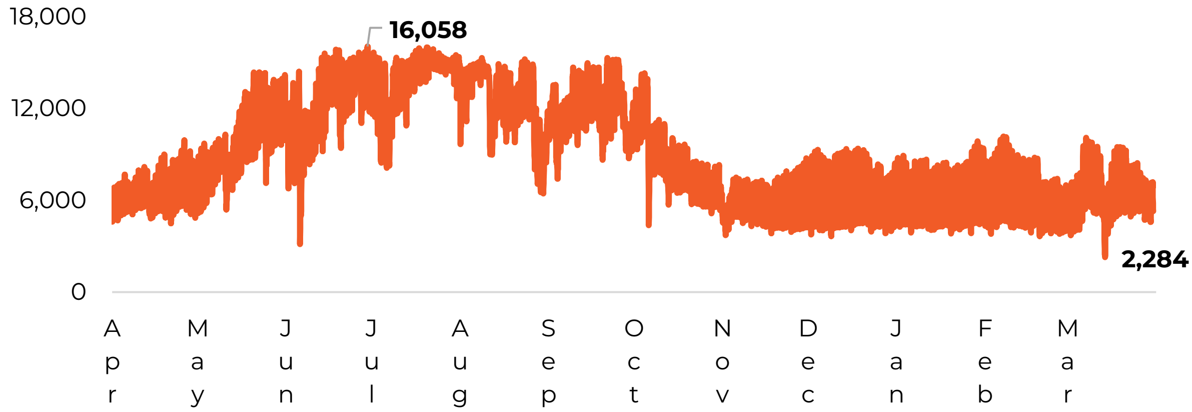
The energy requirement, availability, and deficit for Punjab from FY 2020 to FY 2025 (CEA, 2024) are depicted in Figure 2. Though the state has sufficient capacity to meet its energy needs, significant deficits were observed in FY 2022 and FY 2023, amounting to 404 million units (MU) and 330 MU, respectively. These deficits were primarily driven by an unexpected surge in industrial consumption in FY 2022 due to the post-pandemic recovery, and increased residential consumption in FY 2023 following the implementation of the 300-units free power supply scheme for the residential sector by the state.

Figure 2: Energy requirement, availability, and deficit



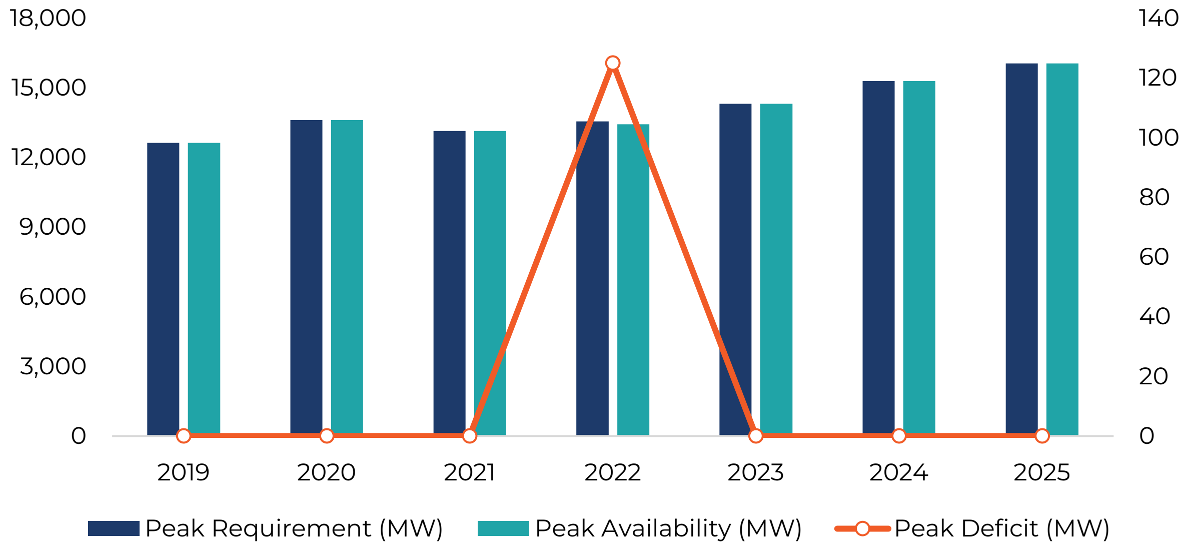
The state recorded a peak demand of 16,058 MW at 1:00 p.m. on 29 June 2024, while the off-peak demand reached 2,784 MW at 3:00 a.m. on 15 March 2025. The hourly load-curve observed in FY 2025 is shown in Figure 3. It has been assumed that the load pattern will remain consistent, with changes only in magnitude, extrapolated through FY 2036.

Figure 3: Hourly load-curve of PSPCL in FY 2025



The state has successfully met its peak demand in all years except FY 2022, when it experienced a peak deficit of 125 MW, as shown in Figure 4. The peak demand has been growing at a compound annual growth rate (CAGR) of 3% between FY 2020 and FY 2025.

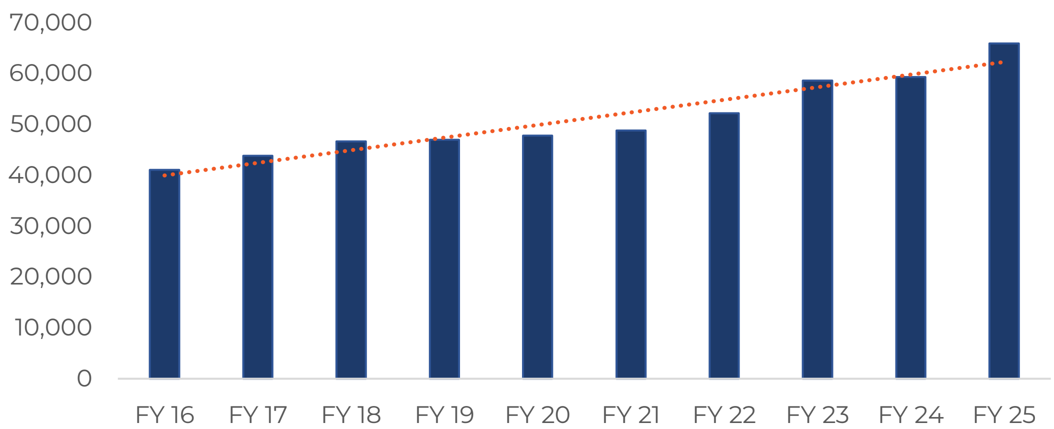
Figure 4: Peak power requirement, availability, and deficit



2.3 Distribution segment

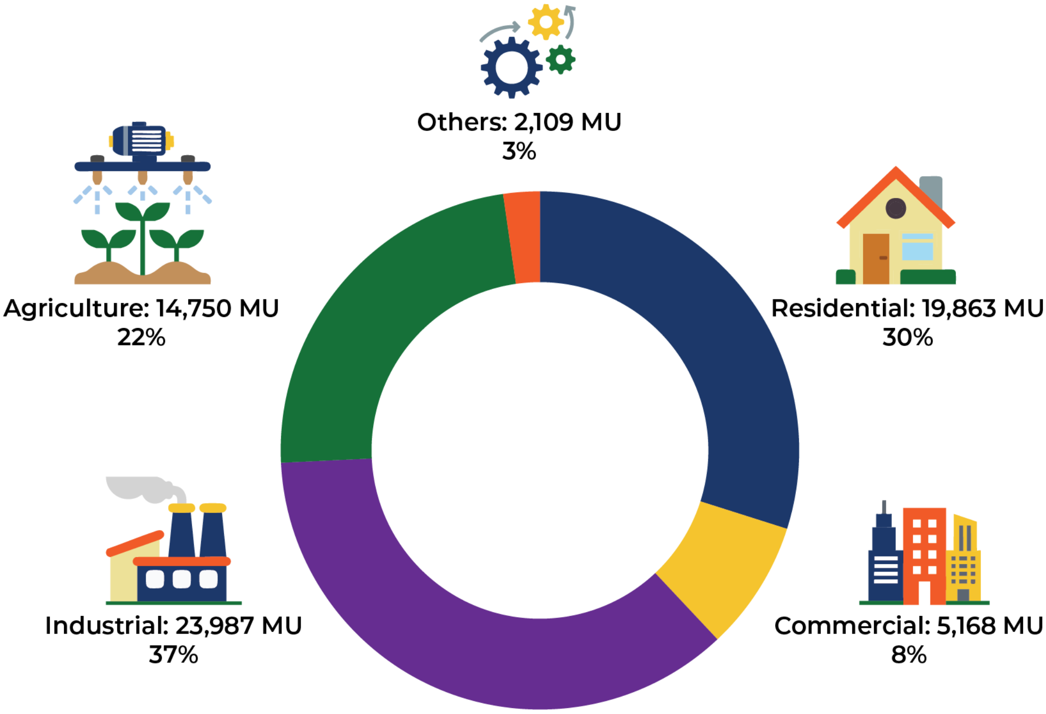
Punjab has seen a steady growth in its energy consumption over the years. Figure 5 depicts the historic energy trend in the state. The energy sales were around 41,016 MU in FY 2016, and reached 65,877 in FY 2025, growing at a CAGR of 5.4%.

Figure 5: Punjab electricity consumption (in MU)



Looking at the categories of accounts that constituted the overall power consumption in FY 2025, it is observed that the industrial category recorded a significant consumption, totalling 23,987 MU, as depicted in Figure 6. The residential category accounted for 19,863 MU of electricity consumption, followed by the agricultural category that consumed 14,750 MU, and the commercial category that accounted for a consumption of 5,168 MU. The remaining 2,109 MU of consumption is attributed to the 'other' category[1].

Figure 6: Category-wise electricity consumption in FY 2025



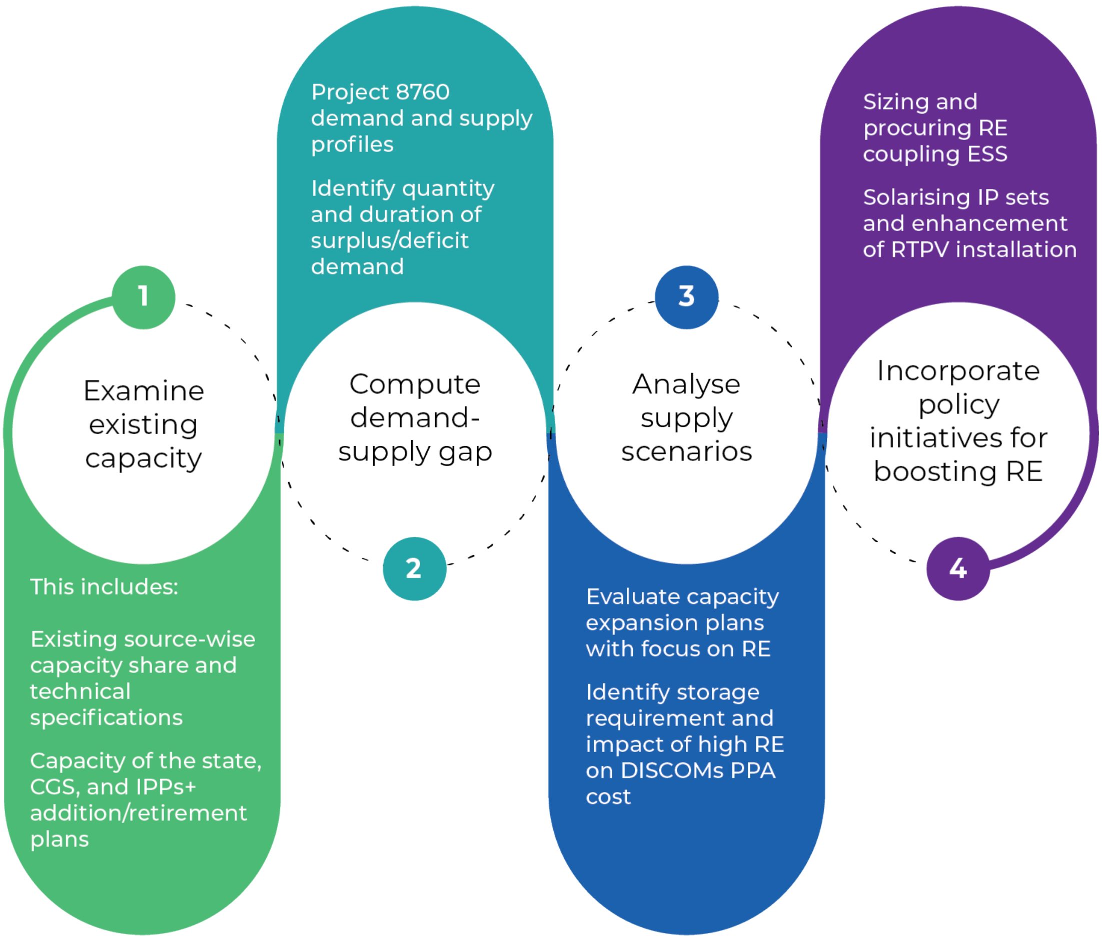
[1] 'Other' category includes bulk supply, railway traction, compost/solid waste management for municipalities, water supply schemes, charitable hospitals, start-up power for generators and captive power plants, and consumption at the Golden Temple and Durgiana Mandir in Amritsar.

3. Methodology

Understanding Punjab's existing power demand and supply, and the demand-supply gap was a prerequisite for our study. For this, we gathered historical electricity consumption data for each consumer category over the past 6 years (FY 2020 to FY 2025), sourced from PSPCL. Using the CAGR method, we projected the business-as-usual (BAU) demand forecast (DF) for each category up to FY 2036. The BAU demand was then overlaid with the policy levers influencing the consumer-category demand, such as potential impact of electric vehicle (EV) adoption, as well as energy efficiency improvements in the residential and commercial sectors. We also factored in the deployment of energy-efficient (EE) pumps and the solarisation of irrigation pump (IP) sets in the agricultural sector to estimate energy demand.

