ASSAM'S

Untapped Energy Reservoir: Pumped Storage As Next Frontier

"Energy Marks The Progress; However, Storage Ensures Quality"

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Cover and design: Sanjay Kr Yadav

Citation: *Saikia, P., Das, R., Arpit, S., Malik, P., Priyadarshini, G., Shivaprakash, K. N., 2025. Assam's Untapped Energy Reservoir: Pumped Storage As Next Frontier. (Swaniti Global, 2025).*

Published by
Swaniti Global
Houston, Texas, United States
www.swaniti.com

Executive Summary

Pumped Storage Hydropower (PSH) is increasingly being recognized as a cornerstone technology in the global renewable energy transition, providing essential grid flexibility and long-duration storage to address the intermittency of solar and wind power. As India accelerates its decarbonization goals, PSH has become a critical enabler for integrating large volumes of variable renewable energy into the national grid. Representing over 90% of global grid-scale energy storage, PSH continues to be the most mature and cost-effective option worldwide. This blog explores India's growing PSH ecosystem with a dedicated focus on Assam, a state that is geographically and strategically well-positioned to lead this transition.

India currently operates eight PSH facilities, with two more expected by 2025, and over 50 additional projects are in various stages of development. In parallel, many states, including Assam, have introduced policies to promote PSH deployment. Assam's 2025 Pumped Storage Power Generation Promotion Policy sets ambitious capacity targets of 2,000 MW by 2030 and 5,000 MW by 2035. The state's mountainous terrain and extensive river networks create ideal conditions for both open-loop and closed-loop PSH systems, while its policy vision reflects a proactive stance toward grid modernization. Major private players such as Greenko, Adani Green Energy, and Hinduja Renewables have announced large-scale PSH projects in Assam, with combined investments exceeding INR 23,000 crore.

However, the high costs of these projects, significantly more expensive than comparable PSH plants in other regions like West Bengal, highlight Assam's topographical complexity, infrastructure gaps, biodiversity-related compensations, and inflation-linked cost escalations. At the same time, Assam also holds immense potential for distributed and modular PSH projects using smaller reservoirs and existing water bodies in eco-sensitive zones, which could provide quicker, more sustainable energy storage solutions.

Importantly, PSH not only supports technical energy needs but also generates socio-economic co-benefits: employment potential during the construction phase is substantial, with an estimated 2.2 full-time equivalent (FTE) jobs per megawatt, and operational sites can catalyze ecotourism and rural income generation. To unlock this potential, Assam must accelerate geospatial site identification, streamline approvals for projects already under Detailed Project Report (DPR) preparation, and institutionalize modular construction practices. Coordination between state authorities, Central Electricity Authority (CEA), and private developers will be vital to maintain project timelines and minimize ecological disruption.

Ultimately, PSH represents a transformative opportunity for Assam not only to meet its own energy needs but to become a regional clean energy hub contributing to India's Northeast vision and cross-border energy trade. With timely investments, policy stability, and institutional commitment, Assam can position itself as a national leader in pumped storage hydropower, delivering on climate resilience, energy security, and equitable development.

Introduction

Climate change is one of the most pressing global challenges of the 21st century, and at its core lies the urgent need to decarbonize the electricity sector. As nations increasingly shift from fossil fuels to low-carbon energy sources like solar and wind, the variability of these renewable sources introduces a critical challenge: How can we ensure energy supply when the sun doesn't shine, or the wind doesn't blow?

To address this issue, electricity grids must evolve to become more resilient and flexible, ensuring round-the-clock reliability. In this context, energy storage systems (ESS) play a pivotal role, and among the available technologies, Pumped Storage Hydropower (PSH) remains the dominant and most mature form of large-scale storage. Globally, PSH accounts for over 90% of installed grid-scale energy storage capacity, offering long-duration storage, fast ramping, and high efficiency.

Understanding PSH: Basic Working Principle: PSH systems operate on a simple yet effective mechanism. During periods of low electricity demand (typically when prices are lower), excess electricity is used to pump water from a lower reservoir to an upper reservoir. When demand rises and electricity prices peak, the stored water is released back down through turbines, generating electricity in the process. This cycle provides not just storage but also crucial services like frequency regulation, peak load shaving, and grid inertia. Figure 1 illustrates a basic schematic of the PSH process[1].

