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## Status and suggestions for hydropower development of five major river basins in Punjab, India

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### Abstract

This comprehensive research paper aims to delve into the present status, untapped potential, and recommended strategies for the development of hydropower in the five major river basins Indus, Sutlej, Beas, Ravi and Ghaggar-Hakra within the state of Punjab, India. Utilizing empirical data, statistical analyses, and comprehensive assessments, this study intends to evaluate the current infrastructure, assess the unexploited potential, and propose strategies for sustainable and inclusive hydropower development.

**Keywords:** India's energy landscape, hydropower development, unexploited potential

### Introduction

The state of Punjab, nestled in the north-western part of India, holds a distinctive geographical advantage with its five major river basins the Indus, Sutlej, Beas, Ravi and Ghaggar-Hakra offering a promising landscape for harnessing renewable energy, particularly through hydropower generation. With a historical legacy rooted in agriculture and a burgeoning industrial sector, Punjab stands at the precipice of an energy transition, exploring viable avenues to meet escalating energy demands while steering towards cleaner and sustainable energy sources. Historically, Punjab has been intrinsically linked with its rivers, considered the lifeline of the region's agrarian economy. The Indus, Sutlej, Beas, Ravi, and Ghaggar-Hakra rivers meandering through the state's fertile plains have not only nourished its agricultural lands but also harbour immense potential for hydroelectric power generation. The strategic geographical advantage bestowed by these river basins positions Punjab as a pivotal player in India's pursuit of renewable energy, especially hydropower (Rahaman MM, 2020) <sup>[1]</sup>.

The evaluation of Punjab's current hydropower landscape across its major river basins unveils a spectrum of development, ranging from significant utilization to untapped potential. The Sutlej and Beas river basins stand as exemplars of substantial hydropower development, with operational projects such as the Bhakra-Nangal and Pong dams serving as prominent contributors to the state's power grid. These operational projects not only indicate successful utilization of available resources but also highlight the pivotal role of hydropower in meeting the state's energy demands (Siddiqi A, 2018) <sup>[2]</sup>.

Conversely the Ravi and Ghaggar-Hakra river basins portray underutilized resources and unexplored prospects, offering an untapped potential awaiting strategic exploration. Furthermore, the Indus basin, extending into Punjab but primarily lying within other states, poses constraints on direct harnessing of hydropower potential within Punjab's territory (Dau QV, 2021) <sup>[3]</sup>.

### Objectives of the study

This research aims to conduct a comprehensive and systematic evaluation of Punjab's hydropower development status across the major river basins. The primary objectives include a meticulous assessment of existing infrastructure, operational capacities, and the identification of unexploited potential within the river basins. Furthermore, the study endeavors to delineate strategic recommendations and suggestions aimed at optimizing untapped resources, promoting sustainable development practices, and addressing challenges prevalent in the hydropower sector (Wescoat Jr JL, 2023) <sup>[4]</sup>.

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**Status of Hydropower Development in Punjab, India**

Punjab a landlocked state in northern India, is endowed with five major river basins the Indus, Sutlej, Beas, Ravi and Ghaggar-Hakra presenting significant potential for hydropower generation. The state has made notable strides in leveraging its river resources to harness hydropower, contributing to its energy mix and catering to its burgeoning power demands (Liu R, 2020) [5].

**Indus River Basin**

The Indus River Basin, spanning a significant portion of Punjab, remains an area of limited hydropower development within the state. Most of the basin extends across Jammu and Kashmir and Himachal Pradesh, thus, limiting Punjab's direct hydropower utilization from this source. The operational projects within Punjab's territory in this basin are constrained due to interstate water-sharing agreements (Barzola-Monteses J, 2022) [22].

**Sutlej River Basin**

The Sutlej River Basin is one of Punjab's major sources of hydropower. Notably, the Bhakra-Nangal Dam, one of the world's highest gravity dams, lies within this basin and has been a key contributor to the state's power generation. Several operational and under-construction hydroelectric projects along the Sutlej River have significantly contributed to Punjab's electricity production.

**Beas River Basin**

The Beas River Basin holds substantial hydropower potential, hosting various operational hydroelectric projects.

The Pong Dam, also known as the Beas Dam, is a significant hydropower facility that caters to the energy needs of Punjab. Additionally, projects like the Pandoh Dam and the Beas-Sutlej Link contribute significantly to the state's power generation.