Next, we performed a comprehensive analysis of supply planning by evaluating the available generation capacity, considering the technical operational limits of plants during the 8,760 hours in each financial year studied. In addition, the future expansion and retirement plans by state and central generating stations (CGS) were also assessed. Further, two scenarios with varying capacity mixes were explored to assess the additional capacity requirements. The methodology is illustrated broadly in Figure 7.

Figure 7: Steps for achieving demand-supply balance



We analysed two supply scenarios, (1) Conventional Scenario (which considered RE addition, along with thermal and nuclear energy sources), and (2) Clean Energy Scenario (which considered RE addition, along with only nuclear energy sources), to determine the generation capacity required by the state to meet the projected demand, along with year-on-year (Y-o-Y) storage requirements to manage RE intermittency and provide round-the-clock power.

We also assessed the impact of RE capacity (particularly solar and wind) on the power purchase cost of distribution companies (DISCOMs) and recommended suitable policy interventions for a smooth transition in the state. The approach took into account the weighted average cost of each energy resource, assuming that the tariffs for thermal, nuclear, gas, wind, other NCEs, and hydro resources remain consistent with the FY 2025 levels, up to FY 2036. However, for solar power purchase agreements (PPAs) commissioned after FY 2025, a reduction in tariff rates has been considered. Additionally, the analysis considered energy charges from purchases made through exchanges, traders, and banking arrangements, along with the average tariff for transmission charges. PSPCL has provided the details of its contracted capacity with various generating stations as of FY 2024 and FY 2025, which have been incorporated into our analysis.

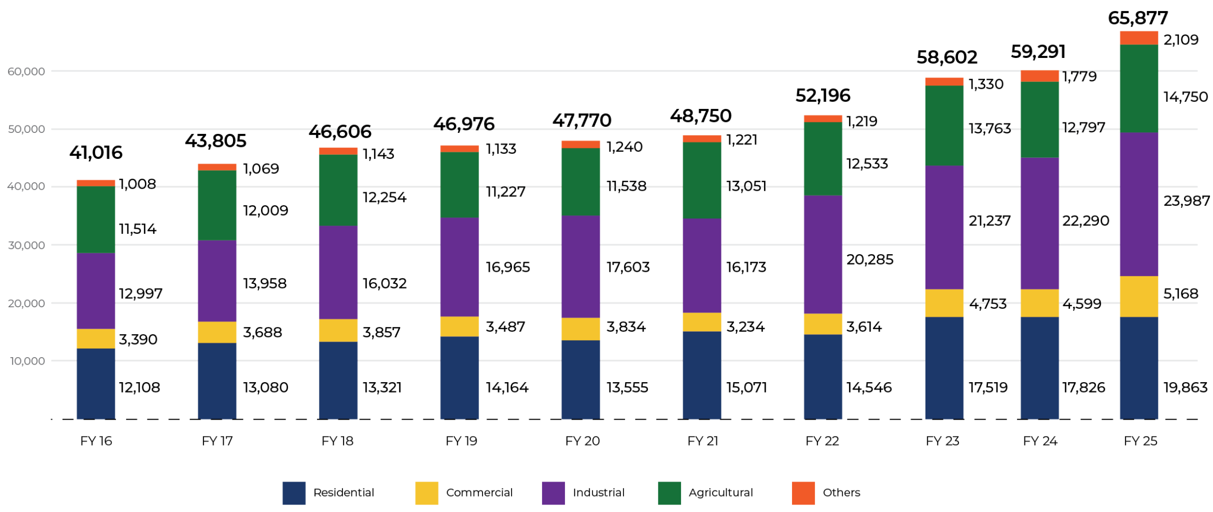
4. Demand Projections: FY 2026 to FY 2036

Demand forecast is crucial for understanding the future energy needs of the state so as to enable an optimal resource planning for meeting these needs effectively. We forecasted the Y-o-Y demand that the state may experience from FY 2026 to FY 2036.

4.1 BAU demand forecast

To estimate the demand for each category within the state, we applied the CAGR method. Figure 8 shows the historical consumption data spanning the past 8 years.

Figure 8: Historic category-wise energy consumption (in MU)



Source: PSPCL

We observed the Y-o-Y growth trends across various categories, which are summarised in Table 1. On examining these trends, we identified significant growth, particularly in the last two years, signalling a shift in the demand patterns for certain categories. The CAGR for the periods 'FY 26–FY 30' and 'FY 31–FY 36' have been projected on the basis of the historical 6-year and 7-year growth rates.

Table 1: Category-wise CAGR (in %)

CAGR Period→	FY 16–FY 25	FY 20–FY 25	FY 26–FY 30	FY 31–FY 36
Category↓	**9-year**	**5-year**		
Residential	6%	8%	**8%**	**3%**
Commercial	5%	6%	**6%**	**4%**
Agricultural	3%	5%	**5%**	**2%**
Industrial	7%	6%	**6%**	**5%**
Others	9%	11%	**11%**	**2%**
Overall	5.4%	6.6%	**6.6%**	**3.6%**

Given this notable uptick in growth, especially in the recent period, we adjusted the traditional CAGR approach to better reflect the evolving demand landscape. Thus, for forecasting the demand from FY 2026 to FY 2030, we considered the latest or higher growth rates observed in the previous year. This adjustment allowed us to capture the current growth momentum in the state's consumption patterns more accurately.

To forecast the demand from FY 2031 to FY 2036, we considered a modulated CAGR approach. This modulation took into account the sustained trends from earlier periods, ensuring that our demand projection aligns with both short-term surges and long-term growth dynamics. These adjustments in the forecast methodology were made to provide a more precise estimation of the BAU demand for each consumption category up to FY 2036, as shown in Table 2. The BAU demand by FY 2036 is estimated to be 1,26,347 MU.

Table 2: Consumer-category-wise projected electricity demand (in MU)

Category	CAGR	FY 26	FY 28	FY 30	Modulated CAGR	FY 32	FY 34	FY 36
Residential	8%	21,440	24,981	29,107	3%	30,879	32,760	34,755
Commercial	6%	5,486	6,182	6,967	4%	7,581	8,250	8,978
Industrial	6%	25,518	28,881	32,686	5%	36,036	39,730	43,802
Agricultural	11%	2,345	2,900	3,587	2%	3,732	3,883	4,039
Others	5%	15,493	17,092	18,857	2%	19,619	20,411	21,236
BAU demand	**6.6%**	**70,283**	**80,037**	**91,203**	**3.7%**	**97,847**	**1,05,033**	**1,12,810**
T&D Loss (%)		13.75%	13.63%	13.50%		13.00%	12.50%	12.00%
Final DF with T&D losses		**79,947**	**90,942**	**1,03,515**		**1,10,567**	**1,18,163**	**1,26,347**
Peak Demand (MW)		**17,109**	**19,462**	**22,153**		**23,662**	**25,288**	**27,040**

4.2 Impact of policy levers on Punjab's energy demand

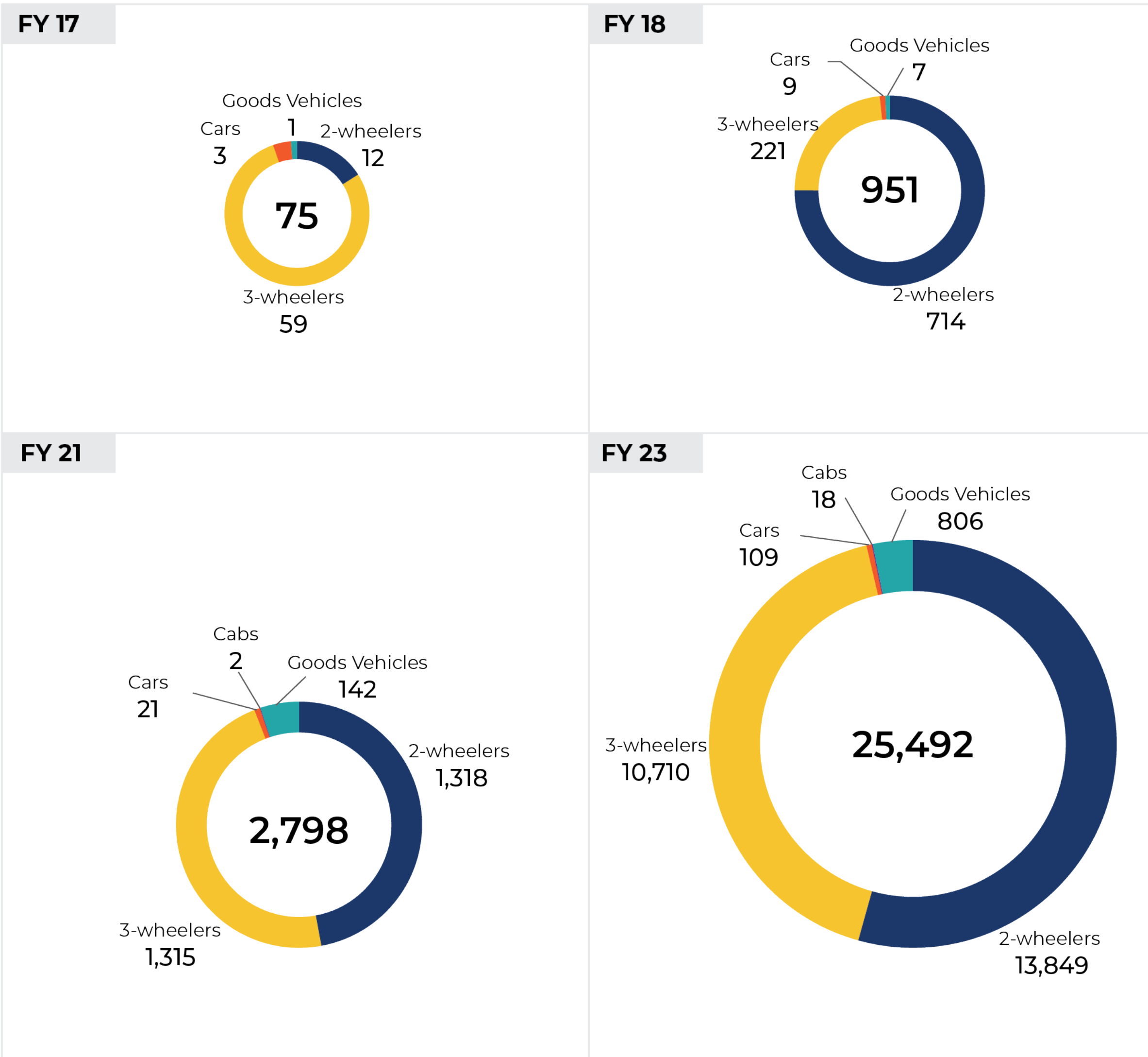
The BAU scenario projected demand on the basis of historical trends. However, accounting for the impact of various policies on the future demand is crucial, especially in the current evolving energy policy landscape. For this, we analysed the prominent developments in this space, such as electric vehicle (EV) adoption, rooftop photovoltaic (RTPV) penetration, energy efficiency measures (with regard to commercial buildings, household appliances, and the agriculture sector), and solarisation of IP sets to assess their potential effects on the state's energy demand. These are detailed in the following subsections.

4.2.1 EV adoption

The transport sector is expected to add considerably to the future electricity demand. Considering the growing consumer interest in EVs, Punjab's EV Policy has set an ambitious goal to have 25% of all new vehicle sales electric by FY 2025 (Government of Punjab, 2023). This push for EV adoption is further strengthened by the Indian Government's 'EV30@30' initiative that aspires to attain a 30% sales share for EVs nationally by 2030 (CEM, 2017).

Vehicle registrations in the state have risen significantly—from 88.7 lakh in FY 2017 to 1.27 crore in FY 2023—reflecting a CAGR of 5.1%. If this growth continues, the total vehicle registrations in Punjab are projected to reach 2.81 crore by FY 2036. The number of new EV registrations has also surged, increasing from 75 in FY 2017 to 25,492 in FY 2023 (Ministry of Road Transport and Highways of India, 2011), representing a CAGR of 164%. Figure 9 lists the category-wise EV registrations in the state during this period.

Figure 9: Category-wise EV registrations in Punjab (FY 2017 to FY 2023)



Source: Vahan Dashboard, Ministry of Road Transport and Highways of India

Since the extremely high CAGR of 164% is not a realistic basis for forecasting future EV penetration, we adjusted our assumptions for EV adoption. Our analysis estimates that by FY 2030, the category-wise share of EVs in all newly added vehicles will be as follows: 36% (of all new 2-wheelers), 48% (of all new 3-wheelers), 10% (of all new cars), 48% (of all new cabs), 21% (of all new buses), and 14% (of all new goods vehicles), as shown in Table 3. By FY 2036, these figures are expected to rise to 71% (for 2-wheelers), 96% (for 3-wheelers), 20% (for cars), 96% (for cabs), 42% (for buses), and 27% (for goods vehicles). These projections indicate that EVs will represent 30% of the total new vehicle registrations by FY 2030, and 60% by FY 2036, as compared to the current 7% (in FY 2023). Table 3 shows the projected EV share across various vehicle categories.

Table 3: Projected vehicle-category-wise share of EVs in new sales

Vehicle type/category	In FY 23	By FY 30	By FY 36
2W	5%	36%	71%
3W	38%	48%	96%
Cars	0.1%	10%	20%
Cabs	0.3%	48%	96%
Buses	2%	21%	42
Goods Vehicles	1%	14%	27%
Total	**6.5%**	**30%**	**60%**

Based on the above considerations, the Y-o-Y category-wise EV numbers were projected (as given in Table 4), with the total number reaching 51.40 lakhs, accounting for 18% of total vehicles by FY 2036.