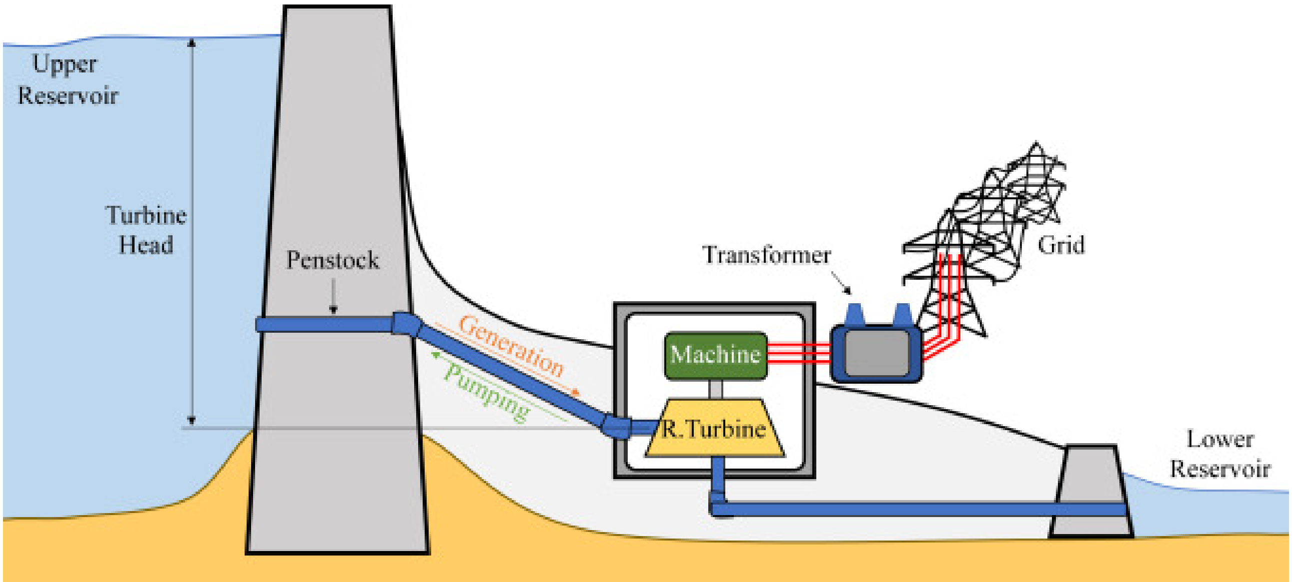


Figure 1: *A schematic representation of PSH technology.*

Global Momentum in PSH Development: Given its advantages, PSH development is expanding rapidly across the globe. Figure 2 presents the pipeline of PSH projects at various stages (announced, under review, approved, or under construction) by region[2]. East Asia and the Pacific currently lead in PSH development, with countries like China investing heavily in this technology to complement their massive solar and wind capacities.

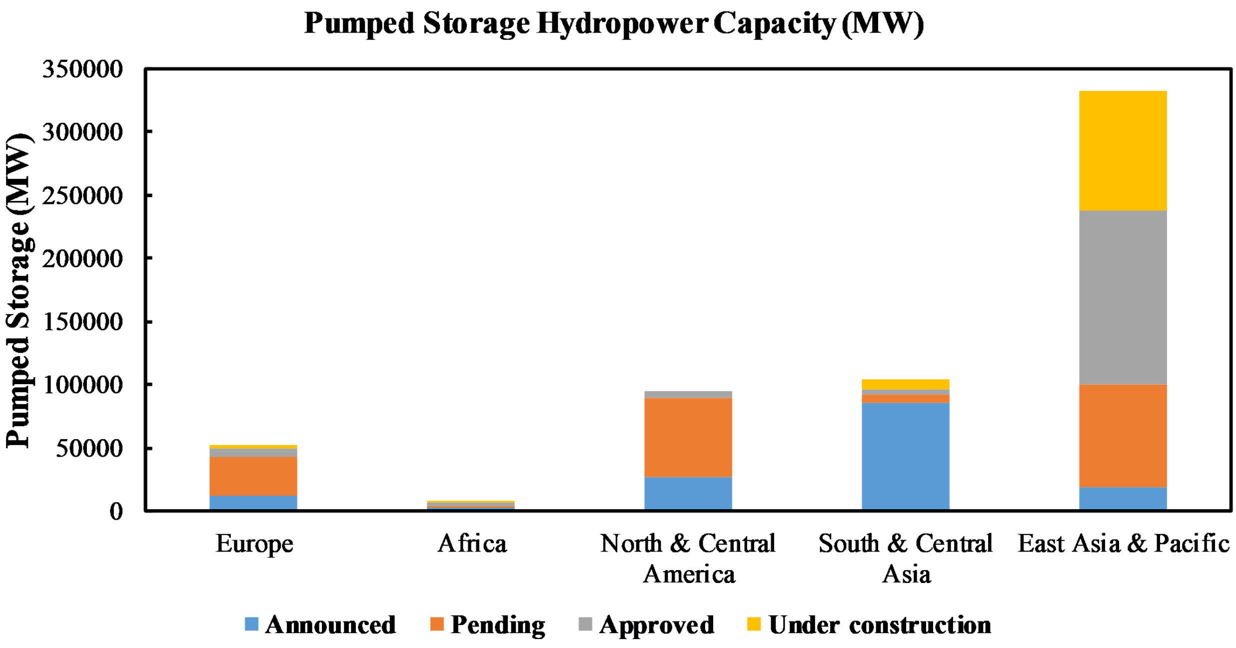


Figure 2: *Pumped storage hydropower pipeline by region and project stage.*

Types of PSH Systems: PSH systems are generally classified into two broad categories:

Open-Loop PSH: These are connected to existing natural water bodies like rivers or lakes. For example, the Bhivpuri Pumped Storage Plant in India[3] uses a river-based system.

