

RENEWABLE ENERGY CORRIDOR

PUMPED HYDRO SYSTEM

LOWER RESERVOIR

INTELLIGENT DISPATCH

GRID BALANCING
98.7%
STABILITY

REAL-TIME OPTIMIZATION

AI OPTIMIZATION
MAX EFFICIENCY
MAX OUTPUT

SYSTEM STATUS

- TURBINES ONLINE
- PUMPS ONLINE
- WATER FLOW OPTIMAL
- GRID SYNC STABLE

DIGITAL TWIN

PUMPED HYDRO STORAGE

HYDRO • GRID STABILITY • RENEWABLE INTEGRATION

PREPARED FOR CORPORATE LEADERS & CLIMATE-TECH STAKEHOLDERS

Energy Storage Pumped Hydro Storage

This section provides key inputs on Pumped Hydro Storage Opportunities for corporate leaders.

Highlights

- Large-scale grid stability solution enabling long-duration energy storage critical for high renewable penetration
- Infrastructure-class asset profile with long lifetimes, stable returns, and suitability for institutional capital
- Growing policy and grid support as India prioritizes storage-backed renewable expansion
- Natural geographic advantage opportunities in hilly and reservoir-rich regions

Key recommendations for corporate leaders include:

- Identify and secure high-quality sites early with strong elevation differential and water access
- Structure projects for infrastructure financing with long-term capacity contracts
- Invest in digital grid optimization and dispatch planning to maximize value capture

Opportunity Snapshot: Pumped Hydro Storage

Store electricity by pumping water to elevation and releasing it to generate power on demand

Market Signal

- Need for long-duration storage solutions
- India potential estimated at nearly **90–100 GW of pumped hydro capacity**
- **Annual Market size by 2030:** 13,000 - 15,000 ₹ Cr



What Makes or Breaks It?

- **Access to suitable sites** (elevation + water availability)
- **Regulatory approvals** and land acquisition efficiency
- **Ability to secure long-term contracts** (peak power / storage services)

Why It Matters NOW?

- Need for reliable & dispatchable power due to solar/wind intermittency.
- Pumped hydro offers **lower lifecycle cost** vs batteries for long duration
- **Grid stability becoming critical** with high renewable share



Well Aligned Opportunity for

- **Large utilities and power developers**
- **Infrastructure and EPC companies**
- **State utilities and hydro developers**



Key Challenges

- **High upfront capex:** ₹6–8 Cr per MW
- **Long gestation (5–7 years)** due to land, environmental clearances



Business Model

- Develop greenfield pumped hydro projects in suitable geographies (hilly regions)
- Partner with state utilities for long-term storage contracts
- Integrate with renewable portfolios (solar + wind + hydro)

Introduction and Business Case

Pumped Hydro Storage (PHS) is the world’s most mature long-duration energy storage technology — using surplus electricity to pump water uphill and releasing it to generate power when demand peaks. For India, with its rapid renewable build-out, PHS solves the intermittency challenge, provides grid stability and reduces reliance on peaking fossil plants.

With suitable topography, falling storage costs and RE-integration needs, PHS is a strategic backbone for India’s 24x7 green power ambitions, and can be an interesting business opportunities for select firms and businesses.

Market Potential for Pumped Hydro Storage in India

Year	Market Size (₹ Cr)	Capacity (GW / GWh)	Drivers
2025	7,000-10,000	3 GW / ~24 GWh	Existing hydro retrofits; early standalone projects.
2030	13,000-15,000	5-7 GW / ~40 GWh	Large-scale RE + PHS hybrids; SECI/NTPC storage tenders.
2040	20,000-25,000	10-12 GW / ~100 GWh	Deep storage for grid balancing; coal replacement.