Table 4: Projected number of EVs (category-wise)

Category/Type	FY 24	FY 28	FY 32	FY 36
2W	1,97,693	4,71,752	18,13,611	46,21,840
3W	14,684	17,823	26,098	40,945
Cars	2,335	9,672	86,998	2,55,072
Cabs	347	1,734	20,599	64,207
Buses	7,275	639	3,550	9,377
Goods Vehicles	205	16,616	60,519	1,48,290
Total	**2,22,540**	**5,18,236**	**20,11,373**	**51,39,732**

The energy demand from each EV category (for charging) was estimated on the basis of an individual vehicle's energy consumption and the average daily kilometres travelled by the vehicle (as given in Figure 10).

Figure 10: EV-category-wise daily energy need

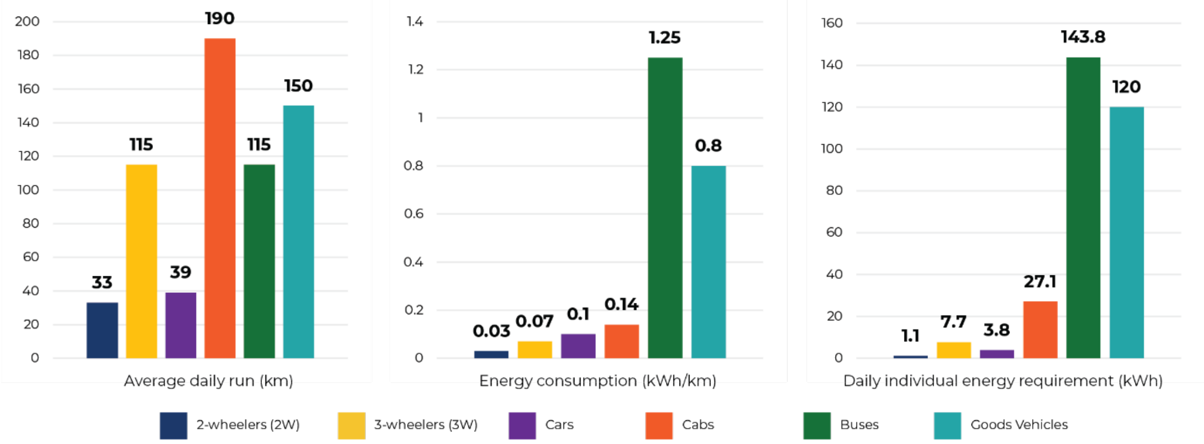


Table 5 lists the annual Y-o-Y energy demand for EVs. With higher EV adoption, the state would experience an additional energy demand of 9,087 MU by FY 2036.

Table 5: Vehicle category-wise daily energy needs

Category	FY 26	FY 28	FY 30	FY 32	FY 34	FY 36
2W	72	173	368	665	1,089	1,695
3W	38	46	55	67	83	105
Cars	3	12	49	111	200	326
Cabs	3	16	76	186	347	581
Goods	291	665	1,370	2,421	3,887	5,932
Buses	10	31	85	170	288	449
Total	**417**	**942**	**2,002**	**3,620**	**5,894**	**9,087**

4.2.2 Rooftop photovoltaic systems

With regard to rooftop photovoltaics, the state's target, according to the Ministry of New and Renewable Energy's (MNRE) state-wise trajectory, was to install 2,000 MW of RTPV capacity by FY 2022. However, as of 30 April 2025, the installed RTPV capacity in the state stood at only 454 MW, indicating a significantly lower-than-expected uptake. Given this slower pace of adoption, we project that the 2,000 MW target will now be reached by FY 2036, assuming a capacity utilisation factor (CUF) of 15%. This extension of timeline indicates a need for concerted efforts to drive RTPV deployment for taking the state closer to its RE goals.

Table 6: Y-o-Y RTPV targets and energy share

Particulars	FY 26	FY 28	FY 30	FY 32	FY 34	FY 36
Total RTPV capacity installed (MW)	520	680	891	1,166	1527	2,000
RTPV energy generation (MU)	683	894	1,170	1,533	2,007	2,628
BAU demand (MU)	70,283	80,037	91,203	97,847	1,05,033	1,12,810
% Energy share from RTPV	1%	1%	1%	2%	2%	2%

Thus, if the state achieves the targeted RTPV capacity (as shown in Table 6), it would be able to meet 2% of its BAU demand by FY 2036.

4.2.3 Energy efficiency in residential and commercial categories

Commercial buildings and household appliances, respectively, occupy a large share of commercial and residential electricity consumption. Enhancing energy efficiency in the residential and commercial categories can significantly reduce the overall electricity demand and support sustainability efforts.

To promote energy efficiency, many states have notified the Energy Conservation Building Code (ECBC). Punjab made ECBC mandatory for commercial buildings in 2016. According to the Punjab ECBC guidelines (PEDA, 2020), the adoption of ECBC in commercial buildings is expected to result in 30% to 40% lesser energy consumption than that in the conventional buildings.

The following assumptions were made for forecasting the demand in the residential and commercial categories, while presuming that energy efficiency measures have been implemented:

- The state population would grow at a CAGR of 1%.
- Residential consumers would grow at a CAGR of 2.4%.
- In the residential category (w.r.t lighting):
    - 60-watt incandescent bulbs would be replaced by 40-watt fluorescent tubes or 8-watt LED bulbs.
    - LED penetration would reach almost 45% in FY 2036, from 21% in FY 2022.
    - Penetration of fluorescent lights would increase from 19% in FY 2022 to 26% in FY 20*36*.
    - Penetration of incandescent bulbs would reduce from 26% in FY 2022 to 8% in FY 2036.
- In the residential category (w.r.t appliances):

   - Penetration of high-efficiency appliances (television, ceiling fans, refrigerators, and room air-conditioners) would increase from 16% in FY 2022 to 35% in FY 2036.
   - Penetration of low-efficiency appliances would reduce from 59% in FY 2022 to 18% in FY 2036.
- In the commercial category:
   - The Energy Performance Index (EPI) of conventional buildings would increase from 90 KWh/m^2/year in FY 2022 to 114 KWh/m^2/year in FY 2036 (Kumar et al., 2017).
   - The ECBC-complaint buildings would have an EPI that is 30% less than that of conventional buildings.
   - The commercial floor area per capita would grow from 0.9 m^2 in FY 2022 to 2.78 m^2 in FY 2036.

The total energy consumption in the residential sector is determined by the equation:

*No. of appliances*Weighted usage hours*Weighted average wattage efficiency across different penetration levels (low/medium/high)*

The difference between the total energy consumption in the BAU case and in the case where the impact of policy developments is incorporated represents the net energy savings for residential consumers.

The energy consumption for commercial buildings (for both conventional and ECBC-compliant buildings) is calculated by the equation:

*EPI per square meter*Total commercial floor space in square meter*

The net energy reduction is then determined by comparing the energy consumption of these two types of commercial buildings.

The increased energy efficiency in lightings and appliances will reduce the overall energy consumption by 19.06% (Table 7) in the residential sector and by 3.19% in the commercial sector by FY 2036 (Table 8).

Table 7: Impact of energy efficiency measures on the residential sector (in MU)

Year	BAU demand (MU)	Energy savings due to energy efficiency measures (MU)	Energy savings (% of BAU demand)	Resultant demand (MU)
FY 26	21,440	2,646	12.34%	18,794
FY 28	24,981	3,573	14.30%	21,408
FY 30	29,107	4,774	16.40%	24,333
FY 32	30,879	5,713	18.50%	25,166
FY 34	32,760	6,146	18.76%	26,614
FY 36	34,755	6,614	19.03%	28,141

Table 8: Impact of energy efficiency measures on the commercial sector (in MU)

Year	BAU Demand (MU)	Energy savings due to ECBC (MU)	Energy savings (% of BAU demand)	Resultant demand (MU)
FY 26	5,486	59	1.1%	5,428
FY 28	6,182	84	1.4%	6,908
FY 30	6,967	119	1.7%	6,848
FY 32	7,581	161	2.1%	7,420
FY 34	8,250	215	2.6%	8,035
FY 36	8,978	286	3.2%	8,691

4.2.4 Solarisation and energy efficiency in agriculture

In the agriculture sector, the number of IP sets—including conventional and EE sets—has grown at a CAGR of 2%, increasing from 12.6 lakh in FY 2016 to 14.2 lakh in FY 2022. Based on this trend, we project a CAGR of 2% up to FY 2030 and 1.5% up to FY 2036, leading to an estimated 18.11 lakh IP sets by FY 2036 (Table 9).

Given the strong support from both state and central governments for solarising agricultural power consumption, we expect that the phased solarisation of around 1 lakh pumps sanctioned under 'Component C: Feeder-Level Solarisation' (FLS) of the *Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan* (PM KUSUM) scheme will, along with additional future sanctions, enable grid-connected IP sets to form 10% of the total IP sets by FY 2036 (PIB, 2023).

Further, a focussed effort by the state to replace conventional pumps with EE ones is crucial for energy conservation. We project a gradual increase in the replacement rate, starting at 1.5% of the total IP sets in FY 2023, and doubling it annually. This approach would enable the state to achieve the replacement of 22% of IP sets with EE alternatives by FY 2036, significantly improving energy efficiency in the agriculture sector.

The state also needs to continue its work on transitioning from diesel-powered pumps to grid-connected systems. In areas where grid access is unavailable, off-grid solar pumps can be deployed as a viable alternative. By FY 2019, around 4,925 off-grid solar pumps had been installed, and by FY 2023, this number increased to approximately 16,710 under the PM KUSUM scheme (MNRE, 2023). With 78,000 solar pumps sanctioned under Component B of the scheme, we estimate that by FY 2036, off-grid solar pumps will account for approximately 5% of the total IP sets, as depicted in Table 10.

Table 9: Projections for grid-connected IP sets

Year	Grid-connected sets			
	EE IP sets	Solar IP sets	Conventional IP sets	Total electric IP sets
FY 26	96,396	35,390	14,01,789	15,33,576
FY 28	1,50,369	61,339	13,83,116	15,94,825
FY 30	2,08,500	89,305	13,60,715	16,58,520
FY 32	2,68,382	1,18,238	13,21.266	17,07,887
FY 34	3,31,645	1,48,815	12,78,263	17,58,724
FY 36	3,98,436	1,81,107	12,31,530	18,11,073

Table 10: Projections for off-grid IP sets

Year	FY 26	FY 28	FY 30	FY 32	FY 34	FY 36
Off-grid solar IP sets	34,405	47,380	61,362	75,829	91,118	1,07,264

The deployment of grid-connected solar pumps is expected to significantly reduce the load on the state's electricity grid. By FY 2036, the deployment of 1,81,107 solar pumps is projected to reduce the energy demand by approximately 2,123.6 MU. In addition, replacing 3,98,436 conventional pumps with EE pumps could further decrease energy consumption. This transition is estimated to reduce energy demand by 23% (TUV SUD South Asia Pvt. Ltd., 2010), leading to a savings of around 1,074.5 MU in FY 2036. The Y-o-Y cumulative energy savings is detailed in Table 11. The above-mentioned measures will, collectively, contribute to easing the pressure on the grid and enhancing overall energy efficiency in the agriculture sector.

Table 11: Demand projections for the agriculture sector (in MU)

Year	BAU demand (MU)	Energy savings due to solarisation and energy efficiency measures (MU)	Energy savings (% of BAU demand)	Resultant demand (MU)
FY 26	15,493	582	3.75%	14,911
FY 28	17,092	1,028	6.01%	16,064
FY 30	18,857	1,561	8.28%	17,296
FY 32	19,619	2,067	10.54%	17,551
FY 34	20,411	2,612	12.80%	17,799
FY 36	21,236	3,198	15.06%	18,038

4.3 Demand forecast incorporating the impact of policy levers

The impact of the policy levers (Table 12) was overlaid on the BAU demand forecast to obtain the final Y-o-Y demand forecasts (Table 13).

Table 12: Y-o-Y impact of policy levers

Impact of policy levers	FY 26	FY 28	FY 30	FY 32	FY 34	FY 36
Reduction in energy consumption due to energy efficiency measures in the residential sector (in % and MU)	12.3% (2,646)	14.3% (3,573)	16.4% (4,774)	18.5% (5,713)	18.8% (6,146)	19.0% (6,614)
Reduction in energy consumption due to energy efficiency measures in the commercial sector (in % and MU)	1.1% (59)	1.4% (84)	1.7% (119)	2.1% (161)	2.6% (215)	3.2% (286)
Reduction in energy consumption due to energy efficiency and solarisation measures in agriculture sector (in MU)	582	1,028	1,561	2,067	2,612	3,198
Reduction in energy consumption due to RTPV adoption (in MU)	683	894	1,170	1,533	2,007	2,628
Increase in energy consumption due to EV penetration (in MU)	417	942	2002	3620	5894	9087

The BAU demand incorporating the impact of policy levers is projected to be 66,731 MU in FY 2026 and 1,09,171 MU by FY 2036 (Table 13), with a Y-o-Y CAGR of 5%. This demand forecast has been made at the consumer end, without the inclusion of T&D losses. The final energy requirement, including T&D losses, is projected to be 75,906 MU in FY 2026 and 1,22,271 MU by FY 2036, as shown in Table 14.