Closed-Loop PSH: These are completely independent of natural water systems and use artificial reservoirs. A classic example is the Ffestiniog Power Station in the UK, which uses two man-made reservoirs and operates entirely off-river[4].

Each configuration has distinct environmental, operational, and site-selection considerations. Table 1 in the report summarizes key variations and technical configurations of PSH systems. Further, underground PSH, modular systems, and variable speed turbines are also gaining attention for improving system flexibility and grid integration.

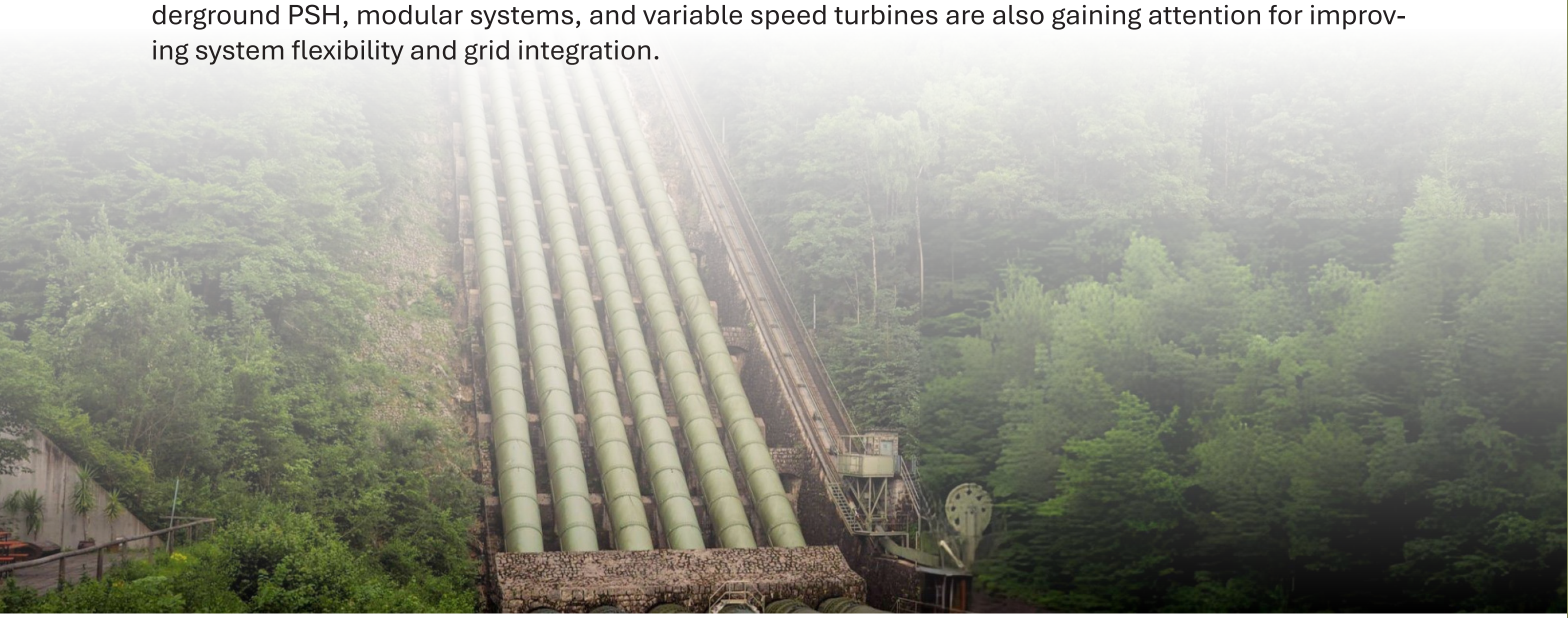


Table 1: *Summary of PSH technologies*

Category	Short description	Name
Planned Caverns	This technology utilises caverns, mines, or underground reservoirs for storing energy, basically a lower reservoir.	Limmern Pumped Storage Hydropower in Switzerland[5]
Retrofitting an existing hydropower reservoir	In the current configuration, the hydropower dams are retrofitted with suitable technology to enable them as PSH.	Tehri PSH[6]
Retrofitting PSH on an open-pit mine	In the present configuration, open-pit mines are used as a lower reservoir.	Fushun West open-pit mine[7]
PSH utilising underground mine	Repurposing existing mine voids as the lower reservoir in a large-scale energy storage system.	Prosper-Haniel mine in Germany[8].
Underground PSH (UPSH) Lower Reservoirs	In this configuration, the vertical wells are crossed by horizontal wells.	Péronnes-lez-Binche in Belgium[9].

PSH Ecosystem in India

As India advances toward integrating large-scale renewable energy, Pumped Storage Hydropower (PSH) has re-emerged as a critical enabler of grid flexibility. PSH projects offer a scalable and proven solution to balance the variability of solar and wind power, and they currently account for over 90% of global grid-scale storage capacity.

Aligning with this global trend, India has significantly ramped up its focus on PSH development in recent years. Table 2 presents the status of pump storage projects in India[10], as of 2023. Of the total 52 projects in the pipeline, 30 are off-river systems highlighting a shift toward low-environmental-impact models.