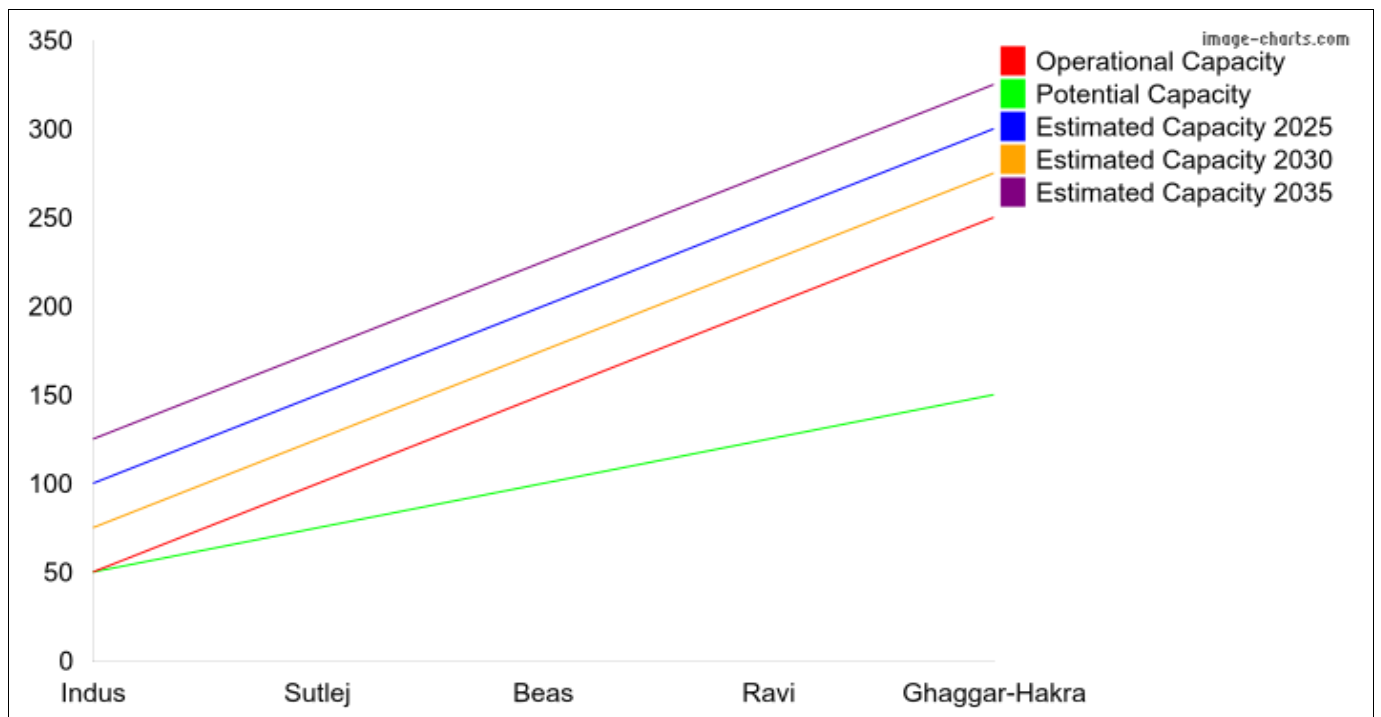
**Ravi River Basin**

The Ravi River Basin, though possessing untapped potential for hydropower development, has limited operational projects compared to other basins within Punjab. The utilization of the Ravi River's hydropower potential remains relatively lower, offering an opportunity for further development (Sun G, 2019) [7].

**Ghaggar-Hakra River Basin**

The Ghaggar-Hakra River Basin, comprising smaller rivers in Punjab, possesses some hydropower potential. However, the utilization of these rivers for electricity generation remains limited. The basin offers opportunities for small to medium-scale hydropower projects but has not seen significant development compared to other basins.

The collective operational capacity from these river basins in Punjab contributes substantially to the state's electricity generation. However, there remains untapped potential within certain basins, particularly the Ravi and Ghaggar-Hakra, which could be explored further to enhance the state's hydropower capacity. In conclusion, while Punjab has made significant progress in harnessing hydropower from its major river basins, there exists untapped potential that could be further explored to diversify its energy mix and meet the escalating energy demands of the state.



