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SAARC ENERGY CENTRE
Energy for Peace & Prosperity

Business Models and Financing for Pump Storage Hydro Projects

22nd September 2025

Agenda

- Setting the Context
- Overview of Pumped Storage Hydropower
- Barriers and Challenges
- International Best Practices & Case Study
- PSH Developments in India
- Recommendations and Way Forward
- Questions and Answers

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Section 1

Setting the Context

After the Paris Agreement (2015), there has been increasing focus in clean energy transition

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The **Paris Agreement** promotes the transition away **from fossil fuels to renewable energy** by establishing a framework for **increased global renewable energy capacity, improved energy efficiency**, and a **phased elimination of fossil fuel subsidies**

*The **Paris Agreement** is a legally binding treaty adopted in 2015 by 195 countries, aiming to **limit global temperature rise to well below 2°C above pre-industrial levels, and preferably to 1.5°C**, by achieving a balance of greenhouse gas emissions*

Key Drivers for Clean Energy Transition

International consensus on climate change

Shifting from fossil fuel-based generation facilities to clean energy sources

Project Sustainability Protocols

Evaluation of projects on ESG parameters to have sustainable outcomes

Climate resiliency for project financing

Climate related impact is major factor for evaluation of projects

Demand of Balancing services

Increasing demand of balancing services to promote integration of RE sources

Regional Cooperation

Regional interconnection to meet consolidated energy demands

The global energy transition from fossil fuels to renewable energy will require large quantities of long duration storage

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Under IRENA's Transforming Energy Scenario for 2050, **86% of electricity generation will be renewable, and 60% would come from solar and wind, with installed capacities of over 6,000 GW (wind) and 8,500 GW (solar), in 2050**.

Relevance of Long-Duration Storage Requirement

Integration of Renewable Energy

- *Supports high penetration of variable renewables like solar and wind.*
- *Stores excess renewable energy generated during peak production for later use.*

Grid Stability and Reliability

- *Long-duration storage helps balance supply and demand over extended periods (hours to days).*
- *Ensures continuous power supply during renewable energy lulls (e.g., night-time, cloudy days).*

Energy Security and Resilience

- *Enhances energy security by providing a buffer against supply disruptions.*
- *Supports grid resilience during extreme weather events or outages.*

Economic Benefits

- *Reduces need for peaking power plants and expensive grid upgrades.*
- *Allows for better utilization of renewable assets, improving overall system efficiency.*

Decarbonization Goals

- *Enables reduction in fossil fuel dependence by storing clean energy.*
- *Facilitates transition to a low-carbon energy system by providing clean backup power.*

Hydrogen : Versatile Energy Carrier

- *Long-duration storage in hydrogen form enables multiple end uses: power generation, transportation fuel, and industrial feedstock.*
- *Hydrogen storage can be scaled and geographically dispersed*

Pump storage hydropower (PSH) is a proven storage technology that offers a cost-effective way to provide reliable large-scale balancing and grid services. Countries and regions are developing storage targets, estimated requirements, and need to ensure PSH is included as part of critical infrastructure planning

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Section 2

Overview of Pump Storage Hydropower

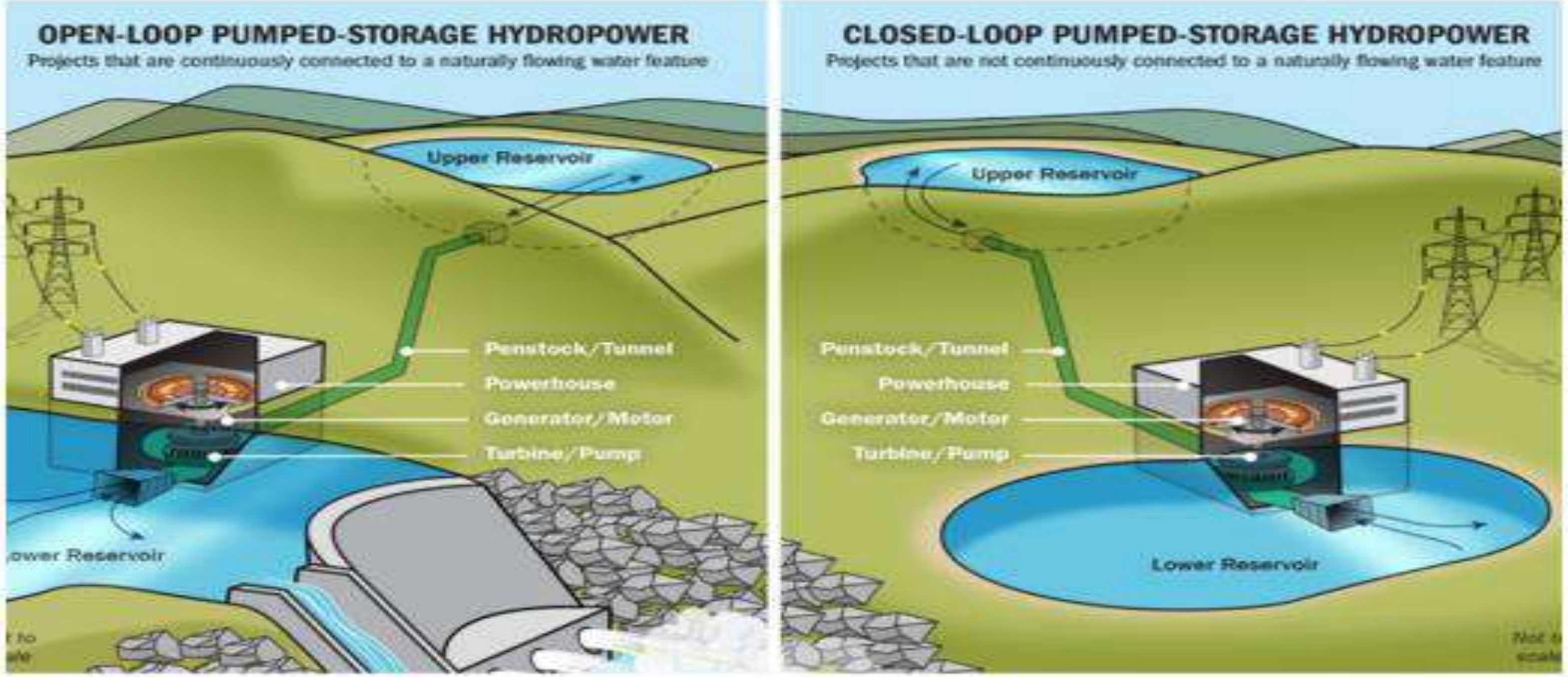
Overview of PSH technology

Key aspects of Pump Storage Hydro Storage (PSH)

- Pump storage hydropower (PSH) is a type of **hydroelectric energy storage**
- A system of **two water reservoirs at different elevations** that generate power as water moves down (discharges) from one to the other, while passing through a turbine
- The system also requires power as it **pumps water back into the upper reservoir** for recharge
- PSH **acts similarly to a giant battery**, because it can **store power and then release** it when needed

PSH consists of two reservoirs at different levels & are of two types – **Open Loop** and **Closed Loop** Pumped Storage Hydropower

Projects that are continuously connected to a naturally flowing water feature	Projects that are not continuously connected to a naturally flowing water feature



Benefits of PSH for Power Systems

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Provisioning of Peaking Support

Ability of hydropower storages to almost instantly ramp up to meet the peak requirements