Table 2: *Status of PSH projects in India (as of 2023).*

Sl.No.	Schemes	On-River		Off-river		Total	
		No of projects	Capacity (MW)	No. of projects	Capacity (MW)	No. of projects	Capacity (MW)
1	Existing PSH	8	4746	NA	NA	8	4746
2	PSH under Construction	3	1580	1	1200	4	2780
3	DPRs Concurred by CEA	1	1000	NA	NA	1	1000
4	Under Examination	1	1350	NA	NA	1	1350
5	Schemes under Survey & Investigation	6	8200	27	33950	33	42150
6	Schemes under Survey & Investigation held up	3	4500	2	820	5	5320
	Grand Total	22	21376	30	35970	52	57346

Current Operational Landscape: As of 2023, India has eight operational PSH projects, with two more — Tehri (500 MW) in Uttarakhand and Pinnapuram (1680 MW) in Andhra Pradesh — expected to be commissioned by 2025. These will bring the total operational capacity to ten PSH projects spread across key states. The spatial distribution of these operational PSH projects is clearly illustrated in Figure 311, which shows both legacy and upcoming projects. Notably:

- **Oldest PSH:** Bhira PSH in Maharashtra, commissioned in 1927 (400 MW)
- **Largest Existing PSH:** Sardar Sarovar RBPH in Gujarat (1200 MW), commissioned in 2005
- **Recent Additions:** Purulia PSH in West Bengal (900 MW, 2007), Srisailam LBPH in Telangana (900 MW, 2001), and Ghatgarh PSH in Maharashtra (250 MW, 2008)
- **Upcoming by 2025:** Tehri (500 MW), Kadamparai (400 MW, Tamil Nadu), and Pinnapuram (1680 MW)

These PSH projects are a mix of river-based and off-river systems, reflecting diverse geographical and hydrological strategies.