Table 13: Y-o-Y final energy demand forecast (in MU)

Consumer category	FY 26	FY 28	FY 30	FY 32	FY 34	FY 36
Residential	18,794	21,408	24,333	25,166	26,614	28,141
Commercial	5,428	6,098	6,848	7,420	8,035	8,691
Industrial	25,518	28,881	32,686	36,036	39,730	43,802
Others	2,345	2,900	3,587	3,732	3,883	4,039
Agricultural	14,911	16,064	17,296	17,551	17,799	18,038
RTPV (-)	683	894	1,170	1,533	2,007	2,628
EV (+)	417	942	2,002	3,620	5,894	9,087
Final demand	**66,731**	**75,400**	**85,580**	**91,993**	**99,947**	**1,09,171**

Table 14: Y-o-Y final energy requirement with T&D losses (in MU)

Year	FY 26	FY 28	FY 30	FY 32	FY 34	FY 36
DF without T&D losses	66,731	75,400	85,580	91,993	99,947	1,09,171
T&D losses (%)	13.75%	13.63%	13.50%	13%	12.50%	12%
Final DF with T&D losses	**75,906**	**85,673**	**97,134**	**1,03,952**	**1,12,440**	**1,22,271**
Peak Demand (MW)	**16,245**	**18,335**	**20,788**	**22,347**	**24,063**	**26,167**

5. Demand-Supply Planning

This section analyses the demand-supply deficit to evaluate how effectively the existing generation capacity can meet the state's projected demand. Following this, the resource requirement for meeting the projected demand primarily through RE sources—in combination with storage systems—has been calculated, considering two specific scenarios.

5.1 Existing generation mix

In FY 2025, Punjab's contracted capacity was 14.86 GW. Of this, independent power producers (IPPs) accounted for the largest share at 44.25%, followed by state-owned capacity at 30.33%, and central generating stations (CGS) at 25.42%. The source-wise and ownership-wise capacity mix is provided in Table 15.

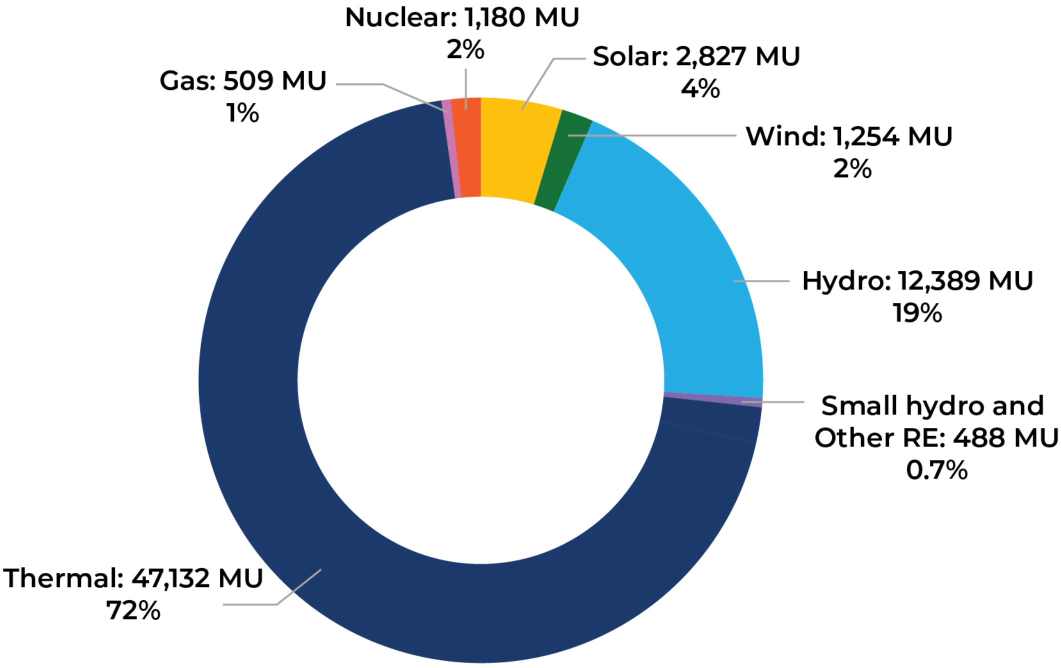
Table 15: Source-wise installed capacity

S. No.	Source	Ownership	Capacity (MW)
1	Thermal	State	2,3309
		CGS	1,440
		IPP	4,493
		Sub-total (A)	*8,233*
2	Gas	IPP (B)	137
3	Nuclear	CGS (C)	197
4	Hydro	State	2156
		CGS	924
		IPP	318
		Sub-total (D)	*3,398*
5	Solar	IPP (E)	2,159
6	Wind	IPP (F)	450
7	Other RES	IPP (G)	287
		Total (A+B+C+D+E+F+G)	**14,861**

The source-wise energy mix is shown in Figure 11. Punjab is extensively dependent on fossil-fuel-based plants that form 72% of its total energy mix (contributing 47,641 MUs); the remaining 28% is made up by clean energy sources (which contribute 18,138 MUs).

Punjab's power sector also typically engages in banking arrangements with various utilities and traders to manage the surplus and deficit power. During periods of low supply, particularly from June to October, the state imports energy to cover deficits. Conversely, surplus energy is exported from November to May. Usually, the state ends up importing more energy than what it exports through these arrangements.

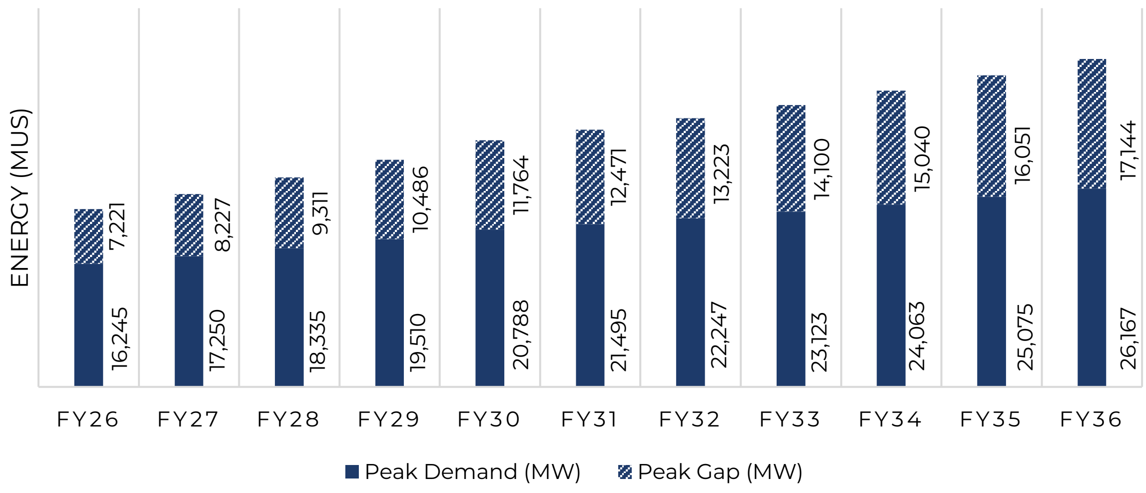
Figure 11: Source-wise energy mix

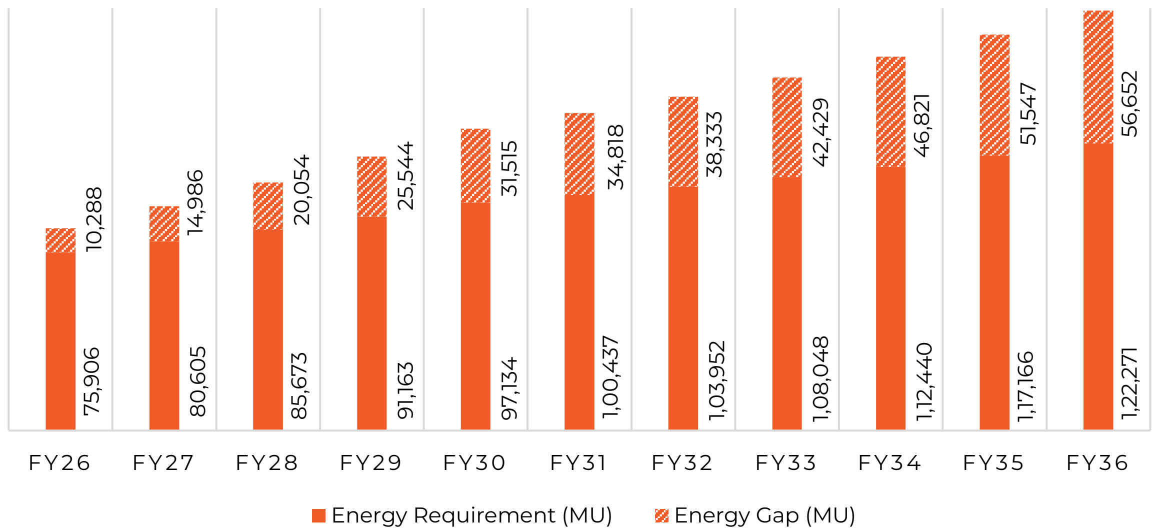


The state's contracted capacity for FY 2025 stood at 14,861 MW, while the available generation capacity at the peak-demand instant was 9,024 MW. Looking ahead, the (projected) peak demand is expected to rise from 16,245 MW in FY 2026 to 26,167 MW in FY 2036, with a CAGR of 4%. Similarly, the projected energy requirement is set to grow at a CAGR of 4%, increasing from 75,906 MU in FY 2026, to 1,22,271 MU in FY 2036.

Consequently, with the current available capacity, at the peak instant, a power deficit of 7,221 MW will occur in FY 2026, which will further increase to 17,144 MW by FY 2036. This underscores the need for additional capacity. The Y-o-Y peak demand and energy requirements, along with the corresponding deficits, are illustrated in Figure 12.

Figure 12: Peak demand and energy gap





5.2 Scenarios for identifying resource requirement

We analysed the demand-supply situation through the following two scenarios to determine the optimal energy mix for Punjab:

1) **Conventional Scenario:** Considers RE addition, along with thermal and nuclear energy sources for meeting projected energy demand and fulfilling RPO targets.

2) **Clean Energy Scenario:** Considers RE addition, along with only nuclear energy sources only for meeting projected energy demand.

For examining these two scenarios:

- The contracted generation capacity and auxiliary consumption details for each plant in Punjab were considered as per the data provided by PSPCL (refer to Appendix A).

- Plant load factor (PLF) for each plant were taken from the FY 2023 technical performance data provided by CEA (Ministry of Power, 2024). Using the average plant availability factor (PAF), the available generation capacity for each of the 8,760 hours was evaluated.
- For hydro plants, month-wise PLFs were used to determine the hourly available generation.
- For solar and wind plants, the hourly generation profiles were modelled using their specific geographical locations and contracted/installed capacities, leveraging the Ninja RE (*Renewables.ninja*, n.d.) and CSTEM PV tools (CSTEP, 2024).
- The state's capacity expansion plans till FY 2036 were considered, and the replacement of older thermal plants—aged above 25 years (extended to 40-45 years)—was considered as per the expiry dates of their PPAs. The details are given in Table 16.

Table 16: Capacity addition and replacement of plants

State capacity addition plan till 2036				
S. No.	**Source**	**Name of the plant**	**State's share (MW)**	**Year of commissioning**
1	Hydro	Parbati-II	80	FY 26
2		Subhansiri Lower (8X250)	64	FY 26
3		Teesta-VI	87	FY 26
4		Ratle HEP	148	FY 26
5		Rangit-IV	21	FY 26
6		Vishnugarh Pipalkoti	27	FY26
Replacement of old plants (25 years of age)				
1	Thermal	Unchahar-II	60	FY 26
2		Singrauli	200	FY 27
3		Rihand-II	102	FY 31
4		Unchahar-III	17	FY 32
5		Rihand-I	110	FY 35
6		Kahalgaon-II (ER)	120	FY 35
7	Gas	Pragati-III	137	FY 30

We used FY 2025 as the base year and extrapolated the load curves for each subsequent year until FY 2036, assuming that the curve shape remains consistent but with growth-related variations in magnitude. We then analysed the demand and supply balance, identifying the total hours of under-generation and over-generation for each case, along with the respective energy volumes.

5.3 Conventional scenario

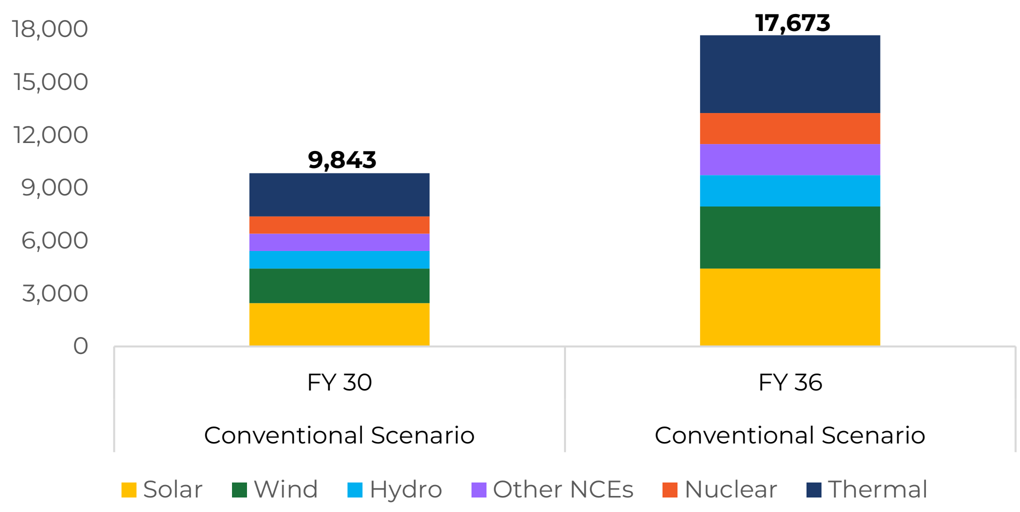
In this scenario, to bridge the anticipated power and energy gaps, we focussed on capacity expansion plans that rely on RE, nuclear, and thermal sources. This analysis assumes that the state opts for a conservative approach to nuclear and thermal capacity expansion, as suggested by the stakeholder. The thermal capacity is assumed to be added from FY 2026 to FY 2030, followed by nuclear capacity additions from FY 2031 to FY 2036.

The different sources recommended for capacity addition include solar (55%), wind (15%), small hydro (8%), bio-power (18%), large hydro (5%), and nuclear and thermal (10%). Additionally, we recommend storage solutions to ensure a smooth integration of the increased RE capacity into the grid.