Quick and Black Start Capability

Capability to run at zero load, ability to restore services in case of cascade tripping more quickly than other sources

Improve System Power Factor

Can be operated in synchronous condenser mode to improve the system power factor

Improves Reliability

Can resume operations without relying on support from external power sources

Frequency Control Ancillary Services

Maintain the frequency within the given margins by continuous modulation of active power

Spinning Reserves

Provisioning of spinning reserves/additional power supply to support system stability in case of unexpected load changes/blackout support

Voltage Support

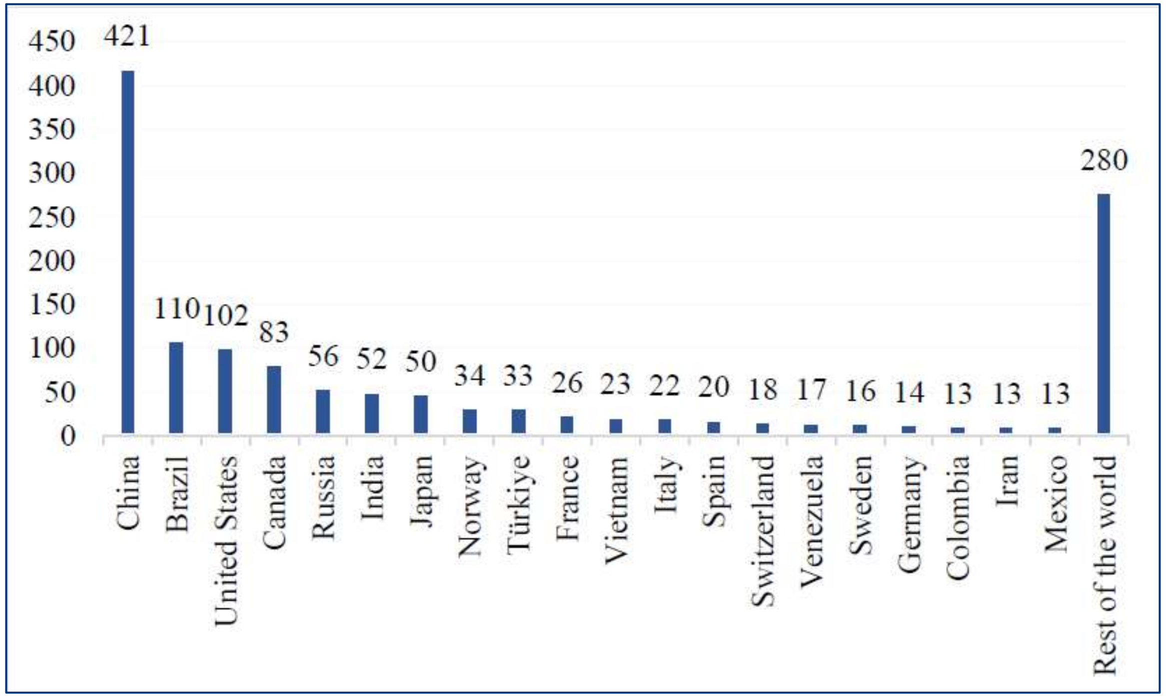
Control of system voltages by ability to supply reactive power

Enhances Flexibility and Integration

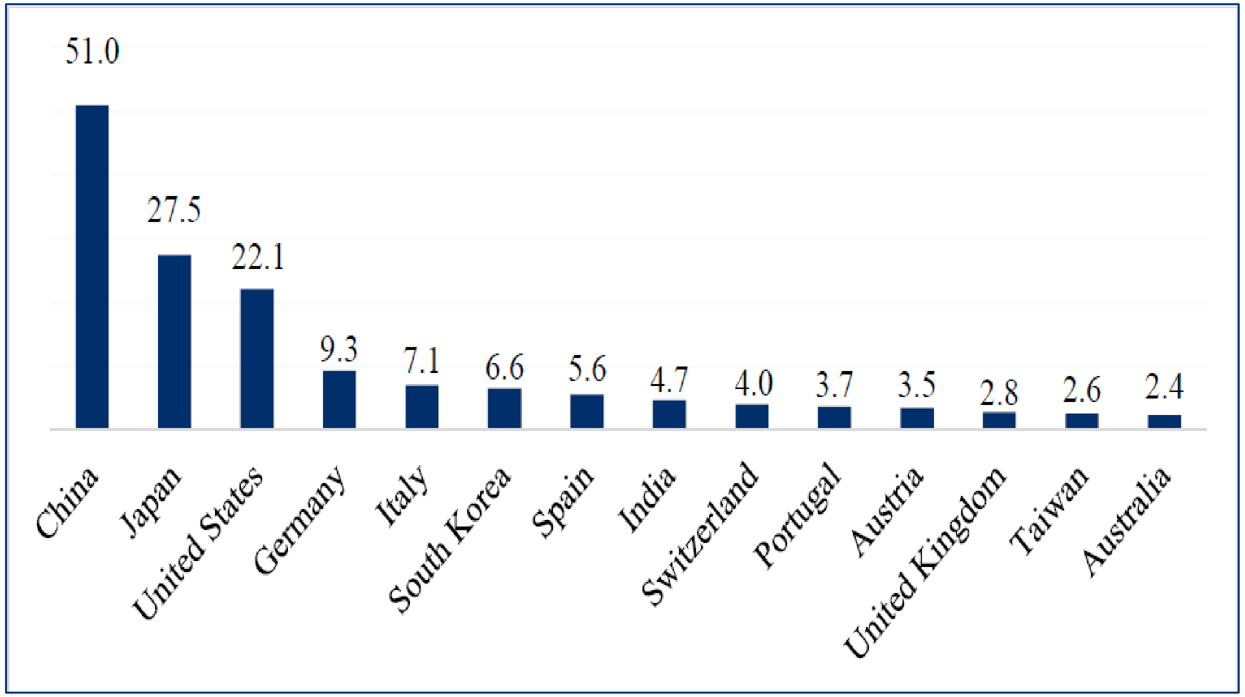
Meet real-time energy needs, is flexible and becomes complementary to other sources of generation

Recent Developments - Global Hydropower and PSH Installed capacity

Installed Hydro Power Capacity (in GW)



Global PSH installed capacity (in GW) as of 2023



Source: International Hydropower Association (IHA)

- **Japan (55%)** and **Germany (66%)** have the highest PSH share—over 50% of their installed hydropower capacity.
- Countries with PSH share between **20%–30%**: **Italy**: 32%, **Spain**: 28%, **Switzerland**: 22%, **United States**: 22%
- **China** has the **largest PSH capacity globally** at **51 GW**, but it represents only **12%** of its total hydropower capacity.