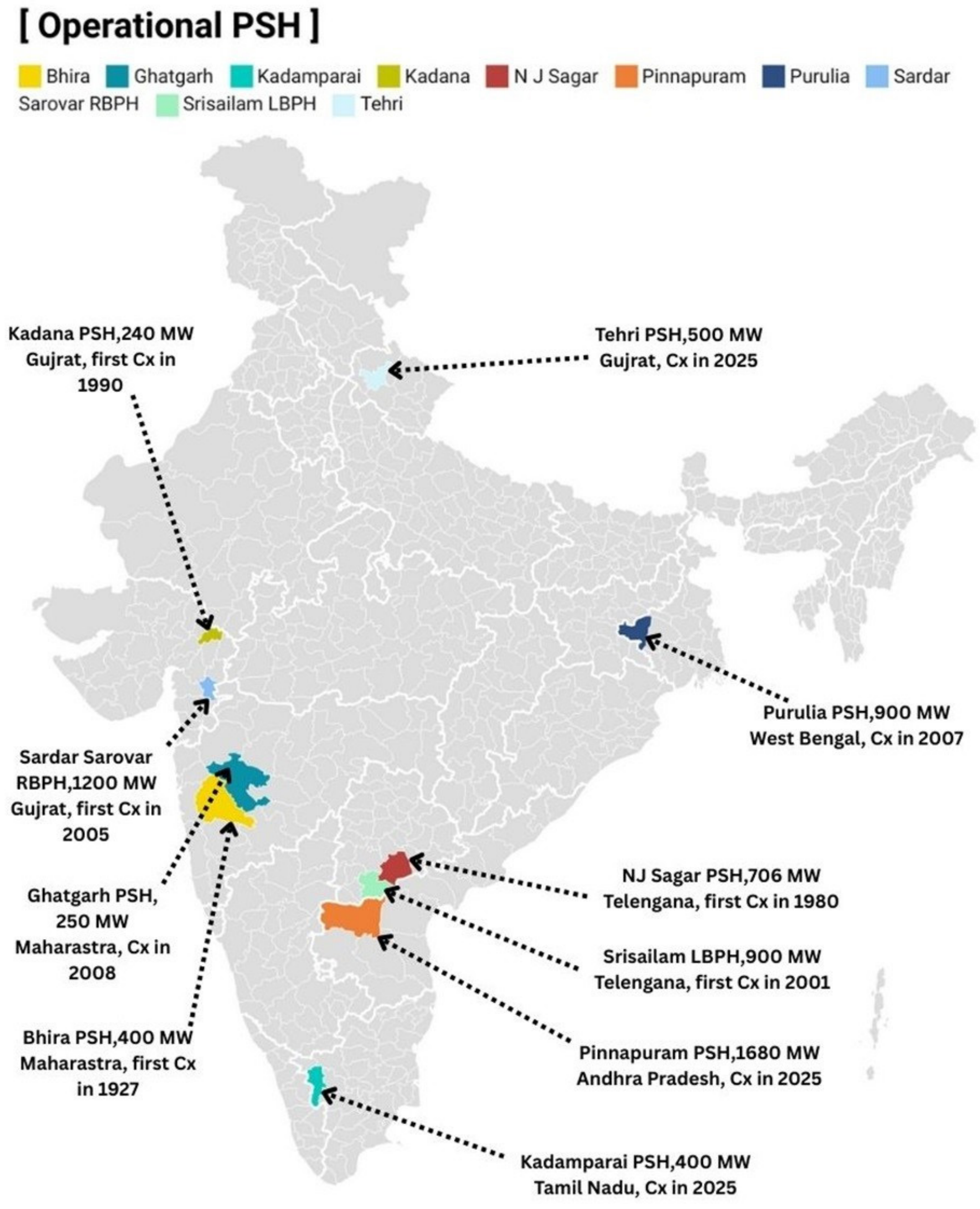


Figure 3: *List of operational PSH in India*

Several Indian states, including Gujarat, Maharashtra, Telangana, and West Bengal, have become PSH leaders by leveraging their terrain and water infrastructure. Importantly, states such as Assam are emerging with ambitious plans. Assam has committed to developing 2,000 MW of PSH capacity under its recent renewable energy policy, signalling a strong alignment with national and global priorities.

Assam's geographic advantages, including undulating terrain and water resources, position it as a prime candidate for scalable PSH deployment. As national momentum grows and policy frameworks become more enabling, Assam has an opportunity to be a frontrunner in the Northeast region's energy transition.

PSH Targets and Potential in Assam

Assam has emerged as a proactive state in advancing Pumped Storage Hydropower (PSH) to meet its clean energy transition goals. Recognizing PSH as a critical enabler for grid flexibility and large-scale renewable integration, the state government has introduced the Assam Pumped Storage Power Generation Promotion Policy 2025, which sets ambitious targets for installed PSH capacity:- 2,000 MW by 2030 and 5,000 MW by 2035[12]. This policy framework is designed not only to unlock Assam's significant hydro-storage potential but also to attract private investment and catalyze infrastructure development in the region.

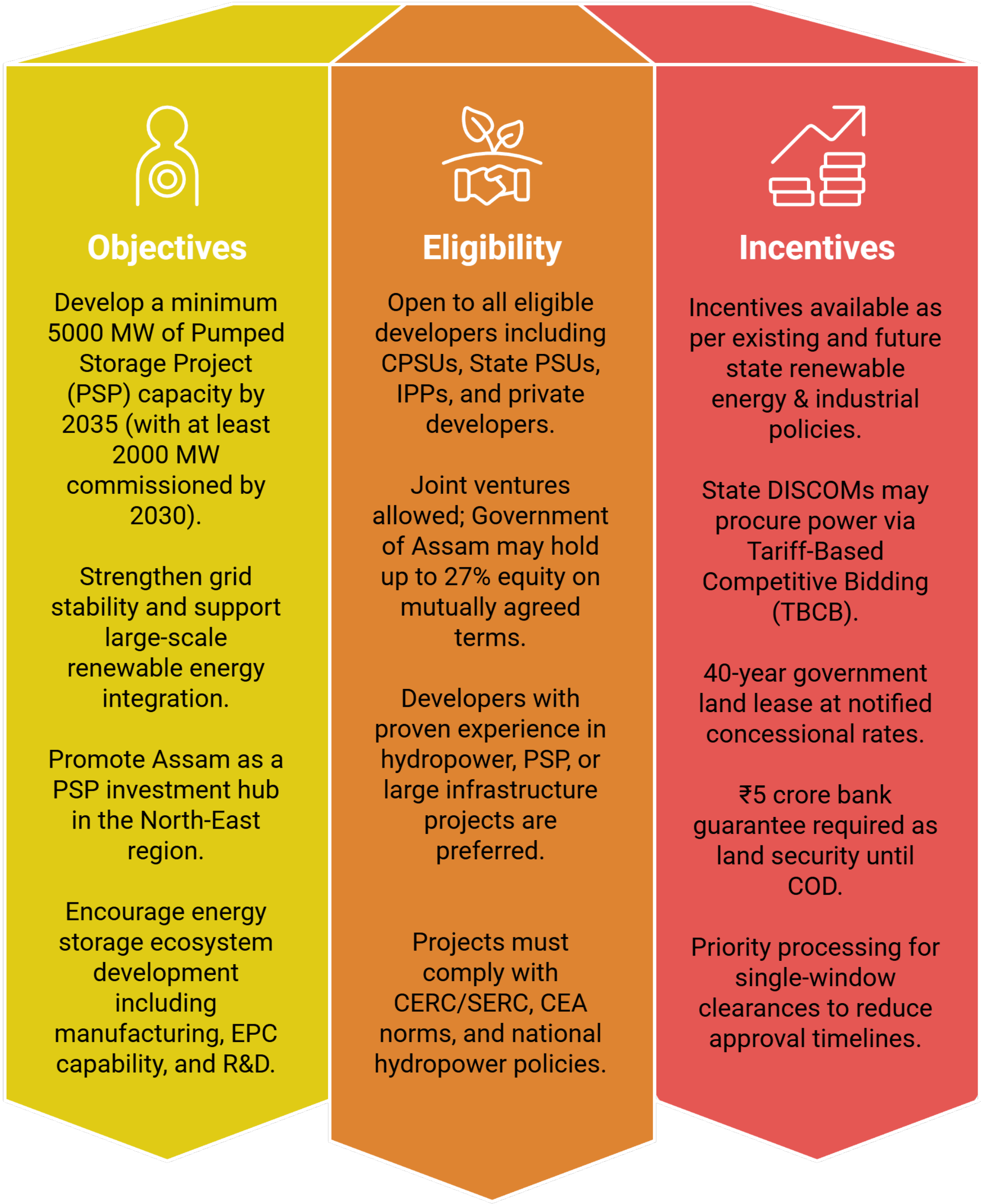


Figure 4: *Different points of Assam Pumped Storage Power Generation Promotion Policy 2025.*