5.3.1 New capacity requirement

For estimating the new capacity requirement for Punjab, we analysed its proposed capacity additions. The state has 427 MW of hydro capacity scheduled for FY 2026, and the phased replacement of older thermal plants (with a capacity of 746 MW) is also coming up between FY 2026 and FY 2036. After evaluating the forecasted hourly demand and the state's existing and proposed supply availability, we proposed capacity additions to overcome the peak demand deficits. The planned additional capacity is illustrated in Figure 13. By FY 2030, an additional capacity requirement of 9,843 MW is projected for the state, alongside its planned capacity addition of 427 MW and the replacement of 397 MW of aging thermal capacity. By FY 2036, the new capacity requirement is expected to be 17,673 MW, considering the replacement of 349 MW of older thermal capacity.

Figure 13: New capacity requirement for conventional scenario (in MW)



The projected cumulative installed capacity for FY 2030 and FY 2036 is presented in Table 17. The share of thermal and gas capacity—which is currently around 56%—is expected to decrease to 42% by FY 2030 and further to 37% by FY 2036. This reduction in fossil-fuel-based capacity is relatively modest compared to that in the 'Clean Energy Scenario' with an increased reliance on RE and nuclear energy.

As a result of the increased RE capacity in the overall mix, the share of clean energy sources is projected to grow from 44% in FY 2025 to 58% by FY 2030 and 63% by FY 2036 (Table 17). To support this significant increase in renewable energy, the state should consider developing 7,451 MW of storage capacity by FY 2036, utilising both pumped-hydro energy storage (PHES) and battery energy storage systems (BESS).

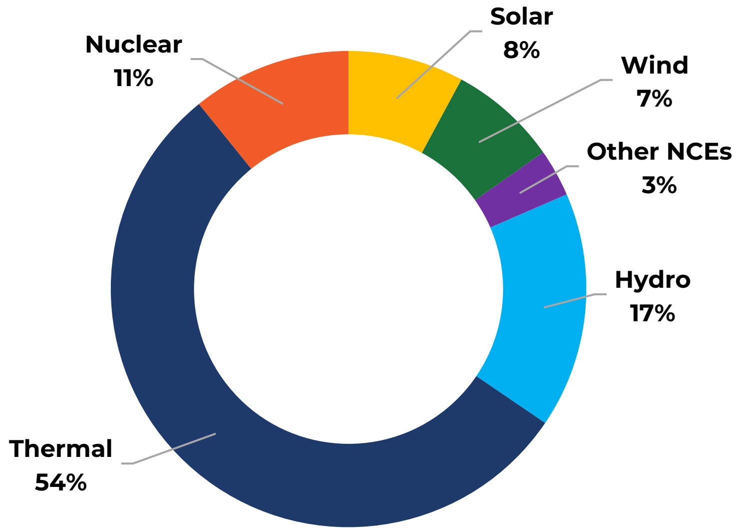
Table 17: Cumulative capacity requirement for conventional scenario (in MW)

Source	FY 30	FY 36
Solar	4,620	6,577
Wind	2,419	3,985
Hydro	4,809	5,592
Other NCEs	1,271	2,054
Nuclear	1,181	1,964
Thermal + Gas	10,433	12,042
Total	**24,733**	**32,214**
Storage	1,953	7,451

5.3.2 Energy mix

With these proposed capacity additions, the state can expect a higher share of clean energy sources in the energy mix by FY 2036, as compared to the FY 2025 mix. The energy mix observed in FY 2036 is shown in Figure 14. The state anticipates that the energy mix will consist of 41% clean energy and 59% fossil-fuel-based energy by FY 2030. By FY 2036, this mix is expected to have 46% of clean energy and 54% of fossil-fuel-based energy.

Figure 14: Energy mix for conventional scenario (FY 2036)



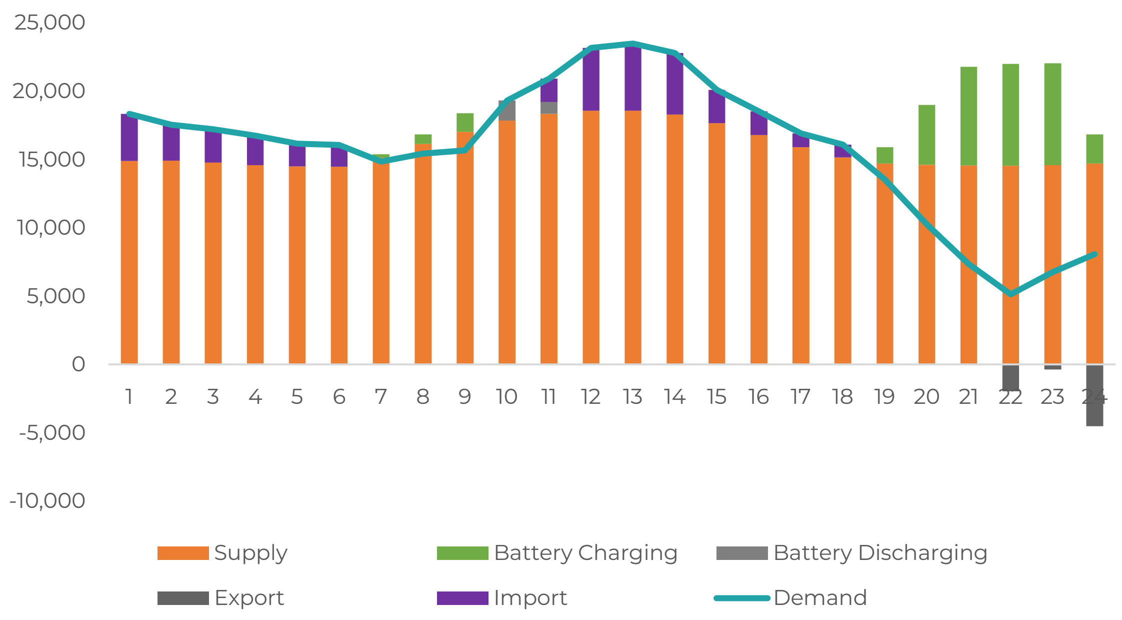
5.3.3 Storage requirement

We identified the maximum energy deficit through an assessment of power surplus and deficit across the 8760 hours studied for each year. We assessed that initially 11% of the peak deficit would be compensated by deploying 1,000 MW of storage capacity by FY 2027. Thereafter, the state would need to expand the storage systems at a CAGR of 25% annually till FY 2036, reaching a cumulative storage capacity of 7,451 MW.

The energy generated during periods of over-generation surpasses that produced during under-generation periods, providing ample energy for charging and discharging storage systems, thereby resolving energy deficits. To effectively manage peak demand, it is advisable to optimise the operation of storage systems by charging them through the excess power available during over-generation hours and discharging them during generation-deficit periods. Any residual surplus power (left after charging) should be exported through energy banking arrangements. Punjab, for instance, has established energy banking agreements with various utilities, allowing it to export surplus power from November to May and receive it back from June to October. If after utilising the storage systems, a deficit remains, this deficit should first be addressed through banking arrangements. Any residual shortfall should be made up for by procuring power from day-ahead markets.

Figure 15 illustrates the hourly analysis of supply, demand, and storage operations on 5 June 2035. The supply curve follows a typical pattern, with a surplus generation during RE availability and a deficit during non-RE periods. Demand surpasses supply during the morning, between 01:00–06:00 hours, resulting in a deficit ranging between 1,598 MWh and 3,431 MWh, which is solely met by imports/purchases from exchanges. The demand decreases between 07:00 and 09:00 hours, resulting in a surplus of 266 MWh to 1,361 MWh, which is used for charging the ESS to a capacity of 2,340 MWh. Again, a deficit occurs between 10:00 and 16:00 hours, ranging from 926 MWh to 4,915 MWh. The deficit of 1,471 MWh occurring at 10:00 hour is fully met through ESS, while the deficit of 2,579 MWh occurring at 11:00 hour is partially met by utilising the remaining stored energy (869 MWh). Since there is no more stored energy left, the rest of the deficit (1,710 MWh) is met through imports. The demand gradually decreases between 19:00 and 24:00 hours, resulting in a surplus at every hour, which ranges between 1,183 MW and 9,406 MW. At every hour, 7,451 MWh of the surplus energy is used for charging the storage, and the remaining is exported or sold in the exchanges.

Figure 15: Demand- supply and storage curve for conventional scenario



The peak demand day (on 29 June of each fiscal year) will experience under-generation for all 24 hours. So, there will not be enough energy to charge the storage and manage the demand, requiring the import of power through banking arrangements to cater to the peak demand.

A demand-supply planning was also carried out for the BAU demand projections and is detailed in Appendix B.

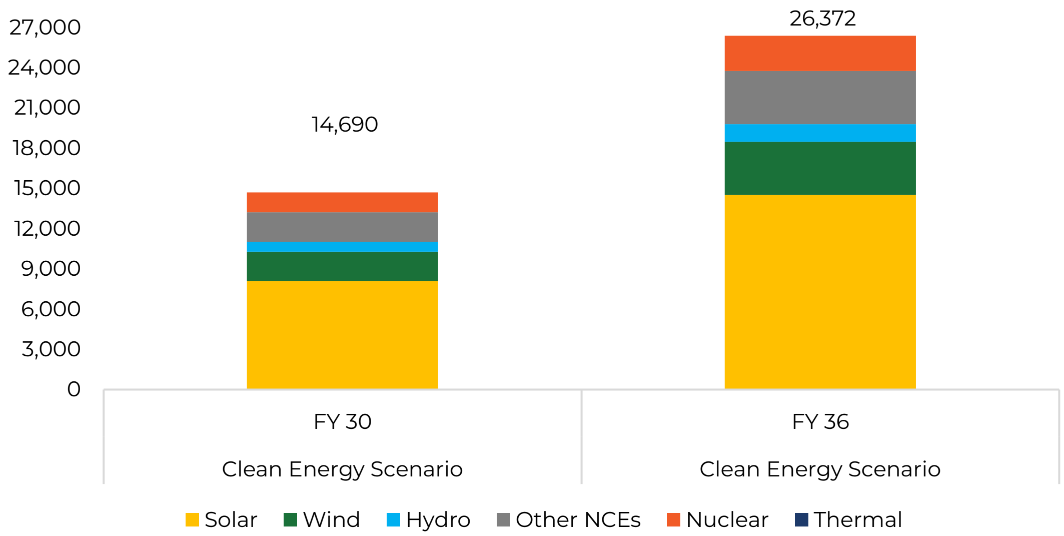
5.4 Clean energy scenario

In this scenario, to address the expected power and energy deficits, we focussed on capacity expansion plans that rely solely on renewable- and nuclear-energy sources. The source-wise capacity addition recommended is as follows; solar: 55%, wind: 15%, small-hydro: 8%, bio-power: 8%, large-hydro: 5%, and nuclear: 10%. Additionally, we suggest storage solutions to facilitate the smooth integration of the increased RE capacity into the grid.

5.4.1 New capacity requirement

To estimate the new capacity requirement, we analysed the state's proposed capacity additions. The state has 427 MW of hydro capacity scheduled in FY 2026, and the phased replacement of older thermal plants (with a capacity of 746 MW) is also coming up between FY 2026 and FY 2036. After evaluating the forecasted hourly demand and the state's existing and proposed supply availability, we proposed capacity additions to overcome the peak-demand deficits. The planned additional capacity is illustrated by the graph in Figure 16. By FY 2030, an additional capacity requirement of 14,690 MW is projected for the state, alongside its planned capacity addition of 427 MW and the replacement of 397 MW of aging thermal capacity. By FY 2036, the new capacity requirement is expected to be 26,372 MW, considering the replacement of 349 MW of older thermal capacity. Though the capacity addition is similar to that in the 'Conventional Scenario', there is no new thermal capacity added in the 'Clean Energy Scenario'.

Figure 16: New capacity requirement for clean energy scenario (in MW)



The projected cumulative installed capacity for FY 2030 and FY 2036 is 29,580 MW and 40,913 MW, respectively, as shown in Table 18. The share of thermal and gas capacity in the current installed mix, which stands at around 56%, is expected to decrease to 27% by FY 2030 and further to 19% by FY 2036. To maintain grid stability in the absence of new thermal capacity additions, it would be advantageous for the state to plan for procuring nuclear capacity from the upcoming plants, which can serve as a reliable base-load generator.

Owing to a higher RE share in the overall capacity mix, the share of clean energy sources is expected to increase significantly, from 44% in FY 2025 to 73% by FY 2030 and 81% by FY 2036. To accommodate this high influx of RE, the state should consider developing storage capacity of approximately 7,451 MW by FY 2036 (Table 18). This can be achieved by exploring both PHES and BESS. In addition to developing storage systems, the state can benefit from procuring temporary power from the unallocated pooling in the northern region, particularly from the National Hydroelectric Power Corporation (NHPC), rather than the usual practice of sourcing power from the National Thermal Power Corporation (NTPC). This approach would be advantageous during June to October for dealing with power deficits, as water availability is typically high during the rainy season, supporting increased power generation.