*With the global push for emission reduction and deeper renewable energy integration, countries are increasingly turning to **PSH** not just as a generation asset, but as **a strategic tool to mitigate renewable variability and enhance grid resilience***

PSH capacity addition and developments in SAARC countries

Pumped storage capacity added in 2023 (MW)

Region	Capacity (MW)
North and Central America	162
South America	0
Europe	121
Africa	0
South and Central Asia	0
East Asia and Pacific	6,206
Total	**6,489**

Country	Developments
Afghanistan	• *Currently hydropower development is limited; no prominent PSH in pipeline.*
Bangladesh	• *Research suggests potential in Chittagong region, but no active projects yet.*
Bhutan	• Integrated PSH, Gongri-Jerichhu in feasibility stage; several other hydro projects (incl. PSH) in pipeline
India	• 8 operational projects, 6 under-development and around 44 announced (pipeline capacity > 60 GW)
Maldives	• *None (focus on solar + battery storage)*
Nepal	• Several *proposals and studies ongoing for PSH development*
Pakistan	• *Research/ planning phase for seasonal PSH in Indus basin*
Sri Lanka	• *Feasibility studies for PSH potential; identified in CEB Long Term Generation Plan*

- *In 2023, the **East Asia and Pacific region** emerged as the global leader in pumped storage hydropower, commanding the highest total installed **capacity at 92 GW** and driving growth with a remarkable **6.2 GW added** in just one year*
- *Key reasons for such dominance of the region are **Rapid Renewable Energy Growth**, **Favorable Topography** and **Strong Policy Push and Long-Term Energy Planning***

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Section 3

Barriers and Challenges

Barriers and Challenges to PSH Development

Key challenges for PSH today include **ensuring profitability of existing plants** and **securing stable economic signals to attract institutional investment for new projects**

High Initial Capital Costs

PSH projects require significant upfront investment for construction, including civil works, turbines, reservoirs, and transmission infrastructure

Site Selection and Environmental Impact

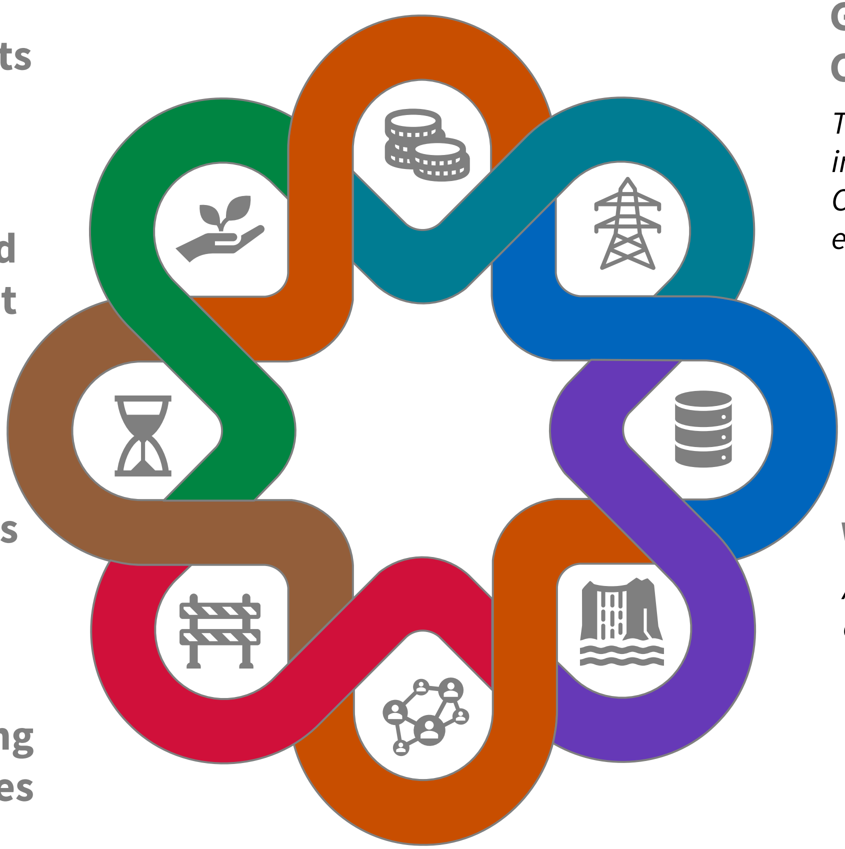
Limited suitable sites and concerns over ecosystem disruption, water use, and land changes pose regulatory and public acceptance challenges

Long Development Timelines

PSH projects typically have long planning, permitting, and construction phases, often spanning several years to decades

Regulatory and Permitting Hurdles

Obtaining necessary environmental and construction permits can be complex and time-consuming, involving multiple agencies and stakeholders



Grid Integration and Market Conditions

The value of PSH depends on electricity market dynamics, including price fluctuations and demand patterns. Changes in market rules or low-price spreads can affect economic viability.

Competition from Other Storage Technologies

Emerging energy storage options like batteries offer faster deployment and modularity, potentially reducing the attractiveness of PSH

Water Resource Management

Availability and management of water resources are critical, especially in regions facing drought or competing water demands

Social Acceptance

Local communities may oppose projects due to environmental concerns, land use conflicts, or displacement issues

*These barriers require careful planning, stakeholder engagement, and supportive policies to enable successful PSH development. Like other large infrastructure ventures, **risk mitigation** is essential due to **large capital outlay** and **revenue uncertainty***

Large capital outlay – project finance risk

- **Hydropower projects, including PSH, require substantial upfront civil works investment**, often before any revenue generation begins
- **Investors bear full cost exposure early**, increasing the project's financial risk profile
- **Bankability concerns arise** due to high capital requirements and delayed cash flows
- **Projects may be deemed financially nonviable**, even if technical or operational risks are low
- **Public sector financial instruments** (e.g., viability gap funding, guarantees) may be essential to mitigate risk and attract private investment

Financial non-viability can be mitigated through:

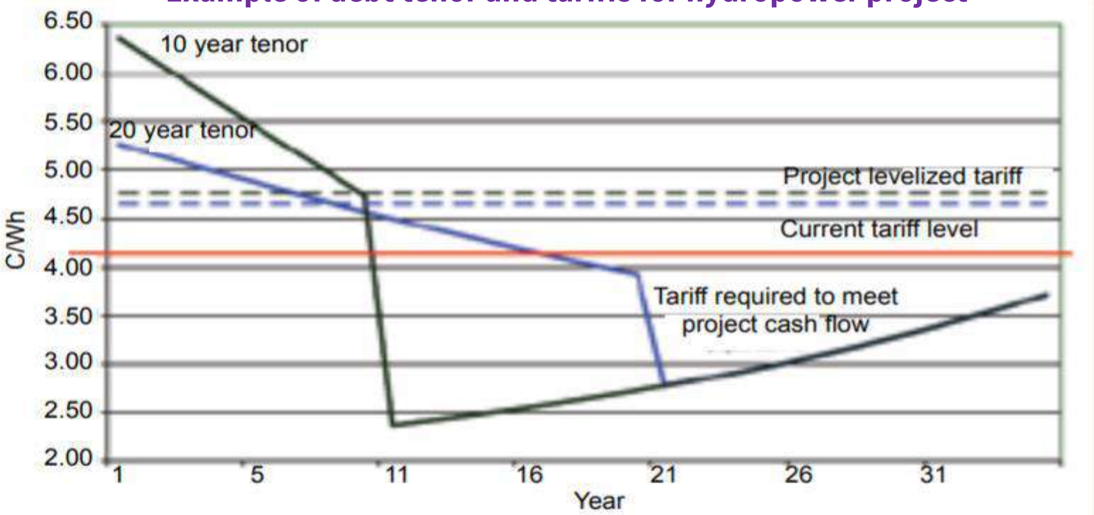
- Government Subsidies
- Tax Concessions
- Public private partnerships (PPPs) – Ownership of assets
- Combination of private or public financing

*Risk profiles considered unacceptable can be made **viable through credit enhancement guarantees** or by **redistributing the risks among the project stakeholders.***

Risk split between public and private sectors:

- **Private sector** handled the **lower-risk power station**.
- **Public sector** managed the **higher-risk dam infrastructure**.