Market Segments and Applications

Segment	Applications	Business Model	Key Drivers
Utility-owned pumped storage	Bulk energy storage, peak shaving	Regulated utility ownership	Grid reliability and renewable integration
Merchant pumped storage	Energy arbitrage, capacity markets	Merchant market participation	Power price volatility
Renewable-linked pumped storage	Wind/solar firming, curtailment reduction	Hybrid renewable + storage ownership	High renewable penetration
National grid-scale storage	System balancing, inertia support	State-backed infrastructure	Energy security and grid stability
Closed-loop pumped storage	Long-duration storage without	Project-financed IPP model	Environmental permitting advantages

	rivers		
Brownfield hydropower upgrades	Adding pumping to existing hydro	Asset repurposing / retrofit	Faster deployment & lower capex
High-head / mountain PHS	Multi-hour to multi-day storage	Long-life infrastructure ownership	Long-duration storage needs
Urban / industrial PHS	Grid support near load centers	Capacity & ancillary service revenues	Congestion management
PHS as grid inertia provider	frequency & voltage stabilization	Grid-service remuneration	Decline of synchronous generation
Technology & EPC services	Turbines, generators, EPC	Equipment supply + EPC contracts	Global PHS capacity expansion

Typical Project Capacities & Investments Required in India

Project Type	Power (MW)	Storage (Hours / MWh)	Indicative CapEx (₹ Cr)
Closed-loop PHES (greenfield, twin reservoirs)	200-1,000	6-12h (1,200-12,000 MWh)	1,400-8,500
Open-loop PHES (existing hydro augment)	300-1,500	5-10h (1,500-15,000 MWh)	1,800-10,500
Mine/quarry pit PHES (brownfield)	50-300	4-8h (200-2,400 MWh)	250-1,800
Cascade hydro + PHES hybrid	500-2,000	6-10h (3,000-20,000 MWh)	3,500-14,000

Underlying Technologies & Processes

Element	Options	Key Traits
Reservoir configuration	On-river • Off-river closed loop • Retrofit to existing dams	Determines site feasibility, cost and environmental impact.
Turbine systems	Reversible Francis • Pump-turbines	Proven, high-efficiency for large capacity swings.
Storage duration	4-10 hours (typical) • 12+ hours (long-duration)	Enables peak shifting, firm RE and baseload substitution.
Integration	With solar/wind hybrids, grid ancillary markets	Provides firm capacity, frequency regulation, black-start.

Digital optimisation	AI/EMS for dispatch scheduling	Maximises arbitrage and grid services value.
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Key Challenges

Challenge Area	Key Issues	Business Impact	India Specific	Strategic Implications
High Capital Intensity & Long Gestation Periods	Large upfront investment with 5–8 year development timelines	Delayed revenue realization and financing pressure	Complex approvals; environmental clearances; long construction cycles	Requires strong balance sheet, phased financing, and patient capital
Land Acquisition & Environmental Approvals	Site-specific topography and water availability constraints	Project delays and cost overruns	Forest clearances, inter-state water issues, local community resistance	Early stakeholder engagement and rigorous site due diligence critical
Revenue Model & Offtaker Uncertainty	Storage revenue streams (peak arbitrage, ancillary services) still evolving	Bankability challenges without clear capacity payments	Market design for storage still maturing; DISCOM financial stress	Diversified revenue stacking (capacity, grid services, RTC contracts) needed
Grid Integration & Regional Infrastructure Constraints	Requires strong transmission connectivity and RE integration	Limits site selection flexibility	Grid congestion in high-RE states; interconnection bottlenecks	Align projects with grid expansion plans and renewable corridors
Policy, Regulatory & Timing Risks	Evolving storage procurement frameworks and tariffs	Investment uncertainty and delayed market maturity	State-specific policies; lack of standardized long-term storage pricing	Policy monitoring and flexible commercial structuring essential

Prominent Players in the Indian Market

Company / Entity	Project Details
Greenko Group	Large-scale IRESP & pumped-hydro storage developer in India.

