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Hydropower Development In Jammu And Kashmir: Technical Potential, Sustainability, And Project Landscape

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Abstract
Jammu and Kashmir (J&K), a union territory nestled in the Himalayan region, possesses abundant hydropower potential due to its topography and perennial river systems such as the Indus, Chenab, Jhelum, and Ravi. Despite an estimated potential exceeding 20,000 MW, only about 3,263 MW—roughly 19.8%—has been harnessed to date. This underutilization stems from geopolitical, environmental, economic, and infrastructural challenges. This paper investigates the current hydropower scenario in J&K, analyzes sustainability and technological considerations, presents detailed case studies of major projects, and offers strategic recommendations for maximizing this renewable resource in a sustainable and inclusive manner.

1. INTRODUCTION

Hydropower is considered a clean, renewable, and reliable source of energy. In India, it plays a vital role in meeting electricity demand, particularly in energy-starved regions like J&K. The territory's geographical features—including snow-fed rivers, steep gradients, and high runoff during summer—offer ideal conditions for hydroelectric generation (Ahmed, 2024; Sharma & Thakur, 2015). Yet, despite these advantages, power generation in J&K remains critically low in comparison to its potential, forcing the state to purchase power from central agencies at high costs. The region also suffers from frequent outages, unreliable supply in rural areas, and limited grid penetration in remote locations (IJTRD, 2024).

2. Need of the Study

The persistent gap between energy demand and supply in J&K necessitates the exploitation of available hydropower resources to ensure energy security and stimulate socio-economic development. Power deficits affect every sector, including agriculture, industry, education, and healthcare. Moreover, the existing reliance on diesel generators and biomass for heating and lighting in remote areas has adverse environmental effects, such as deforestation and air pollution (Sharma & Thakur, 2015).

Given that over 16,000 MW of technically feasible hydropower potential remains untapped, there is a pressing need to accelerate project development while ensuring minimal environmental disruption and fair community participation. Additionally, infrastructure modernization and policy reforms are essential to address administrative bottlenecks, inter-agency conflicts, and financing issues.

3. LITERATURE STUDY

Extensive academic and institutional literature has explored various dimensions of hydropower in J&K.

Ahmed (2024) provides a comprehensive breakdown of the identified versus exploited hydropower capacity, emphasizing that only 19.8% of potential has been tapped. The report notes sectoral division—state-owned, centrally operated (mostly by NHPC), and a small private sector contribution.

Sharma and Thakur (2015) advocate for prioritizing small hydropower projects (SHPs), especially run-of-the-river (RoR) types, due to their lower environmental impact and greater suitability for remote and ecologically fragile areas.

Kumar and Katoch (2015) utilized the Analytical Hierarchy Process (AHP) to evaluate the sustainability of various SHPs. Their study concludes that projects in the 1–5 MW range rank highest in terms of environmental and social sustainability.

Betti et al. (2019) emphasize the role of digitalization, specifically intelligent condition monitoring systems, in enhancing efficiency, predictive maintenance, and reducing costs in geographically challenging terrains like Kashmir.

Nisar and Monroy (2011) stress the importance of implementing Strategic Environmental Assessments (SEA) to mitigate the cumulative ecological impacts of multiple hydropower installations within a single watershed.

1. Updated situational snapshot Recent reports reaffirm that Jammu and Kashmir's hydropower potential remains substantially underutilized. Government surveys estimate the identified capacity at around 14,800–18,000 MW, while only about 3,200–3,540 MW has been harnessed, i.e., just 20–24% of potential (New Indian Express, 2025; Hindustan Times, 2025). This persistent gap underscores the urgency of expediting development while ensuring sustainability.

2.Project-levelupdates Several large projects illustrate both progress and challenges. The Baglihar project (900 MW) has demonstrated the benefits of a run-of-the-river scheme with pondage for seasonal regulation (Power-Technology, 2024; Wikipedia, n.d.-a). Similarly, Dul Hasti (390 MW) showcases engineering complexity in underground works (Global Energy Monitor, 2025). The Salal project (690 MW) highlights critical sedimentation issues that have drastically reduced reservoir storage and efficiency (Wikipedia, n.d.-b). Uri I & II (720 MW) exemplify how RoR schemes experience pronounced seasonal variability in output (Wikipedia, n.d.-c). Meanwhile, the Kiru (624 MW) and Pakal Dul (1,000 MW) projects, currently under construction in Chenab Valley, represent efforts to scale up capacity, though they raise concerns about cumulative impacts (Global Energy Monitor, 2025; Wikipedia, n.d.-d).