Example of debt tenor and tariffs for hydropower project



*Ownership and financing model assessment includes evaluating the debt repayment period (tenor). High upfront civil works costs increase financial risk. **Graph** illustrates that:*

- ***20-year debt tenor** brings the break-even tariff closer to the levelized tariff*
- ***10-year debt tenor** results in higher tariffs in early years, making projects less attractive*

*PSH projects typically have **long technical lifespans**, while **debt tenors are relatively short**. Short-tenor financing may require higher short-term tariffs or deter investment. Tariff levels directly influence project bankability and investor interest.*

*Securing a stable revenue stream is **critical** to: **1) Remunerate PSH for all services provided., 2) Reduce financial and revenue uncertainty***

Revenue uncertainty

Key reasons for revenue uncertainty

- **Long-term revenue predictability is limited** due to evolving market conditions and emerging technologies
- **Current market and regulatory frameworks** compensate storage assets for only a fraction of the value they provide
- **Investment recovery is challenged** by the inability to forecast revenues over the 40+ year lifespan of PSH assets
- **Market-altering operations** (charging/discharging) introduce feedback effects that make price impacts hard to predict
- **Unclear or restrictive market rules** limit PSH participation across generation, transmission, and distribution functions
- **Key system services** like inertia and primary frequency response are not monetized in most electricity markets
- **PSH's role in enhancing reliability and resilience** is undervalued, especially as VRE penetration increases
- **Lack of dual-role recognition** (as both generation and transmission asset) restricts PSH from accessing full revenue streams

Breakdown in remuneration services provided in different country's electricity markets,

Remuneration for multiple grid services

Country	Sub-seconds to seconds Inertia, voltage control, reactive power, etc.	1-5 minutes Primary and secondary, frequency regulation
Austria	🔴	🟢
Czech	🔴	🟢
Germany	🔴	🟢
Belgium	🔴	🟢
Italy	🔴	🟢
France	🔴	🟢
India	🔴	🟡
Turkey	🔴	🟡
China	🔴	🟡
US – CAISO	🔴	🟢
US – PJM	🔴	🟢
US – ERCOT	🔴	🟢
US – MISO	🔴	🟢
Australia	🟡	🟢
Colombia	🟡	🟡
Switzerland	🟡	🟡
Canada – Quebec	🟡	🟡
Canada – Alberta	🟢	🟢
Japan	🟡	🟡
Ireland	🟢	🟢
Finland	🟢	🟢
Norway	🟢	🟢
Sweden	🟢	🟢
United Kingdom	🟢	🟢

🟢 services remunerated 🟡 services partially remunerated 🔴 services not remunerated

Source: IEA - Hydropower Special Market Report Analysis and forecast to 2030

Changes in the operations of existing PSH

Earlier Role: *Primarily supported non-flexible generation (e.g., nuclear) by shifting peak demand*

Market Evolution: *Transitioned to market-driven operations in Europe and the U.S., responding to price signals*

Price Arbitrage: *Historically, sustained revenues through arbitrage of market price variations*

Impact of Renewables: *Increased renewable deployment led to more volatile price spreads*

Challenges Post-2008:

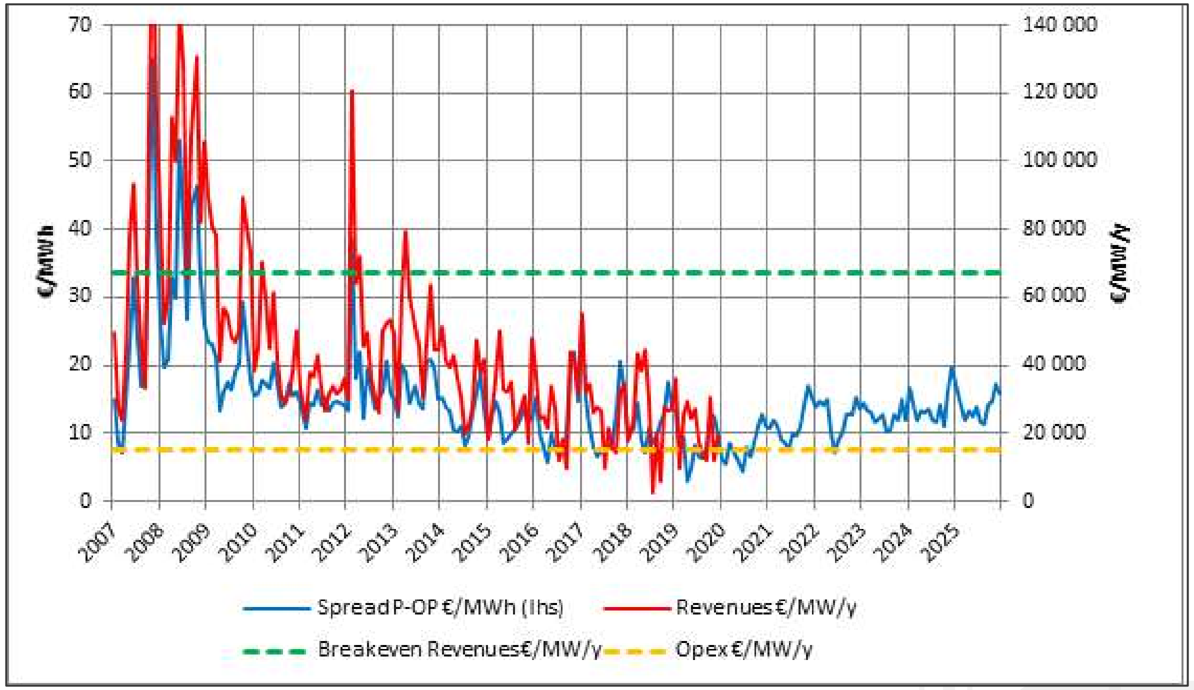
- *Declining demand after the financial crisis*
- *Emergence of low-cost, fast-responding natural gas units*
- *Reduced price spreads and arbitrage opportunities*

Revenue Pressure: *Lower arbitrage revenues have made capital cost recovery difficult*

Regional Differences:

- ***U.S.***: *Flexible PSH operations supported by robust ancillary service markets*
- ***Europe***: *Less flexible operations due to weaker ancillary service markets*

Figure below highlights PSH performance in the Swiss market. **Revenues per capacity have dropped significantly since 2008** with dropping prices and price spreads and have **fallen below project breakeven revenue**. They have maintained above OPEX allowing existing projects to continue operating but preventing any new development



*Beyond revenue uncertainties, additional economic barriers hinder investment in energy storage technologies. In several EU countries, operators of pumped storage plants **face double grid charges—paying both when consuming (load charge) and generating electricity (generator charge).** These charges **undermine the role of storage in balancing the electricity system***

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Section 4

International Best Practices & Case Study

International Best Practices (1/2)

Government Policies

- *Governments should set **mandates, targets**, and **support mechanisms** for PSH development*
- ***Clear policies** to allow PSH to compete in providing grid services considering lifecycle costs and performance*
- ***Supportive licensing**, **permitting**, and **ownership frameworks***

- *In 2016, the UK government agreed an inflation-linked set rate for 35 years for the Hinkley Point C nuclear station*
- *Portugal's National Plan on Dams with High Hydro Power Potential (2007-08) focused on increasing hydropower including PSH to support renewables and climate targets*
- *Australia has the Underwriting New Generation Investment scheme supporting dispatchable generation including PSH projects in the Tasmanian Battery of the Nation initiative*