The high PSH potential in Assam stems from a convergence of geographical and strategic factors. The state's hilly terrain provides the required elevation differential for energy storage, while its abundant river systems and natural reservoirs are ideal for both open-loop and closed-loop PSH systems. These geographical advantages are reinforced by rising electricity demand, peak load deficits, and a growing share of intermittent renewable energy sources such as solar and wind. In this context, PSH serves as a mature, scalable, and dispatchable solution to ensure grid stability and reliability.

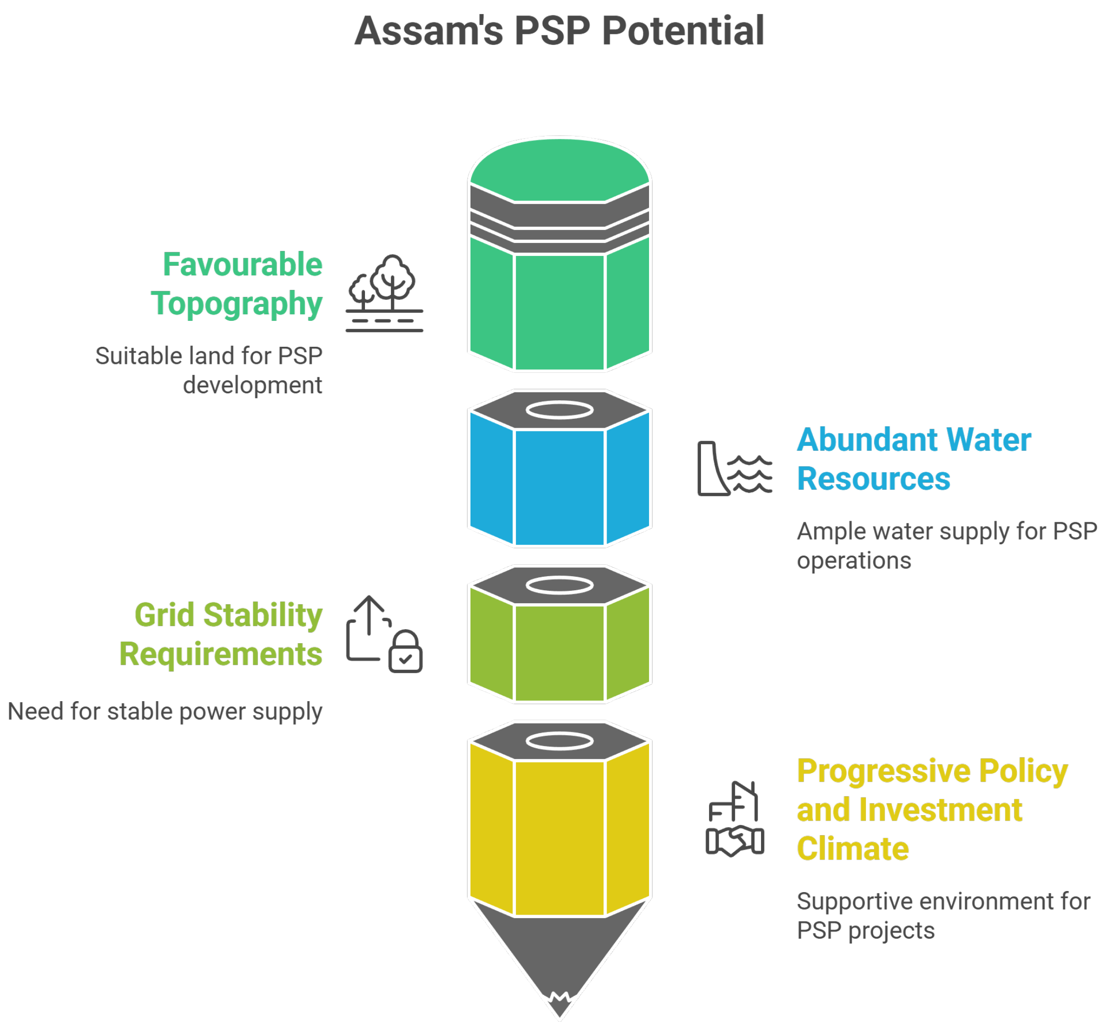


Figure 5: *Different reasons for developing Assam's PSH.*

In recent years, Assam has taken bold steps to operationalize its PSH vision. The state cabinet has approved a 900 MW pumped storage project in West Karbi Anglong, to be developed by Greenko Energies Pvt. Ltd., with an estimated investment of INR 5,849.49 crore[13]. Additionally, Hinduja Renewables has committed to develop 2,500 MW of PSH capacity in Assam[14], and Adani Green Energy Ltd. has announced plans to invest approximately INR 15,000 crore in two PSH projects totaling 2,700 MW. These developments underscore the state's commitment to build a strong pipeline of storage assets to complement its renewable energy goals.