3. Geopolitical and legal constraints Hydropower development in J&K is influenced by international obligations under the Indus Waters Treaty (IWT), which historically limited reservoir storage on western rivers (CSIS, 2025). However, recent diplomatic developments — particularly India's announcement in 2025 of treaty suspension — have shifted the policy environment, creating both opportunities for expanded storage and risks of regional tensions (Reuters, 2025; The Guardian, 2025).

4. Environmental and sustainability issues Environmental challenges remain central. The Salal project exemplifies how Himalayan rivers' heavy silt loads can sharply reduce reservoir life (Wikipedia, n.d.-b). Basin-wide planning is essential since clusters of RoR projects can fragment aquatic ecosystems and alter natural flow regimes (Global Energy Monitor, 2025). Climate change projections indicate shifting snowmelt timing and monsoon variability, further complicating hydropower reliability (CSIS, 2025; Reuters, 2025).

5. Technology and operationsDigitalization and predictive maintenance are increasingly important for Himalayan hydropower. Condition monitoring and intelligent control systems can reduce forced outages and optimize generation, particularly under variable inflows (Betti et al., 2019; Power-Technology, 2024)

4. Case Studies of Major Hydropower Projects

4.1 Baglihar Hydroelectric Project

Baglihar, located on the Chenab River in Ramban district, is a hybrid dam plus RoR scheme with a capacity of 900 MW. It is crucial for managing seasonal river discharge and supporting peak electricity demand. The project features a substantial underground powerhouse and is designed to balance sedimentation and flood control through controlled reservoir operation (IJTRD, 2024).

Source : tribuneindia

4.2 Dul Hasti Hydroelectric Project

Situated in the Kishtwar district, Dul Hasti is a 390 MW project that serves as a base-load and peaking power provider for the Northern Grid. It is known for its complex engineering, involving a long tunnel

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and underground powerhouse, which are necessary due to the rugged topography of the region (Ahmed, 2024).

Source: NHPC India

4.3 Salal Hydropower Station

Salal, also on the Chenab River, has an installed capacity of 690 MW. Although initially a model dam-based generation project, its efficiency has declined due to severe sedimentation. The decreasing live storage capacity affects water regulation and overall energy yield (Ahmed, 2024).

Source: Wikipedia

4.4 Uri-I and Uri-II Projects

These two RoR projects are located on the Jhelum River near the Line of Control. Combined, they produce 720 MW. However, in winter months, due to reduced flow, Uri-I generates as little as 200 MW against its installed 480 MW, highlighting the seasonal limitations of RoR projects (IJTRD, 2024).

Source: NHPC India - URI - I Project

Source: NHPC India - URI - II Project

4.5 Kiru and Pakal Dul Projects (Under Construction)

Kiru (624 MW) and Pakal Dul (1,000 MW) are part of the Chenab Valley Power Projects. Pakal Dul, when completed, will be the largest hydroelectric project in the region. These projects are strategically important and represent a shift toward self-reliance in energy by J&K (Ahmed, 2024).

Source :Wikipedia

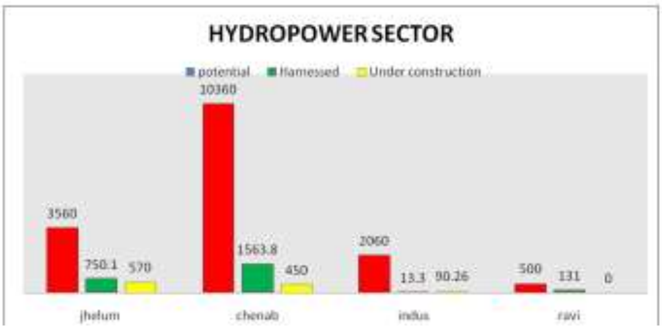
5. Technological and Environmental Aspects

Hydropower development in J&K must balance energy generation with ecological preservation. Technologies such as **intelligent condition monitoring systems**, **remote diagnostics**, and **automated plant control** have become vital for optimizing operations in inaccessible mountainous regions. These tools help detect faults early, schedule maintenance proactively, and minimize plant downtime (Betti et al., 2019).

Environmental sustainability is a growing concern. RoR projects are preferred due to their lower ecological footprint. However, multiple installations in a single watershed can disrupt aquatic ecosystems and seasonal migration of species. Hence, **cumulative impact assessments** and **basin-wide planning** are essential. Strategic Environmental Assessments (SEA) can guide site selection and operational policies to ensure long-term environmental viability (Nisar & Monroy, 2011).