Table 18: Cumulative capacity requirement for clean energy scenario (in MW)

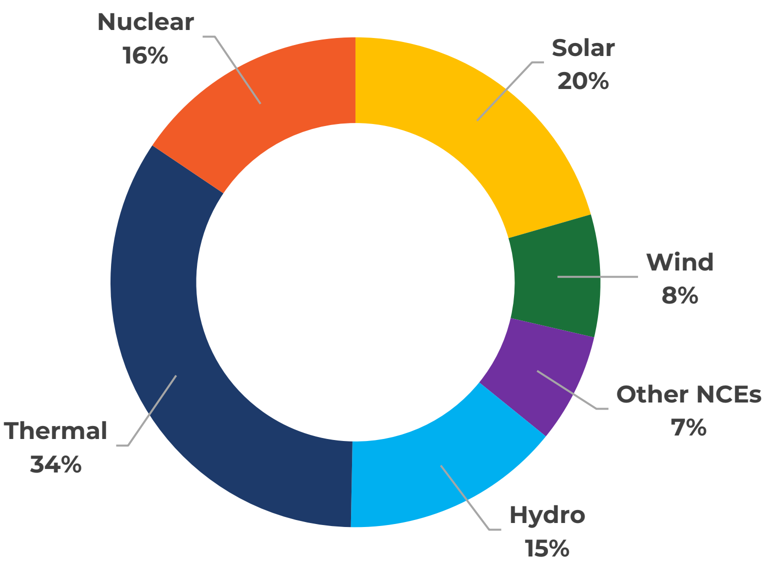
Source	FY 30	FY 36
Solar	10,239	16,664
Wind	2,654	4,406
Hydro	4,560	5,144
Other NCEs	2,490	4,242
Nuclear	1,666	2,834
Thermal/Gas	7,972	7,623
Total	**29,580**	**40,913**
Storage	1,953	7,451

5.4.2 Energy mix

With these proposed capacity additions, the state can expect a higher share of clean energy sources in the energy mix by FY 2036, as compared to the FY 2025 mix. The energy mix observed in FY 2036 is shown in Figure 17. The state anticipates that the energy mix will consist of 45% clean energy and 55% fossil-fuel-based energy by FY 2030. By FY 2036, this mix is expected to have 66% clean energy and 34% fossil-fuel-based energy.

It can be seen that in the 'Clean Energy Scenario', the energy mix includes a higher share of clean energy (66% by FY 2036), with a lower reliance on fossil fuels, as compared to the 'Conventional Scenario' (46% by FY 2036).

Figure 17: Energy mix for clean energy scenario (FY 2036)



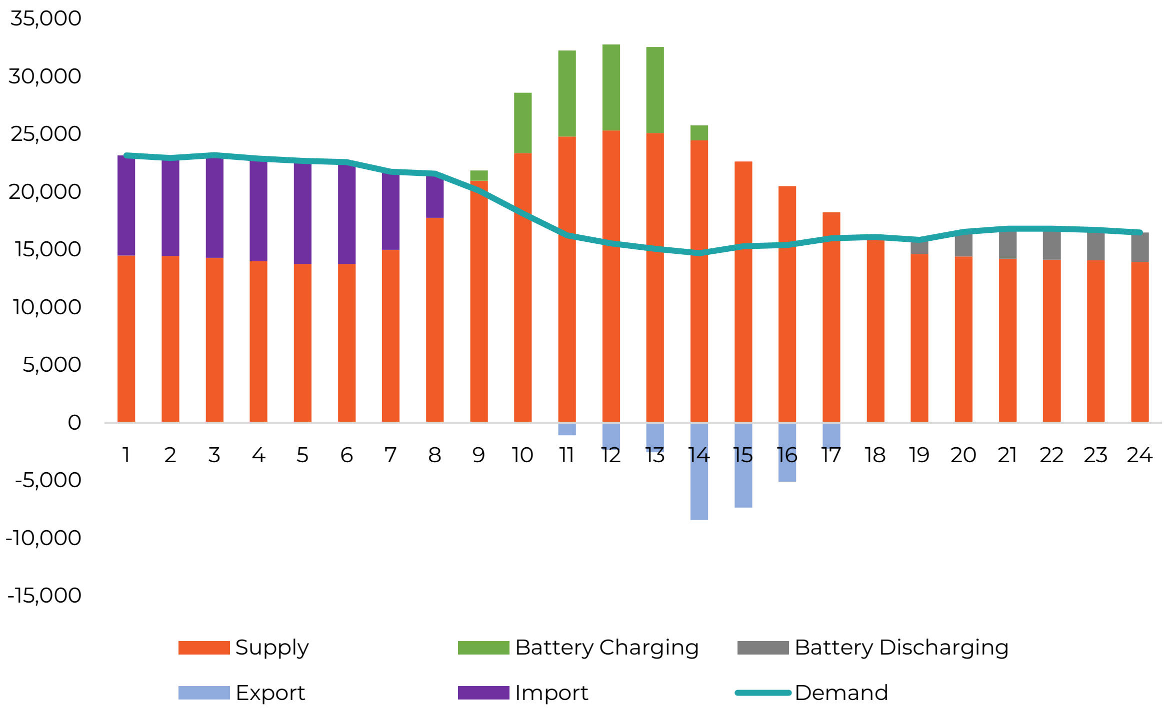
5.4.3 Storage requirement

We identified the maximum energy deficit through an assessment of power surplus and deficit for all the 8760 hours studied for each year. We assessed that initially 11% of the peak deficit would be compensated by deploying 1,000 MW of storage capacity by FY 2027. Thereafter, the state would need to expand storage systems at a CAGR of 25% till FY 2036, reaching a cumulative storage capacity of 7,451 MW.

Figure 18 presents the hourly analysis of supply, demand, and storage operations throughout a day (11 August 2035). The supply curve follows a typical pattern, with a surplus generation during periods of RE availability and a deficit during non-RE periods. Demand surpasses supply between 01:00 and 08:00 hours, with the deficit ranging between 8,913 MWh and 13,818 MWh, which is solely met through imports/ purchases from exchanges. The demand decreases between 09:00 and 17:00 hours, resulting in a surplus. The surplus energy during these hours is used to charge the ESS to its full rated storage capacity of 29,802 MWh. The remaining energy is exported or sold in the exchanges. The demand again exceeds supply between 18:00 and 24:00 hours and the deficit in each of these hours is met by the ESS.

A demand-supply planning was also carried out for the BAU demand projections and is detailed in Appendix B.

Figure 18: Demand-supply and storage curve for clean energy scenario

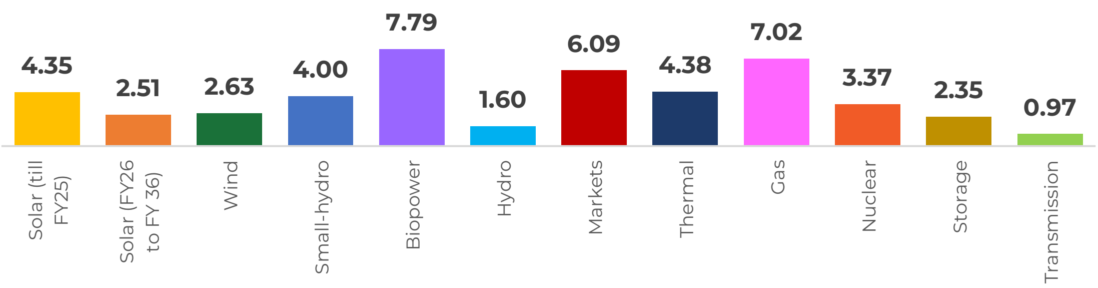


6. Impact of Higher RE on the Power Purchase Cost of DISCOMs

In recent years, the cost of generating electricity from renewable sources has been decreasing, which could influence the overall cost of electricity procurement for DISCOMs and potentially lead to adjustments in tariff rates. Therefore, harnessing low-cost RE is essential for building a sustainable power sector that can ensure affordability and energy security. Considering this, our study also analysed the unit cost of power purchase from various sources from FY 2026 to FY 2036. Figure 19 presents the weighted average per unit cost of power from FY 2026 to FY 2036.

Currently, the weighted average cost of electricity generated from thermal plants stands at INR 4.38/unit (Figure 19). Our analysis considers the replacement of older thermal plants, and it is recommended that plants with a cost higher than INR 5/unit be phased out first to achieve economic benefits. Although bio-power is categorised as clean energy, its current weighted average tariff (viz., INR 7.79/unit) is relatively high, making it the most expensive among renewable sources.

Figure 19: Source-wise weighted average power purchase cost (in INR/unit)



6.1 Energy cost and storage analysis

The analysis indicates that considering the current energy tariffs under various tariff orders of FY 2025 and data from PSPCL, the 'Clean Energy' scenario is expected to see a 7.7% decrease in per unit cost—from INR 4.81/unit in FY 2025 to INR 4.44/unit by FY 2036—with a total power purchase cost of around 55,345 crore (Table 19). Similarly, in the 'Conventional Scenario', which also includes thermal power capacity, the benefits of RE penetration are slightly offset by the higher-costing thermal power. This leads to a 4.3% decrease in per unit cost (INR 4.60/unit) by FY 2036, which is slightly higher than that in the 'Clean Energy' scenario and thus, the total power purchase cost works out to be approximately INR 58,073 crore. This decrease in per unit cost is largely driven by the increased penetration of renewable energy. Therefore, it is advisable that Punjab's power sector increases RE integration and reduces reliance on thermal power, which can be further supported by expanding nuclear capacity in the future. Table 19 outlines the unit cost of power for DISCOMs under the two scenarios in FY 2036.

Table 19: Source-wise power purchase cost by FY 2036

Source	Description	Conventional Scenario	Clean Energy Scenario
Solar (till FY 2024)	Energy (MU)	2,827	2,827
	Cost (INR crore)	1,229	1,229
Solar (FY 2025 to FY 2036)	Energy (MU)	6,479	21,021
	Cost (INR crore)	1,626	5,276
Wind	Energy (MU)	9,316	10,277
	Cost (INR crore)	2,454	2,707
Small Hydro	Energy (MU)	2,436	5,284
	Cost (INR crore)	975	2,115
Biopower	Energy (MU)	1,631	3,217
	Cost (INR crore)	1,271	2,506
Hydro	Energy (MU)	21,157	19,381
	Cost (INR crore)	3,377	3,094
Markets/Banking/Traders	Energy (MU)	8	1
	Cost (INR crore)	5	0
Thermal	Energy (MU)	68,761	43,971
	Cost (INR crore)	30,105	18,814
Nuclear	Energy (MU)	13,648	19,794
	Cost (INR crore)	4,601	6,673
Transmission & State Load Dispatch Centre	Energy (MU)	1,26,860	1,26,978
	Cost (INR crore)	12,203	12,061
Storage	Energy (MU)	595	2,205
	Cost (INR crore)	235	870
Total	**Energy (MU)**	**1,26,860**	**1,26,978**
	Cost (INR crore)	**58,073**	**55,345**
Average power purchase cost	*INR/unit*	*4.60*	*4.44*

It is expected that power purchases from thermal sources will dominate the state's total power procurement costs. Given the state's significant potential in biomass generation—owing to the availability of paddy and wheat straw—it would be beneficial to increase viability gap funding (VGF) for setting up biomass plants, which would help lower their energy tariffs in the long run.

The cost of storage was evaluated considering a combination of PHES and BESS. It has been assumed that from FY 2024 to FY 2030, the storage systems will comprise 75% PHES and 25% BESS. However, from FY 2031 to FY 2036, the share of PHES and BESS is projected to be 50% each. This shift is attributed to a significant reduction in the levelised cost of storage (LCOS) for BESS (Deorah et al., 2020), which is expected to decrease by 30% by FY 2036 (from INR 4.86/unit in FY 2026 to INR 3.42/unit in FY 2036), while PHES costs are anticipated to fall by 26% over the same period (from INR 6.07/unit in FY 2026 to INR 4.48/unit in FY 2036). Therefore, capitalising on the more rapidly declining BESS costs, and increasing its share to 50% from FY 2031 to FY 2036 is recommended.

A power purchase cost analysis was also performed considering the BAU demand projections, and is detailed in Appendix B.

7. Conclusions and Recommendations

Punjab's power sector—particularly its distribution and generation segments—is experiencing significant transformations driven by the evolving consumer behaviour and shifting demand dynamics. Besides the increased industrial activity post the pandemic, these changes have been brought about by the policy developments in this space, such as free power-supply schemes, the rise of EVs, the adoption of RTPV systems, and energy efficiency measures in residential, commercial, and agricultural sectors, including the solarisation of IP sets.

The generation segment of Punjab's power sector is under pressure to meet the growing demand in the state. As the segment relies heavily on fossil-fuel-based generators, it faces coal availability issues on the one hand, and on the other hand, continues to contribute significantly to air pollution, which is further worsened by stubble burning in the winter season. It is, therefore, imperative that Punjab develops robust, future-proof strategies for the generation and distribution segments of its power sector to ensure energy security for consumers, while aligning with India's net-zero goals.

Our study anticipates that Punjab will need an additional 26,372 MW of clean energy capacity and 7,451 MW of storage systems by FY 2036 to provide a reliable, round-the-clock power supply. To achieve this, the state must focus on implementing targeted measures to expand its clean energy portfolio and improve grid stability.

Based on our findings, we put forth recommendations to address the challenges posed by the growing demand and the expansion of RE generation capacity in Punjab. The critical focus areas for action within the distribution and generation segments have been identified and segment-specific measures have been recommended to form a roadmap that can help Punjab in overcoming the existing challenges effectively.

7.1 Distribution

Our study makes the following broad recommendations for the key areas that Punjab can focus on in the distribution segment, specifying the current challenges in each of these areas and listing the corresponding solutions.