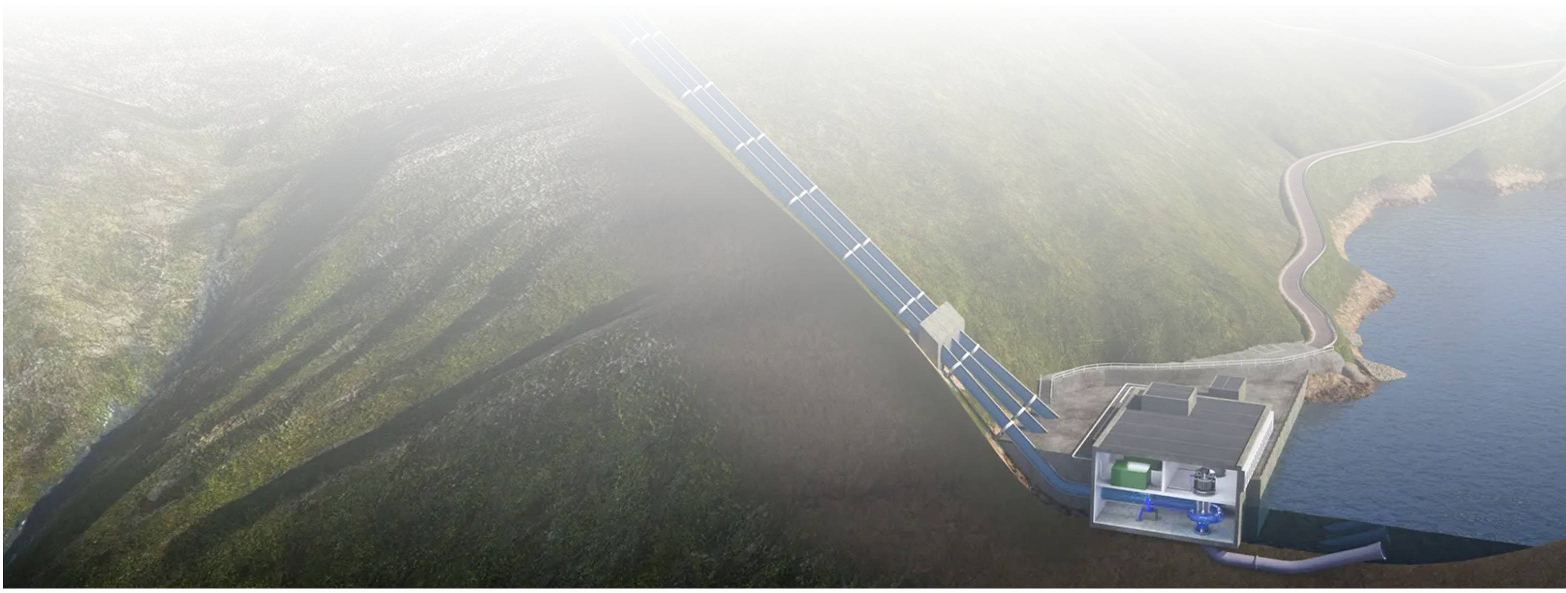
A comparative analysis between Assam's West Karbi Anglong PSH and West Bengal's Purulia PSH, both with an installed capacity of 900 MW, reveals significant cost differences. The Purulia project, with a head of 177 meters, was completed at a cost of INR 2,952.60 crore (INR 3.28 crore/MW)[15], while the West Karbi Anglong project, despite a higher head of 367.5 meters, is projected to cost INR 5,849.49 crore (INR 6.50 crore/MW). A cost comparison of Purulia PSH16 with West Karabi Anglong PSH is presented in Table 3[16]. This cost disparity is likely due to Assam's more complex topography, biodiversity offsets, weaker road infrastructure, and higher inflationary inputs. Such insights emphasize the need for careful terrain-specific planning and adaptive cost estimation frameworks in Northeast India.

Table 3: *Cost Comparison of Different PSH Projects.*

Project	State	Head (m)	Capacity (MW)	Cost of Project (Rs.Crore)	Cost of Project (Rs.Crore/MW)
Purulia PSH	West Bengal	177	900	2952.60	3.28
West Karbi Anglong PSH	Assam	367.50	900	5849.49	6.50

Beyond large-scale developments, Assam's policy and topography are also well-suited for promoting modular, distributed PSH systems. These small- to medium-sized installations can be integrated with rural energy systems, leveraging existing bunds, reservoirs, and off-grid applications. Given Assam's ecological sensitivity and decentralized settlement pattern, modular PSHs offer a more sustainable, faster-to-deploy, and lower-impact approach to meeting storage needs across the state.

Overall, Assam's strategic and policy-led push towards PSH positions it as a key leader in India's Northeast for clean energy storage. The combination of policy ambition, geographical advantage, and early project momentum offers a replicable model for other states with similar terrain and energy challenges.