Financing Support

- *Use of **recoverable grants** that share project risks between government and private sectors*
- *Financing mechanisms including **R&D funding, grants, green bonds**, and **regional projects** of common interest*
- ***Risk-sharing models** to mitigate large capital outlays.*

- *In UK, First Hydro operates 2 GW of PSH and secured a 15-year contract via the Capacity Market in 2016 for its 360 MW Ffestiniog plant, enabling a £50m modernization investment announced in 2017 to improve performance and extend life*
- *EU and other regions use R&D funding, grants, green bonds for PSH. The Climate Bonds Initiative recognizes PSH for green bond certification, opening over US$1 trillion green bond market for hydropower finance*

Other Sectors' Initiatives

- ***Coordination** with transmission development plans and **interconnector projects***
- *Initiatives from other sectors to **incorporate PSH in broader energy system planning***

- *European platforms (PICASSO, MARI, TERRE) support cross-regional markets and ancillary service exchanges.*
- *Australia's Integrated System Plan assesses system-wide benefits and the need for 6-19 GW new dispatchable storage including PSH to support variable renewables*

Wholesale Market Signals

- *Move towards **real-time dispatch** and **settlement to incentivize** PSH flexibility*
- *Market designs enabling **PSH participation in energy markets** with short-term price signals*

- *Markets in the US, Europe, Australia moving toward real-time dispatch and settlement*
- *This incentivizes flexible PSH operation responding to short-term price signals*
- *Example of Hydro Tasmania's "Virtual Storage" contract allowing sale and purchase of stored energy rights to capture price spreads*

International Best Practices (2/2)

Ancillary or Flexibility Support Services

- ***Payment for ancillary services*** *such as frequency regulation, inertia, voltage/reactive power support, black start capability*
- ***Competitive tenders*** *and* ***contracts for ancillary services*** *(examples: UK National Grid, Ireland, New Zealand).*
- ***Performance incentives*** *for response speed and startup/shutdown times.*

- *UK National Grid's contracts with Drax PSH, Ireland's inertia/fast frequency response market product, competitive tenders in New Zealand, Texas, Alberta, and Ontario*
- *Israeli PSH contracts include performance incentives such as speed of response and startup/shutdown times*

Capacity and Availability Payments

- ***Contracts*** *that* ***include capacity****, availability, energy, and performance payments*
- ***Long-term contracts*** *to provide revenue certainty and support PSH investment.*

- *Israel Electric Corporation developed a payment mechanism paying on plant availability over 18-20 years, supporting private financing for the 344 MW Kokhav Hayarden and 300 MW Gilboa PSH projects*
- *UK's Capacity Market provides long-term contracts supporting PSH modernization and operation*

Others *(Hybrids, Auctions, Firming Products, PPA)*

- ***Hybrid projects*** *combining renewables and PSH, sometimes co-developed or contracted together*
- ***Firming contracts*** *to turn variable renewables into dispatchable capacity*
- ***Multi-part payment contracts****,* ***auctions for service provision****, and* ***innovative PPA structures*** *(e.g., Hawaiian Electric example)*

- *Snowy Hydro (Australia) signed 888 MW wind and solar contracts firmed by Snowy Hydro's assets*
- *Hawaiian Electric developed PPAs for renewable dispatchable generation, guaranteeing payment for net energy potential and availability rather than energy delivery*
- *Nevada Energy uses a peak-hour PPA paying 6.5 times the price of off-peak hours, incentivizing capacity and dispatch flexibility*
- *Hydro Tasmania's "Virtual Storage" contract is a world-first financial derivative offering revenue certainty for PSH*

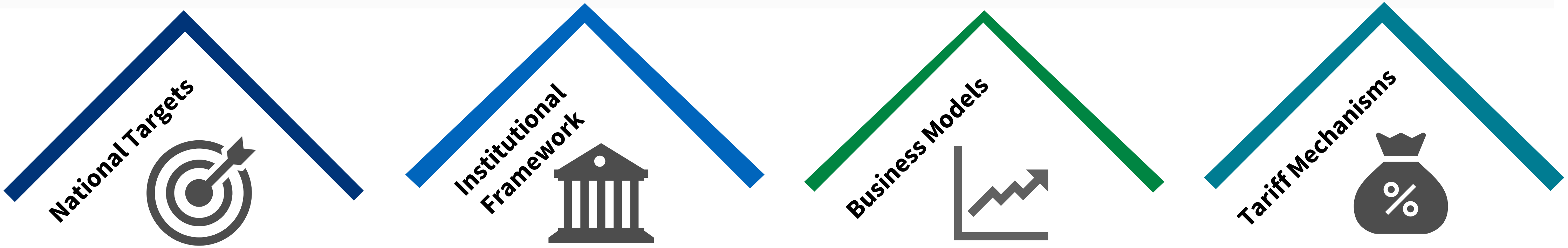
Drivers and Business Models for PSHs development

Case Study: China

To meet rising power demand and diversify its energy mix, **China** has been developing **PSHs since 2010**, with **over 26 PSHs (50 GW) under construction** and **30 more (42 GW) planned** as of **2023**

China's success in developing pumped storage hydropower (PSH) is driven by its **targeted strategy** and **well-defined initiatives**. This strategy rests on four key pillars :

1) ***Ambitious National Targets***
2) ***Robust Institutional Framework***
3) ***Strong Business Models***
4) ***Realistic Tariff Mechanism***



National Targets

- *NEA's mid- and long-term plan-* ***62 GW PSH capacity by 2025. 120 GW by 2030***
- *Currently* ***89 GW under construction; 80 GW additional target by 2027*** *under new national policy*