7.1.1 Smoother and faster adoption of EVs

The state has seen a notable increase in EV adoption in recent years, with significant potential for further expansion. This momentum supports the state's efforts to meet its EV policy targets and align with the global 'EV 30@30' initiative. Our study projects that the state will see the adoption of 5.1 million EVs by FY 2036, resulting in an additional energy demand of 9,087 MU. To ensure a smooth integration of EVs into the distribution grid, it is crucial to prepare the infrastructure for the additional energy demands associated with EV charging, while maintaining stable operations. Table 20 illustrates the existing challenges, along with the specific recommendations to overcome them:

Table 20: Faster adoption of EVs: Existing challenges and recommended actions

Challenges	Recommendations	Responsibility
Inadequate charging infrastructure	State government to open a single window/platform (that includes the power and transport departments) to plan for adequate charging infrastructure and the associated distribution infrastructure.	• State Government • Power and Transport Departments • Industry Players
Monitoring and management of EV load	• Deploy smart meters for EV consumers. • Leverage AI solutions for tracking EV load and optimising demand response. • Introduce time-of-use tariffs to incentivise EV-charging during non-peak hours. • Promote vehicle-to-grid (V2G) integration with attractive compensation. • Undertake strategic deployment of BESS near high-demand areas.	PSPCL
Lack of policy push for electrification of vehicles used in agriculture	• State government to include manufacturing and adoption of e-tractors and e-lorries under state EV policy. • Provide support for R&D for electrification of vehicles in agriculture sector.	• Department of Industries and Commerce • Department of Power • Department of Transport • Manufacturing Units • R&D Institutes

7.1.2 Integration of RTPV into the distribution grid

The state had set a target of installing 2,000 MW of rooftop solar capacity by FY 2022 but has managed to install only 265 MW as of May 2023. To accelerate RTPV deployment, the state must foster a conducive environment that supports consumers, offering financial incentives and benefits. It is estimated that the state could install RTPV systems at a CAGR of 17% from FY 2024 to FY 2036. Table 21 depicts some key measures that can help in driving a higher RTPV integration:

Table 21: RTPV integration: Existing challenges and recommended actions

Challenges	Recommendations	Responsibility
Low adoption of RTPV systems	• Conduct awareness programmes for RTPV adoption. • Develop supportive policies (rebates, incentives, energy bill savings) to encourage participation. • Promote the 'PM Surya Ghar: Muft Bijli Yojana' for subsidised residential consumers as a one-time investment, to reduce the long-term subsidy burden. • Pilot execution of peer-to-peer (P2P) energy trading to encourage consumers in decentralised energy markets.	• State Government • PSPCL
Identifying potential RTPV installation sites	Use drone-based aerial photogrammetry to identify RTPV installation sites on: • Government buildings • Municipal/local body premises • Schools and hospitals • Major commercial spaces	State government, in consultation with: • PSPCL • Department of Power • Department of Housing & Urban Development • Local Bodies

Such steps will not only boost RTPV integration but also support EV adoption in the state. The synergy between RTPV and EVs can be further enhanced by enabling consumers to trade surplus RTPV energy through peer-to-peer trading. DISCOMs can explore pilot projects on decentralised energy market mechanisms to facilitate this integration.

7.1.3 Energy efficiency initiatives in residential and commercial categories

The state needs to adopt energy efficiency measures in both residential and commercial categories. These measures will not only help in managing the future energy demand but will also provide substantial cost savings on energy.

Our analysis projects that by FY 2036, the state could achieve energy savings equivalent to 19% of the BAU residential category demand (amounting to 6,614 MU), driven by the increased use of EE appliances in households. In the commercial category, energy savings that are equal to 3% of the BAU commercial category demand (amounting to 286 MU) are anticipated, primarily through the Energy Conservation Building Code (ECBC) compliance. The state has already notified the 'Punjab Energy Conservation Building Code Rules 2020' and has made notable progress in its implementation. However, more attention, encouragement, and policy support are needed to achieve its full potential. Looking at the challenges in this area, we recommend the following measures (Table 22):

Table 22: Energy efficiency measures in residential and commercial categories: Existing challenges and recommended actions

Challenges	Recommendations	Responsibility
Limited enforcement of ECBC (residential standards in new buildings)	• Ensure mandatory and strict compliance with 'Eco-Niwas Samhita 2018' (ECBC–Residential) for new residential buildings, through building by-laws and approvals by municipalities/urban-bodies. • Conduct public awareness drives and social media campaigns for highlighting the cost and benefits, energy savings, and improved living conditions that would result from such measures.	• Department of Housing & Urban Development • PSPCL
Low incentives for ECBC (commercial buildings and retrofitting)	• Support such building construction/retrofitting with low-interest rates through green finance. • Enable such consumers to repay loans through monthly energy bills. • Provide incentives or rebates on electricity bills/property tax.	State government to offer rebates/subsidies in collaboration with: • Department of Housing & Urban Development • Department of Finance • PSPCL • Local Bodies (Municipalities/Panchayats)
Inefficient energy monitoring and management	• Deploy smart meters and energy management systems to monitor and optimise energy consumption. • Track energy performance index (EPI) scores to improve consumption patterns and highlight economic benefits.	PSPCL

7.1.4 Energy efficiency and solarisation measures in agriculture

The agriculture sector forms the backbone of Punjab state's economy and is also the third-largest consumer of electricity. It thus carries a significant potential for energy savings through the deployment of EE pumps and solarisation of electric IP sets.

Our analysis indicates that the agriculture sector can reduce its energy consumption by 15% with the above measures (as compared to the BAU agriculture consumption) by FY 2036. This can be achieved by replacing 22% of the total IP sets with EE alternatives and solarising 5% and 10% of the total IP sets in the off-grid category and the grid-connected category, respectively. Solarising IP sets not only ensures a reliable power supply for farmers but also allows them to generate an additional income by selling the surplus power to DISCOMs. Both, the DISCOMs and the government, stand to benefit from these measures in the form of reduced T&D losses and a lower subsidy burden, respectively.

For effectively implementing these measures, the following recommendations are made (Table 23):

Table 23: Energy efficiency and solarisation in agriculture: Existing challenges and recommended actions

Challenges	Recommendations	Responsibility
Unavailability of land parcels	• A land-use tool should be developed for identification of non-fertile land parcels. • Farmers should provide land parcels based on the capacity of their pump sets to facilitate decentralised solar installations. • Government should secure monetary support for covering capital cost. • Third-party vendors should be engaged to install and maintain solar systems with a 6-to-7-year period for return on investment, after which the systems can be fully transferred to the farmers.	• State Government • PSPCL • Financial Institutions • Agriculture Department • Revenue Department • PSPCL
Inefficient pumps and lack of awareness on EE pumps	• Introduce buy-back scheme for older and inefficient pumps and provide EE star-rated pumps at subsidised cost, starting with pilot projects for large-scale deployment. • Run awareness campaigns to educate farmers on the benefits of EE IP sets, water optimisation, and better cropping patterns.	• State Government • PSPCL • Department of Industries and Commerce • Agriculture Department • Punjab Energy Development Agency (PEDA) • Bureau of Energy Efficiency (BEE) • Financial Institutions

7.2 Generation

Our study makes the following broad recommendations for the key areas that PSPCL can focus on in the generation segment. It identifies the existing challenges within each of these areas and provides corresponding solutions.

7.2.1 Increased RE capacity additions

As indicated by the National Institution for Transforming India (NITI) Aayog, Punjab has a limited RE potential (just 7,183 MW of RE sources), which makes RE capacity expansion challenging. To overcome this and integrate more RE into the grid, the state should consider the following strategies (Table 24):

Table 24: Increased RE penetration: Existing challenges and recommended actions

Challenges	Recommendations	Responsibility
Inadequate land availability	Identify suitable land parcels by creating a land-aggregation tool for solar parks and conduct techno-commercial feasibility studies within the state.	• State Government • PEDA • Revenue Department • Agriculture Department • PSPCL
Low RE potential for meeting RPO targets	Explore low-cost RE power purchase agreements (PPAs) with RE-rich states like Rajasthan (solar and wind); Himachal Pradesh (hydro); and Gujarat (wind).	• PSPCL
High per unit cost of existing thermal/gas plants	Replace high-cost plants (those costing more than INR 5/unit), specifically gas plants, with low-cost RE plants.	• PSPCL
High capital expenditure for biomass developers and high energy tariffs	Capitalise on biomass potential through VGF for flexible supply and reduced emissions.	• State Government. • PSERC

7.2.2 Integration of storage systems

The addition of more RE capacity to Punjab's power grid would adversely affect its stability, owing to the intermittent nature of RE sources like solar and wind. This highlights the critical need for storage systems that can provide flexibility, reliability, and round-the-clock power supply. Our study estimates that Punjab will require an initial storage capacity of 1,000 MW by FY 2027 (about 11% of the BAU peak deficit), with a projected Y-o-Y growth of 25%. By FY 2036, the optimal storage capacity is expected to reach 7,451 MW. Considering the lack of PHES potential in Punjab, strategic planning would be required for the efficient deployment of storage systems. Recommendations in this regard are provided in Table 25.

Table 25: Integration of storage systems: Existing challenges and recommended actions

Challenges	Recommendations	Responsibility
Meeting the evening peak load when there is insufficient RE availability	Develop 1,000 MW of storage by FY 2027 and increase it to 7,451 MW by FY 2036 to manage intermittent RE generation and meet evening peak demand.	• State Government • PSPCL
High cost of BESS over PHES	• Create a comprehensive storage policy to promote energy storage development by both public and private sectors. • Prioritise PHES (75%) over BESS (25%) from FY 2027-2030; then shift to a 50%:50% ratio by FY 2031-2036 as battery technology improves and costs decrease.	• State Government • PSPCL
Lack of PHES potential within Punjab	Secure PPAs or joint ventures with neighbouring states that have or are planning PHES projects, to leverage regional PHES development.	• State Government • PSPCL

7.2.3 Considering nuclear capacity addition

Incorporating nuclear energy—along with RE—in the state's energy mix can help Punjab achieve grid flexibility and meet its base-load requirements as RE penetration increases. This combination is particularly vital for future capacity addition plans (where conventional thermal plants are absent) and can help the state in transitioning smoothly toward net-zero emissions. Currently, Punjab's nuclear capacity accounts for just 1.3% (197 MW), and our analysis projects a need for 2,637 MW by FY 2036 under the 'Clean Energy' scenario. Leveraging nuclear energy—a clean energy source with a low cost of INR 3.4 per unit—offers an opportunity to reduce power purchase costs and replace thermal energy sources. Known for its high plant load factor (PLF) and consistent availability, nuclear energy is a strong candidate for reliable power generation. Although Punjab currently lacks nuclear facilities, the state can procure nuclear power from the upcoming plants in neighbouring states, and in the future, explore small modular reactors (SMRs) as they develop. Accordingly, Table 26 lists the recommendations in this regard.

Table 26: Nuclear capacity addition: Existing challenges and recommended actions

Challenges	Recommendations	Responsibility
Low contracted nuclear capacity for clean energy transition	Procure 2,637 MW of nuclear capacity by FY 2036 to align with the 'Clean Energy' scenario and meet net-zero goals.	• PSPCL
Lack of base-load generators in future years	To support base-load requirements for the grid and handle RE-intermittency issues, explore nuclear energy procurement from upcoming plants like: • Rajasthan (RAPP, Mahi-Banaswara) • Haryana (Gorakhpur)	• State Government • PSPCL
Centralised large-scale reactors	The state government should explore potential opportunities in SMRs as the technology progresses, offering better scalability and safety.	• State Government • PSPCL

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9. Appendix A

Table A1: Details of thermal and gas plants

S. No.	Name of power station	Owner	Total capacity (MW)	PSPCL share (MW)	PLF (%)	Auxiliary consumption (%)	Available capacity (MW)
1	Singrauli	NTPC	2,000	200	93	7.1	172
2	Rihand-I		1,000	110	92	8.0	94
3	Rihand-II		1,000	102	92	6.3	88
4	Unchahar-II		420	60	66	9.8	36
5	Unchahar-III		210	17	66	9.0	10
6	Kahalgaon-II (ER)		1,500	120	79	6.3	89
7	Rihand-III		1,000	83	92	6.3	72
8	Meja		1,320	48	75	6.3	34
9	Durgapur TPS	DVC	1,000	200	88	5.8	166
10	Raghunathpur		1,200	300	70	5.8	198
11	Bokaro		500	200	79	5.8	149
12	CGPL Mundra UMPP	Tata Power	4,150	519	43	8.4	206
13	Sasan UMPP (RPL)	Reliance Power	3,960	594	91	6.0	506
14	TSPL	Vedanta	1,980	1,980	67	7.0	1,239
15	GSTPP	GVK	540	540	41	9.0	199
16	NPL	L&T	1,400	1,400	93	5.7	1,223
17	GGSSTP Ropar	PSPCL	840	840	54	8.5	416
18	GHTP Lehra Mohabbet		920	920	48	8.5	405
19	Pragati III Gas	PPCL	1371	137	31.2	3	42
	Total		**29,711**	**8,369**			**5,342**

Table A2: Details of hydro plants

S. No.	Name of power station	Owner	Total capacity (MW)	PSPCL share (MW)
1	Koldam	NTPC	800	62
2	Sewa-II	NHPC	120	10
3	Uri-II		240	20
4	Parbati-III		520	41
5	Chamera-III		231	18
6	Dulhasti		390	32
7	Chamera-II		300	30
8	Dauli Ganga Stage-I		280	28
9	Bairasiul		180	84
10	Salal		690	184
11	Tanakpur		120	17
12	Chamera-I		540	55
13	Uri		480	66
14	Nathpa Jhakri HEP	SJVNL	1,500	152
15	Rampur HEP		412	23
16	Tehri HEP	THDC	1,000	77
17	Koteshwer HEP		400	25
18	Mallana-II	PTC	100	88
19	Karcham Wangtoo HEP		1,000	200
20	Tala		1,020	30
21	Shanan	PSPCL	110	110
22	UBDC-I & II		91	91
23	RSPP		600	452
24	ASHP		134	134
25	MHP		225	225
26	Mini/micro hydel		2.5	2.5
27	Bhakra share	BBMB	1,397	646.68
28	Dehar share		990	409.56
29	Pong share		396	84.86
	Total		**11,486**	**3,398**