Employment Opportunity

Beyond its technical and energy transition potential, pumped storage hydropower (PSH) presents considerable socio-economic benefits, particularly, in generating employment across both the construction and operational phases of the project lifecycle[17]. Studies suggest that PSH projects can create approximately 2.08 full-time equivalent (FTE) jobs per megawatt (MW) during the construction and commissioning phase[18]. For example, a 1,000 MW PSH facility such as the proposed West Karbi Anglong project in Assam could generate over 2,000 direct jobs during its multi-year construction period. These roles encompass a wide array of civil, mechanical, and electrical tasks, including excavation, tunnelling, turbine installation, logistics, and quality control, which in turn boost demand for skilled, semi-skilled, and unskilled labour, often drawn from local communities. Globally, hydropower (including PSH) remains one of the largest employers in the renewable energy sector. According to the latest estimates, the hydropower sector supported nearly 2.49 million direct jobs worldwide in 2022, marking a 2.3% increase from the previous year[19].

Once operational, PSH plants continue to support stable employment, with an estimated 0.57 FTE jobs per MW annually for operations, maintenance, and administrative tasks[18]. This means a 1,000 MW plant could generate around 570 steady jobs per year, spanning roles in grid interface management, dam and reservoir upkeep, turbine maintenance, safety, and monitoring. These long-term opportunities make PSH attractive as a consistent source of green livelihoods, especially in regions like Assam, where alternative large-scale employment is limited.

Additionally, PSH reservoirs have the potential to catalyse regional development through tourism and allied services. In various international and Indian contexts, such reservoirs have been repurposed into eco-tourism hubs with boating, scenic trails, and visitor facilities, creating indirect employment in hospitality, local transport, guide services, and retail. Such economic diversification can be particularly beneficial in hilly and remote districts, expanding the development impact of PSH beyond the energy sector.

In the context of Assam, where many planned PSH sites are located in rural and forested areas, the employment opportunity becomes even more significant. These regions face limited industrial development and high levels of underemployment. A PSH driven infrastructure boom, combined with targeted skill-building and community engagement can meaningfully enhance livelihoods, reduce migration, and uplift regional economies. Assam's favourable topography and its recent policy push for 5,000 MW of PSH by 2035 further underscore the employment and economic promise of this sector.

However, it is essential that these benefits are equitably realized. Prioritizing local hiring, ensuring skill training, and adhering to environmental and social safeguards are crucial to building inclusive and sustainable employment ecosystems. If implemented effectively, PSH projects in Assam could serve as a model for combining clean energy infrastructure with meaningful job creation and rural development.

Recommendations: Scaling Pumped Storage Hydropower (PSH) in Assam

To accelerate renewable energy integration and ensure grid stability in the long term, energy storage obligations, particularly through Pumped Storage Hydropower (PSH), must be made mandatory. The Government of India already recognizes Large Hydro Power (LHP) plants above 25 MW, including PSHs, as part of the Hydropower Purchase Obligation (HPO), contributing to the overall Renewable Purchase Obligation (RPO) targets[20].

In addition, repurposing older hydroelectric assets such as non-powered dams and underutilized reservoirs for PSH operations can be a cost-effective and environment-friendly approach to expand storage capacity without major new ecological footprints.

Strategic Recommendations for Assam: Given Assam's hydrological richness, topographical diversity, and energy transition priorities, the following recommendations are proposed to unlock the full potential of PSH in the state:

Geospatial Site Identification for PSH Deployment: A comprehensive GIS-based terrain and water-body mapping exercise should be conducted to identify feasible upper and lower reservoir combinations for closed-loop or off-river PSH systems. This geospatial planning must factor in elevation gradients, land availability, existing infrastructure, and environmental sensitivities.

Timely Project Completion with Contextual Flexibility: For PSH projects in the pipeline (e.g., those currently under DPR preparation), a typical two-year timeline can be retained. However, Assam's complex terrain, monsoonal impacts, and remote locations warrant context-sensitive relaxation of deadlines, along with stronger project management support from central agencies.

Modular and Scalable Design Approach: PSH technologies should be modularized, enabling phased development, faster regulatory clearances, and parallel construction activities. This approach can help scale up capacity in stages while reducing financial risks and accelerating commissioning timelines.

Grid Planning with Storage Benchmarks: The Central Electricity Authority (CEA) should define state-wise optimal storage capacities (in MWh) based on peak demand projections and RE capacity targets. This would guide Assam's DISCOMs and developers in planning PSH capacities aligned with expected grid balancing requirements.

Regional Energy Cooperation and Cross-Border Trade: Expanding PSH capacity in Assam could also position the state as a clean energy hub for Northeast India and neighboring countries like Bhutan, enabling cross-border electricity trade and enhancing regional energy security. Strategic interconnection and policy alignment with regional players would be key to realizing this vision.

In conclusion, Pumped Storage Hydropower has emerged as a strategic pillar for Assam's sustainable energy future. Its natural terrain and water resources, combined with national policy support and demand for flexible storage, make PSH a compelling investment. With targeted reforms, technology choices, and institutional backing, Assam can become a model state for PSH-driven energy transition in the Northeast region.

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