Institutional Framework

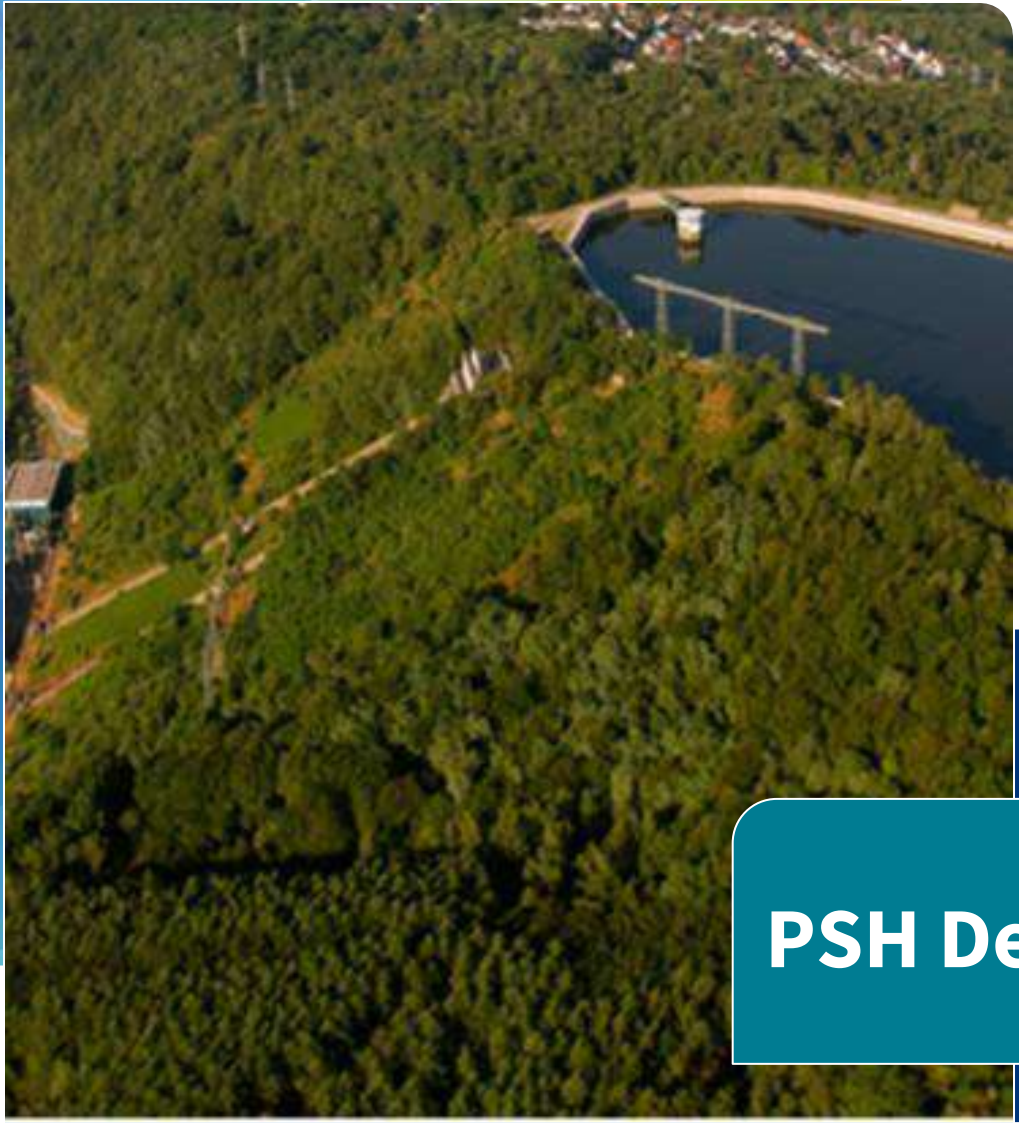
- *National Energy Administration* ***(NEA) oversees PSH industry***
- ***Majority*** *PSH projects by* ***state-owned enterprises (SOEs)***
- *Increasing* ***participation by private*** *companies*

Business Models

- ***Market-Driven Model*** *with* ***competition*** *and* ***price fluctuations***
- ***Bilateral contracts*** *between PSHs and power generators/grid operators*
- *Government-Supported Model with* ***subsidies*** *and* ***feed-in tariffs.***

Tariff Mechanisms

- ***Capacity tariff*** *supports* ***ancillary services*** *(frequency regulation, system backup)*
- ***Electricity tariff*** *supports* ***peak shaving***
- ***Different mechanisms*** *for areas with and without spot power markets* ***to ensure cost recovery*** *and* ***incentives***



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Section 5

PSH Developments in India

PSH development in India

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There are currently **58 Pump Storage Hydro (PSH)** sites in various stages of development across India, with a **combined installed capacity** of approximately **69.9 GW**

India's Commitments at COP 26

- ***500 GW*** *of non fossil fuel installed capacity by 2030*
- ***50%*** *of energy generation from renewable sources by 2030*
- ***1 billion tonnes*** *reduction in projected emissions by 2030*
- ***45%*** *reduction in carbon intensity by 2030*
- ***2070*** *as the target year for achieving net zero*

Status of PSH Development in India *(as of September 2024)*

Status	On River		Off-River		Total	
	No of Schemes	Installed Capacity (MW)	No of Schemes	Installed Capacity (MW)	No of Schemes	Installed Capacity (MW)
In operation	6	3305.6	-	-	6	3305.6
Not working in Pumping mode	2	1440	-	-	2	1440
Under Construction	3	2850	1	1200	4	4050
Construction held-up	1	80	-	-	1	80
DPR concurred by CEA	1	1000	-	-	1	1000
Under Survey & Investigation	6	7440	38	52610	44	60050
Total	**19**	**16115.60**	**39**	**53810**	**58**	**69925.60**

Source: Central Electricity Authority (CEA), India

Hydropower Potential in India (CEA Study: 2017–2023)

- *India's* ***exploitable large hydro potential*** *stands at an impressive* ***133.4 GW****, highlighting significant untapped renewable energy capacity*
- *Country has an* ***identified pumped storage potential*** *of approximately* ***181.4 GW****, offering a robust solution for grid stability and energy storage*

Tariff Insights for Pump Storage Hydro Projects

- *Under the base case scenario (capital cost: ₹6.5 crore/MW; return on equity: 16.5%), the* ***levelized tariff*** *is estimated at* ***₹4.98/unit***
- *When factoring in the cost of energy required for pumping, the* ***landed tariff*** *rises to* ***₹8.92/unit****, underscoring the importance of optimizing operational efficiency and energy sourcing*

Different phases of Hydro / PSHs in India

Overview of HEP planning & implementation processes

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Hydro Electric Power / PSH Projects

Planning Phases
Cover essential steps from site selection to DPR preparation

- **Site Identification**
  Focus on selecting optimal locations based on hydrological data & feasibility
- **Survey & Investigation**
  Incorporate geological, hydrological & environmental studies for project justification

Technical Evaluation
Assess mechanical design aspects & overall project efficiency for power generation

- **Design Criteria**
  Evaluate the specifications for hydraulic structures & turbine systems
- **Cost Estimation**
  Calculate realistic project budgets considering all associated costs & financial packages

Regulatory Approvals
Identify necessary clearances from different government bodies for project execution

- **Environmental Clearance**
  Ensure compliance with environmental regulations & impact assessments
- **Techno-Economic Clearance**
  Submit reports to CEA for professional evaluation & clearance

Evaluation Studies
Examine project viability based on power potential studies & economic factors

- **Power Potential**
  Analyze energy generation possibilities under different operational scenarios
- **Financial Viability**
  Calculate projected income & costs to ensure project sustainability over time

Policy and regulatory framework and government initiatives

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To promote hydropower development, the Indian Government has implemented key policies ensuring fair land acquisition, resettlement, and tariff support. Some of the recent policies, amendments and schemes expedite the development of the Hydropower plant including PSH in India

Timeline of recent key developments

2019

Mar 8, 2019: *Large hydro (>25 MW) classified as renewable; infra support announced*

Nov 8, 2019: *Guidelines issued to curb delays and cost overruns*

2021

Sep 2021: *Procedure released for budgetary support to flood moderation/storage hydro*

2022

Jul 19, 2022*: CPSEs advised to rationalize manpower at stalled projects*

2023

Mar 2023: *CEA cut DPR approval time from 90 to 50 days for bid-based PSHs*

Apr 2023: *MoP issued PSH guidelines covering market, policy, and safety*

Jun 2023*: DPR approval time for PSHs reduced from 125 to 90 days*

Oct 5, 2023: *CEA released slope stability guidelines for hydro projects*

Oct 20, 2023: *HPO trajectory for FY25–FY30 notified*

2024

Sep 2024: *₹12,461 crore budgetary support announced for transmission, ropeways, rail sidings, and comm infra*