JSW Energy	~6 GW hydro-pumped storage projects across multiple states; platform capacity ~9.1 GW.
Adani Green Energy	Exploring large PHS + RE hubs in various places in India.
NHPC Ltd.	State-owned hydro giant; evaluating pumped storage retrofits at multiple dams.
SJVN	Central PSUs planning pumped storage alongside hydro fleet.
Tata Power	Operating legacy PHS at Maharashtra; exploring new hybrid projects.

Innovation Perspectives

Innovation	Business Opportunity	For Senior Management
Closed-loop pumped storage	Modular PHS development platforms	Faster permitting, broader siting options
Renewables + PHS hybrid hubs	Firm renewable power plants	Converts intermittent renewables into firm power
PHS as long-duration storage backbone	Long-duration storage utilities	No battery degradation
Brownfield hydro retrofits	Brownfield hydro retrofits	Low capex, quick deployment
Variable-speed PHS technology	Advanced PHS tech licensing	Higher grid service revenues
PHS for grid inertia & stability	Stability-as-a-service models	Critical as thermal plants retire
Merchant + regulated hybrids	Flexible PHS financing structures	Risk-balanced returns
Urban-adjacent PHS	Congestion-relief assets	Reduces transmission congestion
Digital PHS optimization	PHS asset-management software	Maximized lifetime value
PHS as national energy insurance	Sovereign-backed storage projects	Policy-backed returns

Concentric & Satellite Opportunities

- Grid & market optimisation software: AI dispatch tools co-optimising day-ahead arbitrage, ancillary services and RE-firming under SSA/market signals.
- Floating PV on reservoirs: Concentric co-location adding daytime pumping energy and reducing evaporation losses for better round-trip economics.
- Hydrology, geotech & environmental labs: India-focused testing/monitoring services for seepage, siltation, biodiversity and community impact.
- Insurance & performance wraps: Products covering geotech delays, availability guarantees and revenue floors to enhance bankability.

Key Takeaway for Senior Management

Takeaway	Details
Pumped hydro is grid infrastructure, not just storage capacity	<ul style="list-style-type: none"> ● Its value lies in grid balancing, peak shaving, and long-duration reliability ● Examples: RTC renewable integration, seasonal storage, frequency regulation ● Innovation focus: intelligent dispatch and grid-responsive control systems ● Competitive advantage: assets positioned as grid infrastructure attract premium contracts
Site quality determines lifetime economics	<ul style="list-style-type: none"> ● Elevation differential, geology, and water access dominate capex and efficiency ● Sub-components: reservoir engineering, tunneling design, turbine selection ● Innovation focus: advanced site modeling and digital simulation ● Competitive advantage: superior site optimization lowers lifetime cost.
Hybrid renewable integration amplifies asset value	<ul style="list-style-type: none"> ● Pumped hydro paired with solar/wind increases utilization ● Examples: co-located renewable portfolios feeding storage reservoirs ● Competitive advantage: higher revenue stacking vs standalone storage
Long asset life creates infrastructure-style returns	<ul style="list-style-type: none"> ● Pumped hydro projects operate for decades ● Examples: 50+ year asset life, stable capacity payments ● Competitive advantage: predictable long-term yield attracts institutional capital

Next Steps for Corporate Leaders

Pumped hydro storage is emerging as a key enabler of long-duration storage as grids integrate higher shares of variable solar and wind generation. Corporate buyers exploring 24/7 clean energy procurement, RE firming, and peak demand management are increasingly evaluating pumped hydro as a complement to BESS and hybrid RE portfolios. Recent policy support, tendering mechanisms, and interest from utilities, miners, and data centers are accelerating feasibility activity — although development timelines, site selection, and capital intensity remain defining constraints.

This could be an attractive climate tech opportunity for industries and firms in specific sectors and industries keen on catering to this market.

Connect with Team EAI to know more about this opportunity and take your corporate's initial steps. Send a note to consult@eai.in or talk to Muthukrishnan - 9952910083