Table A3: Details of small-hydro plants

S. No.	Name of the firm	Installed capacity (MW)
1	M/s Aqua Power Ltd.	2
2	M/s Aqua Power Ltd.	2
3	M/s Aqua Power Ltd.	1.2
4	M/s Abohar Power Generation Pvt. Ltd.	0.9
5	M/s Abohar Power Generation Pvt. Ltd.	1
6	M/s Abohar Power Generation Pvt. Ltd.	1.1
7	M/s Abohar Power Generation Pvt. Ltd.	1.05
8	M/s Abohar Power Generation Pvt. Ltd.	1.25
9	M/s Kotla Hydro Power Ltd.	1.25
10	M/s Kotla Hydro Power Ltd.	1.75
11	M/s Kotla Hydro Power Ltd.	1.2
12	M/s Atlantic Power Pvt. Ltd.	0.65
13	M/s Atlantic Power (Phoola) Pvt. Ltd.	0.6
14	M/s Gill Acqua Hydro Power Generation Co. Pvt. Ltd.	6
15	M/s Gill Acqua Hydro Power Generation Co. Pvt. Ltd.	3.8
16	M/s Gill Power Generation Company(P) Ltd.	2.7
17	M/s Kotla Renewables Pvt. Ltd.	1.5
18	M/s Kotla Renewables Pvt. Ltd.	0.8
19	M/s Kotla Renewables Pvt. Ltd.	0.8
20	M/s Majha Canal Hydro Projects, Pathankot	0.65
21	M/s P & R Gurdittiwala Hydro Power Pvt. Ltd.	2
22	M/s Sam India Hydro Power Pvt. Ltd. Delhi	1.2
23	M/s Sidhwan Hydro Power Pvt. Ltd.	0.7
24	M/s SKR Hydro Power Generators Pvt. Ltd.	0.4
25	M/s UBDC Hydro Company	2
26	Punjab Genco Ltd.	1.5
27	M/s Punjab Genco Ltd. (a subsidiary of PEDA and formerly known as Punjab Renewable Energy Development & Power Generation Co. Ltd.)	1

S. No.	Name of the firm	Installed capacity (MW)
28	M/s Punjab Genco Ltd.	1.5
29	M/s Punjab Genco Ltd.	1.5
30	M/s Punjab Genco Ltd.	1.000
31	M/s Punjab Genco Ltd.	1.3
32	M/s Punjab Genco Ltd.	1
33	M/s Punjab Genco Ltd.	1
34	M/s Himalayan Renewable Energy Pvt. Ltd., Sangrur	0.6
35	M/s Preetech Power Pvt. Ltd., Jallandhar	0.85
36	M/s Atlantic Power Pvt. Ltd.	0.3
37	M/s Salasar Hydro Urja Pvt. Ltd., Ferozepur	1.5
38	M/s Preetech Power Pvt. Ltd., Kalabala, Gurdaspur	0.8
39	M/s Hydro Energy & Infrastructure, Sangrur	0.25
Total		**52.6**

Table A4: Details of nuclear capacity

S. No.	Name of power station	Owner	Total capacity (MW)	PSPCL share (MW)	PLF (%)	Auxiliary consumption (%)	Available capacity (MW)
1	NAPP	NPCIL	440	51	68.41	10.5	31
2	RAPP (3 & 4)	NPCIL	440	100	78.88	10.5	71
3	RAPP (5 & 6)	NPCIL	440	46	78.88	10.5	32
Total			**1,320**	**197**			**134**

Table A5: Details of 'other' RE plants

S. No.	Type	Name of power station	Installed capacity (MW)	PSPCL share (MW)	Auxiliary consumption (%)	PLF (%)	Dispatchable capacity (MW)
1	Cogen-Baggase	M/s A.B. Sugars Ltd.	23	20	10	85	15.3
2		M/s Chadha Sugars & Ind. Ltd.	23	20.5	10	85	15.7
3		M/s Indian Sucrose Ltd.	40	30	10	85	23.0
4		M/s Nawashahar Power Pvt. Ltd.	15	13.5	10	85	10.3
5		M/s Rana Sugars Ltd.	34	20	10	85	15.3
6		M/s Wahid Sandhar Sugars Ltd.	12	7	10	85	5.4
7		The Bhogpur Co-operative Sugar Mills Ltd.	15	8.54	10	85	6.5
8	Cogen-Biomass	M/s A.B.Grain Spirits Pvt. Ltd.	5.5	3	10	85	2.3
9		M/s Chandigarh Distillers & Bottlers Ltd.	8.25	5	10	85	3.8
10		M/s Chandigarh Distillers & Bottlers Ltd,	3.9	2.5	10	85	1.9
11		M/s NV Distilleries &Breweries (P) Ltd	10	6	10	85	4.6
12		M/s Shree Ganesh Edibles Pvt. Ltd.	15	4	10	85	3.1
13		M/s OM Sons Marketing Pvt. Ltd.	9	3			
14		M/s Indian Acrylics Ltd.	7.75				
15	Bio-power		98.2	98.2	5	85	79.3
Total			**320**	**241**			**186**

Table A6: Details of solar and wind plants

S. No.	Type	Plant name	PSPCL share (MW)
1	Solar	NVVN Bundled Solar Power	37.00
2		Small solar plants within the state	884.22
3		SECI Solar Power	30.00
4		SECI 500 MW Hybrid Power PSA (Solar)	400.00
5		NHPC 300MW Solar Power	300.00
6		RTPV systems within the state	301.57
7	Wind	50 MW M/s Adani Green Energy (MP) Ltd.	150
8		300 MW M/s Green Infra Wind Energy Ltd.	200
9		SECI (M/s Adani Hybrid Energy Jaisalmer Three Ltd.)	40.00
10		SECI (M/s Adani Hybrid Energy Jaisalmer Two Ltd.)	60.00
		Total	**2,403**

10. Appendix B

Demand-supply planning for BAU demand projections

Figure B1: New capacity requirement for 'Conventional Scenario' considering BAU demand forecast

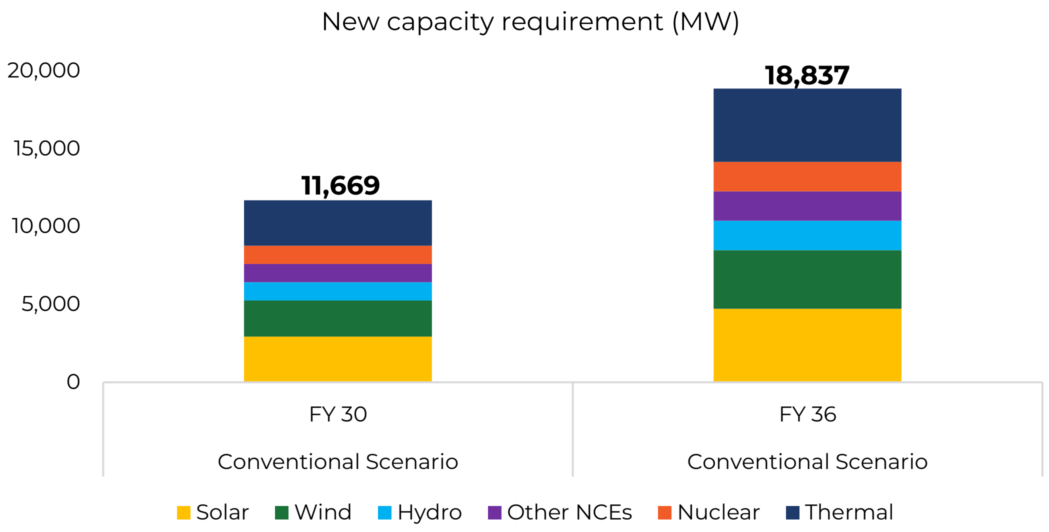

Table B1: Cumulative installed capacity for 'Conventional Scenario' considering BAU demand forecast

Source	FY 30	FY 36
Solar	5,076	6,868
Wind	2,784	4,217
Hydro	4,992	5,709
Other NCEs	1,454	2,170
Nuclear	1,364	2,081
Thermal/Gas	10,890	12,333
Total	**26,559**	**33,378**
Storage	1,953	7,451

Figure B2: Energy mix for 'Conventional Scenario' considering BAU demand forecast

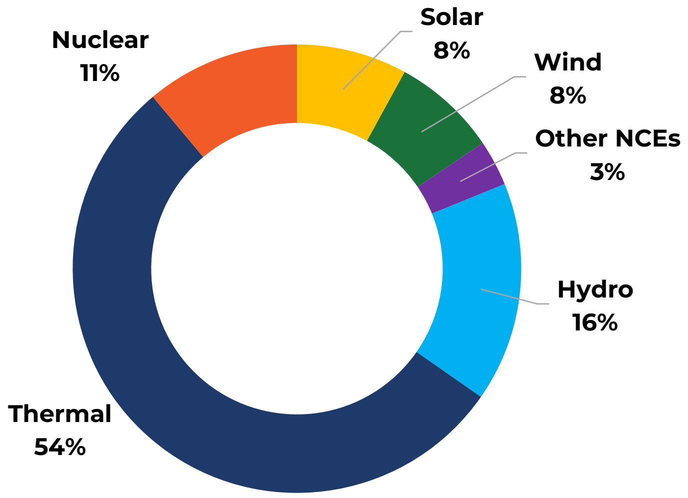

Figure B3: New capacity requirement for 'Clean Energy Scenario' considering BAU demand forecast

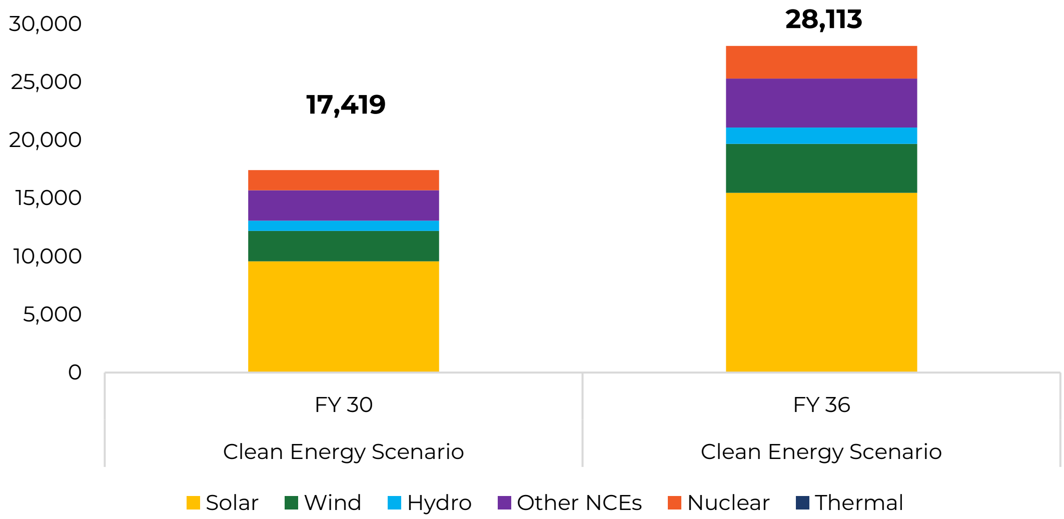

Table B2: Cumulative installed capacity for 'Clean Energy Scenario' considering BAU demand forecast

Source	FY 30	FY 36
Solar	11,740	17,621
Wind	3,063	4,667
Hydro	4,696	5,231
Other NCEs	2,899	4,504
Nuclear	1,939	3,008
Thermal + Gas	7,972	7,623
Total	**32,309**	**42,654**
Storage	1,953	7,451

Figure B4: Energy mix for 'Clean Energy Scenario' considering BAU demand forecast

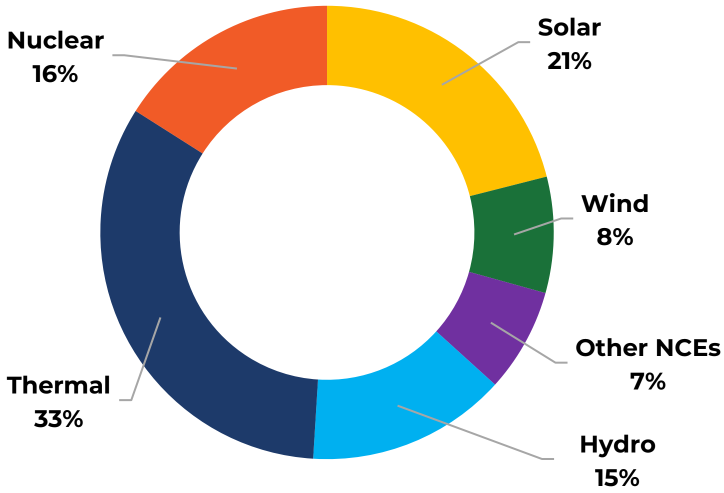

Table B3: Source-wise power purchase cost (considering BAU demand forecast)

Source	Description	Conventional Scenario	Clean Energy Scenario
Solar (till FY 2024)	Energy (MU)	2,827	2,827
	Cost (INR crore)	1,229	1,229
Solar (FY 2025 to FY 2036)	Energy (MU)	6,931	22,380
	Cost (INR crore)	1,740	5,617
Wind	Energy (MU)	9,847	10,872
	Cost (INR crore)	2,593	2,863
Small Hydro	Energy (MU)	2,588	5,623
	Cost (INR crore)	1,036	2,251
Biopower	Energy (MU)	1,716	3,407
	Cost (INR crore)	1,337	2,654
Hydro	Energy (MU)	20,640	18,748
	Cost (INR crore)	3,295	2,993
Markets/Banking/Traders	Energy (MU)	1	1
	Cost (INR crore)	1	0
Thermal	Energy (MU)	70,592	43,413
	Cost (INR crore)	30,907	19,007
Nuclear	Energy (MU)	14,473	21,026
	Cost (INR crore)	4,879	7,088
Transmission and State Load Dispatch Centre	Energy (MU)	1,29,612	1,28,295
	Cost (INR crore)	12,529	12,401
Storage	Energy (MU)	610	2,378
	Cost (INR crore)	241	939
Total	**Energy (MU)**	**1,31,086**	**1,31,205**
	Cost (INR crore)	**59,971**	**57,055**
Average power purchase cost	*INR/unit*	*4.60*	*4.43*

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