Dec 2024: *Draft National Hydro Power Policy 2024 circulated internally*

Tariff Rationalization

- *Tariff Flexibility (Mar 2019):* ***Extended project life (40 yrs), longer debt repayment (18 yrs),*** *and* ***2% annual tariff escalation*** *enabled backloaded tariff structure*
- *Transmission Charge Waiver (Jun 2021):* ***Full waiver*** *for PSHs commissioned by* ***30 June 2025***
- *ISTS Charges Waiver (May 2023):* ***Waiver for PSHs awarded by 30 June 2025****; partial waiver (25% steps) from Jul 2025 to Jul 2028 for projects awarded by 30 June 2028*
- *Draft Bidding Guidelines (Aug 2024):* ***Competitive procurement framework*** *for PSHs to promote development, transparency, and stakeholder risk-sharing.*

Operational and Administrative Initiatives

- ***Nov 2019:*** *Guidelines issued for better scheduling, dispute resolution, and use of digital tools.*
- *Jul 2022:* ***Advisory*** *to CPSEs* ***for manpower rationalization at stalled sites***
- *Mar 2023: CEA cut* ***DPR concurrence timeline*** *for bid-based PSHs* ***from 90 to 50 days***
- *Focus on* ***realistic timelines, sunset clauses, delegated powers,*** *and* ***milestone-linked incentives***

Budgetary Support

- *Launched in 2019; expanded in 2024 to cover broader infrastructure —* ***₹12,461 crore outlay***
- *Covers* ***~31,350 MW hydro capacity****, including private and pumped storage; eligible if LoA issued by June 2028.*
- ***Funding capped*** *at ₹1 crore/MW (≤200 MW), ₹200 crore + ₹0.75 crore/MW (>200 MW), and up to ₹1.5 crore/MW in special cases.*

Policy Thrust on CPSU

- ***CPSUs chosen as key developers*** *for their proven project management, large-scale execution experience, and access to low-cost capital.*
- *Ministry of Power has allocated* ***73 GW of PSH sites to CPSUs*** *to fast-track capacity deployment.*

Dispute Settlement Measures

- ***Timely claim settlement*** *and* ***dispute resolution*** *reinforced through updated guidelines.*
- ***Global best practices*** *adopted to* ***limit delays*** *and* ***control costs***
- ***Mobilizing resources*** *and* ***incentivizing labour*** *to uphold timelines and reduce conflicts.*

Supportive Tariff Regulation for PSH development in the country

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The Central Electricity Regulatory Commission (CERC), through its recent tariff regulations 2024, has introduced cost-reflective tariffs and mechanisms to enhance revenue streams—directly promoting PSH development and accelerating its growth

Mitigating Tariff Front-Loading

Depreciation period extended to 15 years from 12 years for new projects, easing early financial load and enabling smoother tariffs. Lower rates allowed with beneficiary consent.

Provision for Local Infrastructure Development

Capital expenditure up to INR 10 lakh/MW permitted for local infrastructure around the plant, adjustable against budgetary support, promoting community development

Separate Treatment of Sensitive Expenses

Security, capital spares, and insurance costs are segregated from normative O&M expenses and allowed separately post prudence check, reflecting true cost dynamics

Equitable Sharing of Non-Tariff Revenues

Non-tariff income from eco-tourism, rentals, and advertisements shared equally (1:1) between the generating company and beneficiaries, encouraging additional revenue streams

Incentivization of Primary Frequency Response

Enhanced Annual Fixed Charges (AFC) up to 3% for stations providing primary frequency response beyond defined thresholds, monetizing grid stability services

Rewards for Peak Hour Generation

Incentive of 50 paise/kWh for delivering scheduled energy above daily averages during peak hours, promoting peak load support

Enhanced Return on Equity for Hydro Projects

Return on equity increased from 16.5% to 17% for new projects to improve financial attractiveness and investment viability for hydro power developers

Greenko Pinnapuram PSH to supply peak power, firm RE and RTC RE power

TETRA TECH

Selection of Project Developers for setting up of 1200 MW ISTS-Connected RE Projects with assured Peak Power Supply in India (ISTS-VII)

Issued By	Solar Energy Corporation of India **(SECI)**
Duration of supply of Power	**6 hours** peaking support on a day-ahead, on demand basis *(any time slots between 5:30 am to 9:30 am and 5:30 pm to 12.30 am)*
Tariff	**Two Part** tariff *(Peak: determined by e-reverse auction, Off Peak: flat rate of 2.88 INR/unit)*
PPA term with Bidder	SECI will sign **25 years PPA** with successful bidders
Grid Connection	**220 kV or above**, where the power from the project is injected into the identified ISTS substation
Eligible Projects for this bid	Only under construction and New Projects

PSH developers can partner with renewable energy developers to jointly bid in competitive power auctions. This could be a potential way to sell power from pumped hydro storage plants

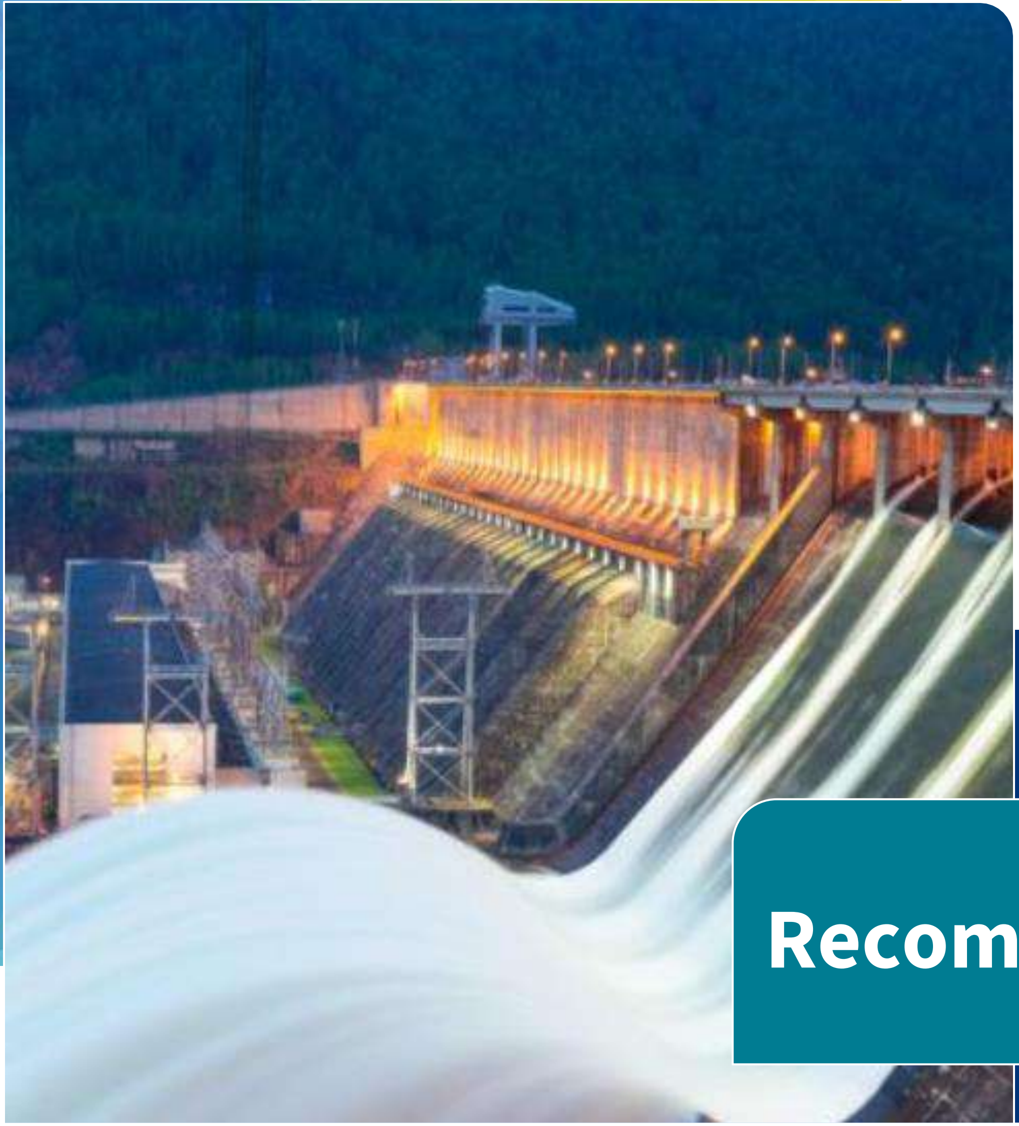
Successful Bidders and Auction rate of Peak Power:

- **Greenko:** *900 MW @ 6.12 INR/Unit*
- **ReNew :** *300 MW @ 6.85 INR/Unit*

Other tie ups for Greenko PSH

- Tie up with **Ayana Renewables to store 6 GWh**
- Up to **1 GW firm RE power** supply to Adani
- MoU with **NVVN to explore RE+RTC**

***Greenko's Pinnapuram** project is the world's first and largest gigawatt scale hybrid renewable energy facility, combining 1000 MW solar, 300 MW wind, and **1200 MW pumped storage in phase 1. With 9 hours of storage**, it can deliver reliable, on-demand renewable power across India. The project is currently under construction*



Section 5

Recommendations and Way Forward

Recommendations to Stakeholders and Way Forward (1/3)

Non-Economic Levers :Policy, regulation, licensing, permitting, and others (modelling, ownership, IRP)

Based on the contributions of the various stakeholders, as well as the best practices identified in some markets, several specific recommendations which could be applied or used as a guide in SAARC region. These recommendations are categorized into ***Non-Economic*** *and* ***Economic Levers***

Policy / Regulation

Strategic Role of PSH: *Recognize PSH's critical role in grid reliability and supporting renewable energy integration during the energy transition*

Flexible Renewable Policies: *Design renewable policies that incorporate PSH to manage grid stability, frequency control, and reserve adequacy effectively*

Technology-Neutral Storage Targets: *Set energy storage targets in gigawatt-hours for both short- and long-duration storage aligned with2030 and 2050 goals*

Support for Hybrid PSH Projects: *Adapt market frameworks to allow hybrid PSH projects with wind or solar, reducing curtailment and emissions*

Inclusion in Green Recovery: *Include PSH investments in green recovery and climate finance to boost jobs, business, and skills*

Modernization of PSH Assets: *Evaluate and modernize existing hydropower assets to PSH with flexible technologies like variable speed systems*

Modelling and System Planning

Standard Methodology: *Develop unified modelling for storage in system planning*

Flexibility Metrics: *Include cycles, ancillary services, MW/MWh ratings*

Stakeholder Awareness: *Promote PSH understanding among planners*

Cross-Border Planning: *Assess grid/storage needs nationally & regionally*

PSH Inventory: *Map and rank sites using multi-criteria analysis*

Innovative Options: *Explore seawater PSH and hybrid models (with batteries or flywheels)*

Licensing / Permitting

Streamline & Sustain: *Fast-track low-impact PSH using best practices and sustainability tools (e.g., IHA ESG)*

Enable & Adapt: *Create supportive frameworks, learn from global best practices, and facilitate early-stage development*

Ownership

Enable TSO Ownership: *Allow Transmission System Operators to own PSH as grid assets to support VRE integration*

Review Network Rules: *Ensure fair competition between PSH and traditional transmission upgrades*

Remove Asset Restrictions: *Eliminate regulatory barriers that prevent efficient PSH procurement by TSOs*

Support Hybrid Models: *Explore regulated PSH models combining transmission and generation functions*

ISO/RTO Contracts: *Consider availability-based procurement of PSH for grid services under Independent System Operators or Regional Transmission Organizations*

Protect Market Integrity: *Design ownership models that avoid market distortions and preserve fair competition*

Recommendations to Stakeholders and Way Forward (2/3)

Economic Levers : Financing, market designs, revenue schemes, other

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Policy / Incentives

Revenue Visibility & Risk Allocation: *Policies should ensure long-term revenue certainty and fair risk allocation to attract private investment*

Technology-Agnostic Investment Signals: *Investment signals must be clear, consistent, and neutral across technologies, backed by secured guarantees*

Compensation for System Services: *Incentives should cover both immediate system services and long-term balancing needs through mechanisms like reserve markets and inertia payments.*

Dedicated Support Schemes :*Introduce storage-specific tax credits and ensure consistent incentives across technologies to avoid inefficiencies.*

Regulatory Review: *Existing standards and incentives should be reassessed to better support long-duration storage investment*

Financing

Tailored Financing Structures: *Financing arrangements must account for long development timelines and high upfront costs to attract private investment*

Access to Green Finance Instruments: *PSH should be eligible and encouraged to participate in green and impact bond markets aligned with recognized standards*

Government Support Mechanisms: *Governments should offer recoverable grants to share project risks and support PSH development alongside private sector investment*

Green Recovery

Strategic Inclusion: *Include PSH in green recovery plans to support net-zero and resilience goals*

Access to Green Finance: *Ensure PSH benefits from green finance and recovery funds, including COVID-related support*

Market Design and Business Models

Innovative Models: *Develop technology-neutral business models based on lifecycle costs and system needs*

Grid Service Access: *Enable PSH to compete for grid services with consistent contracts and bundled service options*

New Market Products: *Introduce services like inertia and ramping; prioritize low-carbon solutions in flexible capacity mechanisms*

Long-Term & Cross-Border Participation: *Secure payments beyond 15 years and harmonize grid tariffs to support cross-border PSH projects*

Examples of Incentive Policies:

- ***Income Floor Model (UK):*** *A Cap and Floor-style model can offer 15–20-year contracts with minimum revenue guarantees, supporting financing and flexibility services*
- ***NSW Investment Safeguard (Australia):*** *NSW provides long-term agreements and grants for PSH, offering minimum price guarantees and feasibility support.*

Recommendations to Stakeholders and Way Forward (3/3)

Summary of Policy Recommendations

- Policymakers should **assess the long-term storage needs** of their future power system now, so that the **most efficient options**, which may take longer to build, are not lost
- **Comparisons between energy storage and flexibility options** must follow **a consistent, technology neutral approach** that considers all impacts and benefits
- Providers of **essential electricity grid, storage, and flexibility services** should be **remunerated for all services** that they provide
- Licensing and permitting arrangements must be **timely, proportionate** and take **advantage of the range of internationally recognized sustainability tools**
- Investors in long lasting assets, such as PSH, must have **long-term visibility of revenues**, **with risk that is shared fairly** to deliver the lowest overall cost to society in the long term
- Existing hydropower assets and prospective sites should be assessed and **mapped for their potenti**al to provide the **most efficient long duration storage**
- **Green recovery programs** should include and support PSH, and **green finance mechanisms** should **incentivise PSH**

Questions ?

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