6 . Breakup of rivers showing the Identified, harnessed and under Construction power potential of J & K State :

Rivers	Jhelum	Chenab	Indus	Ravi
Potential	3560	10360	2060	500
Harnessed	750.1	1563.8	13.3	131
Under construction	570	450	90.26	0



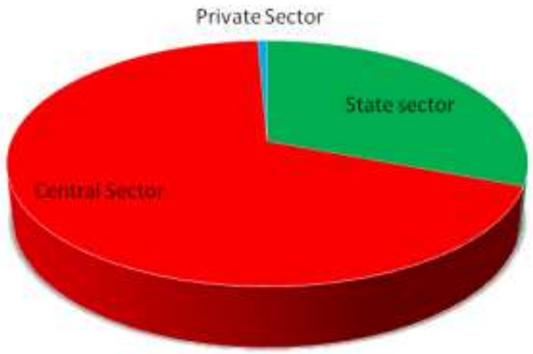
Source: Economic Survey of J&K State (2011)

From the above table river Chenab is considered as the mightiest river of the state and has the highest potential to harness the hydroelectricity in the state that is 10360 MW followed by river Jhelum which has 3560 MW, Indus ranked at third position. Instead of higher power generating potential these rivers have low storage capacity due to run of rivers. In such a situation, the State has been able to harness only about 2500 MW.

A. Existing power projects of Jammu and Kashmir

S.NO	PROJECT	BASIN	CAPACITY IN MWS
State sector			
1	LJHP	Jehlum	105.00
2	USHP-II Kangan	Jehlum	105.00
3	USHP-I	Jehlum	22.60
4	Ganderbal	Jehlum	15.00
5	Pahalgam	Jehlum	3.00
6	Karnah	Jehlum	2.00
7	Baglihar-I	Chenab	450.00
8	Chenani-I	Chenab	23.30
9	Chenani-II	Chenab	2.00
10	Chenani-III	Chenab	7.50
11	Bhaderwah	Chenab	1.00
12	Iqbal	Indus	3.75
13	Sumoor	Indus	0.10
14	Hunder	Indus	0.40
15	Bazgo	Indus	0.30
16	Igo- Marcelloung	Indus	3.00
17	Marpacho	Indus	0.75
18	Haftal	Indus	1.00
19	Satakna	Indus	4.00
20	Sewa III	Ravi	9.00
	Sub total		**758.70**
Central Sector			
1	Salal	Chenab	690.00
2	Dulhasti	Chenab	390.00
3	Uri –I	Jhelum	480.00
4	Sewa –II	Ravi	120.00
	Sub total		**1680.00**
Private Sector			
1	Athwatoo	Jhelum	10.00
2	Brenwar	Jhelum	7.50
	Sub total		**17.50**
	GRAND TOTAL		**2456**

Sector wise Distribution of power projects in Jammu & Kashmir



Source: J&K State Hydroelectric Project Development Policy 2011

The above table reveals that the state has 20,000 MW Power generating potential out of which only 2556 MW is harnessed consisting of 758.70 MW, from 20 power projects from the state sector and 1680 MW of the 4 power projects under Central Sector (NHPC), i.e. 690 MW from Salal Hydel Electric Project, 480 MW from Uri-I Hydel Electric Project, from Dulhasti 390 MW and 120 MW from the Sewa II, only 17.50 MW is harnessed from the private sector consisting of Athwatoo and Brenwar.

7. Data & Methods

For data, this study can combine multiple sources: (**a**) project-level technical reports from the NHPC, (**b**) river flow time-series from the Indian Meteorological Department (IMD) and Central Water Commission (CWC), and (**c**) satellite-based land-use/erosion indices for sediment risk assessment. A simple inflow seasonality analysis, such as monthly hydrographs for 3–5 gauging stations across the Chenab, Jhelum, and Indus sub-basins, is recommended to capture variability. Such methodological approaches have been effectively applied in hydropower assessment case studies (Power Technology, 2024; Kumar & Katoch, 2015).

Sustainability Scoring

To evaluate sustainability, tools like the **Hydropower Sustainability Assessment Protocol (HSAP)** or multi-criteria methods such as the **Analytic Hierarchy Process (AHP)** can be applied. Prior research has successfully employed AHP for ranking small hydropower projects, balancing environmental, social, governance, and technical factors (Global Energy Monitor, 2025; Kumar & Katoch, 2015). Sensitivity analysis can further test robustness under different discount rates and social-welfare weightings.

Sediment Management Module

Given the high silt loads in Himalayan rivers, reservoir **trap efficiency** and sedimentation risks must be assessed. Mitigation could include sluicing schedules, upstream check-dams, afforestation, and sediment bypass tunnels. Historical cases like **Salal Dam** illustrate the severe consequences of unchecked siltation (Wikipedia, n.d.-b; Nisar & Monroy, 2011). Estimating live storage reduction rates using published sediment load data from the Chenab is essential.