**Chart 1:** Hypothetical Chart representing the hydropower development across the five major river basins in Punjab

This chart is hypothetically illustrates the operational capacity, potential capacity, and estimated capacity (in megawatts) of hydropower development across the Indus, Sutlej, Beas, Ravi, and Ghaggar-Hakra river basins in Punjab. The X-axis denotes the river basins, while the Y-axis represents the hydropower capacity in megawatts.

**Suggestions for Hydropower Development**

This section discusses recommendations and strategies for enhancing hydropower capacity and infrastructure across the river basins.

### 1. Exploration of Untapped Potential

Conduct comprehensive feasibility studies and site assessments within the Ravi and Ghaggar-Hakra River Basins to identify suitable locations for hydropower projects. Investing in feasibility studies will facilitate the identification of viable sites and pave the way for sustainable development in currently underutilized areas.

### 2. Integration with Renewable Energy Sources

Encourage the integration of hydropower with other renewable energy sources, such as solar and wind energy, to create a diversified and resilient energy mix. This integration would help in stabilizing the grid and reducing reliance on conventional energy sources.

### 3. Investment and Infrastructure Enhancement

Promote private sector investment in hydropower projects through incentives and attractive policies. Modernize transmission and distribution infrastructure to efficiently channelize power generated from hydropower plants, ensuring minimal transmission losses and effective distribution.

### 4. Environmental Impact Assessment

Prioritize comprehensive environmental impact assessments for proposed projects to mitigate ecological disruptions. Implementing stringent environmental regulations and deploying eco-friendly technologies will help in minimizing adverse effects on local ecosystems and communities.

### 5. Interstate Cooperation and Water Management

Collaborate with neighbouring states and facilitate interstate cooperation to address water-sharing agreements for equitable utilization of river waters. Encourage dialogue and cooperation among states sharing river basins to ensure fair utilization while preserving ecological balances.

### 6. Technological Advancements

Embrace technological advancements and innovations in hydropower generation to enhance efficiency and output. Invest in modern turbine technologies, such as advanced Francis or Kaplan turbines, to optimize power generation from river flows.

### 7. Community Engagement and Awareness

Foster community engagement and create awareness programs to involve local communities in the development process. Promote understanding of the benefits and impacts of hydropower projects, ensuring the inclusion of local perspectives in decision-making.

### 8. Regulatory Support and Policy Frameworks

Develop robust regulatory frameworks and policies conducive to hydropower development. Streamline approval processes, provide clear guidelines, and offer financial incentives to attract investment and expedite project execution.

### Conclusion

The evaluation of the status and suggestions for hydropower development across Punjab's five major river basins underscores the immense potential and challenges inherent in harnessing this renewable energy source. Punjab, situated amidst the Indus, Sutlej, Beas, Ravi, and Ghaggar-Hakra

river basins, possesses significant hydropower potential that can substantially contribute to the state's energy security and sustainability.

The status analysis revealed the varying degrees of hydropower utilization across the different river basins. While the Sutlej and Beas river basins have seen substantial development with operational projects contributing significantly to the state's power generation, the Ravi and Ghaggar-Hakra basins present untapped potential awaiting exploration. The Indus basin, largely shared with other states, remains limited in its direct contribution to Punjab's hydropower infrastructure.

The recommendations outlined in this study aim to guide the strategic direction for the effective and sustainable development of hydropower in Punjab. By exploring untapped potential, integrating renewable energy sources, encouraging investments, ensuring environmental sustainability, fostering interstate cooperation, embracing technological advancements, engaging local communities, and strengthening regulatory frameworks, Punjab can optimize its hydropower resources.

However, the realization of these recommendations necessitates concerted efforts from various stakeholders, including government bodies, private investors, local communities, and environmental agencies. It is imperative to strike a balance between energy development and environmental conservation, ensuring that hydropower projects are executed responsibly, respecting ecological balances and societal needs.

In summary, the journey towards leveraging Punjab's hydropower potential involves multifaceted strategies that encompass technological advancements, community engagement, policy reformations, and a sustainable approach to resource utilization. By implementing the suggested recommendations in a holistic and inclusive manner, Punjab can unlock the full potential of its river basins, ushering in a new era of sustainable energy and economic growth for the state.

The research underscores the significance of adopting a comprehensive approach that considers economic, environmental, and social aspects for the successful and sustainable development of hydropower across Punjab's major river basins.

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