Social & Benefit-Sharing Metrics

Hydropower projects in J&K must be evaluated not just technically but also socio-economically. A **benefit-sharing matrix** could include local employment opportunities, displacement risks, electrification access, irrigation benefits, compensation mechanisms, and local procurement policies. Aligning these with international best practices such as HSAP enhances community acceptance (Global Energy Monitor, 2025; Kumar & Katoch, 2015).

Policy & Finance

Institutional and financial models are equally important. Evaluating **public–private partnerships (PPP)** and blended financing models, as well as state–central coordination mechanisms (e.g., JKSPDCL–NHPC cooperation), can reduce delays. Policies around tariffs and power-purchase agreements (PPAs) should also incentivize small hydropower plants in remote regions. Recent reviews highlight J&K's challenge of harnessing only about **24% of its identified hydro potential**, emphasizing the need for financing and policy reforms (New Indian Express, 2025; Hindustan Times, 2025).

8. Challenges and Strategic Recommendations

8.1 Challenges

- **Geopolitical constraints:** The Indus Waters Treaty restricts reservoir construction on major rivers, limiting design options (IJTRD, 2024).
- **Topographical difficulties:** Harsh winters, landslides, and seismic risks affect project execution and maintenance (Ahmed, 2024).
- **Environmental resistance:** Several proposed projects face delays due to environmental clearances and protests from local communities.
- **Cost-effectiveness:** RoR projects, while environmentally benign, are costlier than high-head dam-based ones and generate below capacity in dry seasons (IJTRD, 2024).
- **Administrative delays:** Conflicts between state agencies (JKSPDCL), NHPC, and the central government hinder smooth project rollouts.

8.2 Strategic Recommendations

Promote SHPs in remote areas, especially in districts lacking grid connectivity.

Encourage PPP models to reduce financial burdens and leverage private expertise.

Enhance local employment and training, creating inclusive growth around projects.

Implement HSAP (Hydropower Sustainability Assessment Protocol) to evaluate and improve performance in social, environmental, and financial terms.

Modernize grid infrastructure, including smart metering, to reduce transmission losses and theft.

Prioritise small hydropower (SHP) & distributed run-of-the-river (RoR)

In remote areas, SHPs and RoR schemes should be prioritised for their ability to provide rapid socio-economic benefits with relatively low displacement impacts. Large storage projects, however, should be restricted to sites with clear legal and transboundary feasibility under the Indus Waters Treaty framework (New Indian Express, 2025; Nisar & Monroy, 2011).

Basin-wide Strategic Environmental Assessments (SEAs)

Before permitting clusters of projects, basin-wide SEAs must be conducted to evaluate cumulative impacts on flow regimes, ecosystems, and downstream users. Such assessments should include mandatory thresholds for cumulative effects (Global Energy Monitor, 2025; Kumar & Katoch, 2015).

Institutional reform

A **J&K Hydropower Coordination Cell** should be established, bringing together state agencies, NHPC, central regulators, and civil society stakeholders. This body could streamline approvals while ensuring social and environmental safeguards (New Indian Express, 2025; Economic Survey of J&K, 2011).

Financing mechanisms

Hydropower development should leverage blended financing models, combining central government equity, multilateral climate finance for sustainability interventions, and PPP frameworks. This approach is particularly useful for mobilising funds for small hydropower and sediment-control infrastructure (Power Technology, 2024; Betti et al., 2019).

Technical safeguards

All new projects should undergo **HSAP-based sustainability audits** and adopt digital monitoring systems for real-time condition assessment and operational optimisation. These measures will enhance reliability and extend project life in the challenging Himalayan terrain (Global Energy Monitor, 2025; Betti et al., 2019).

8. CONCLUSION

The ongoing power projects in the State are considered as a core heated discussion between India and Pakistan, in this manner severely affecting the development of the State. Additionally, the harnessed power potential is based on run-of-the river project, which cannot produce optimum generation. These run-of-the-river projects cannot meet the growing power demands of the State, resulting in shortage of power. Due to this there are number of villages in various districts which are still under dark. as a result, the State is forced to purchase power from outside, for which a major part of the State's budget gets exhausted, and therefore, it appears to be a serious obstacle for Jammu and Kashmir's economic independence.

Jammu and Kashmir holds immense hydropower potential that remains largely underdeveloped due to geopolitical, technical, and institutional challenges. However, recent developments in SHPs, digital technology, and basin-wide planning offer a renewed opportunity to harness this renewable energy in a sustainable and inclusive way. A balanced approach—prioritizing environmental integrity, community participation, and efficient governance—can transform the region into a leading clean energy hub in northern India.

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