

The 1 TWh Storage Opportunity

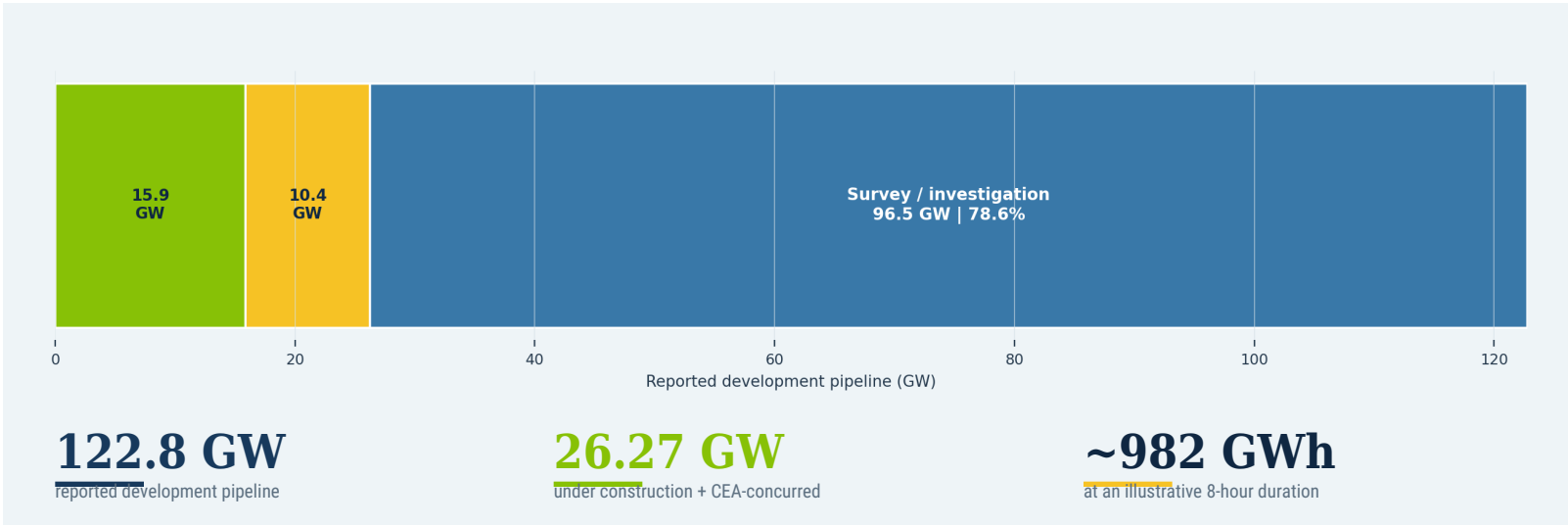
Decoding India's pumped-hydro pipeline

India's pumped-storage build-out is best understood as an energy-shifting opportunity, not simply a capacity figure. The 122.8 GW development pipeline is large enough to approach a terawatt-hour of storage only if a substantial share reaches commissioning and projects are configured for long-duration operation. The central analytical question is therefore not how large the pipeline looks, but how much of it can become dispatchable energy.



Hydro and grid imagery adapted from the supplied Firstgreen magazine template; illustrative, not project-specific.

01 What is actually advanced?



02 Four facts behind the opportunity

Pipeline maturity

About 78.6% of the reported pipeline remains at survey / investigation stage. This means the dominant uncertainty is conversion from early-stage concepts into projects with clearances, finance and executable schedules.

Scale-up challenge

The development universe is about 20.5× the present pumping-capable operating fleet. Scaling at that speed requires parallel growth in hydro EPC capacity, tunnelling resources, electro-mechanical supply chains and transmission readiness.

Duration changes the answer

The same MW figure produces very different energy outcomes. At four hours the full pipeline represents ~491 GWh; at eight hours ~982 GWh; and at ten hours ~1,228 GWh before allowing for development attrition.

Bankability is the real filter

Transmission access, geology, environmental and land approvals, usable reservoir volume, construction risk and financing determine which projects reach COD. Technical potential therefore has to be screened through an execution and revenue lens.

Reading the pipeline: only about 26.3 GW of the 122.8 GW reported universe is in construction or CEA-concurred stages. The remaining volume is exposed to survey, approval, financing and execution attrition. For investors and policy makers, the most useful metric is therefore not the gross pipeline alone, but the share that progressively crosses defined maturity gates and can support a credible commissioning schedule.

Evidence / model: Firstgreen PSP analytics workbook; user-supplied Livemint article; CEA PSP status and roadmap datasets.

122.8 GW is not yet 1 TWh

The 1 TWh proposition becomes meaningful only after storage duration and project realisation are made explicit.

A 1 TWh proposition can be directionally useful, but it is not a single engineering number. Storage duration, realised capacity, reservoir volume, hydraulic head, round-trip efficiency and operating constraints determine how much dispatchable energy the system can actually call on. The conversion from GW to GWh should therefore be shown transparently as a scenario, not treated as a fixed attribute of the development pipeline.

03 Follow the MWh, not the MW

A pumped-storage project is rated in MW, but the system value depends on how many hours that power can be sustained. Converting the reported pipeline into energy therefore requires an explicit duration assumption. Two projects with the same MW rating can provide very different amounts of energy if one has four usable hours of reservoir storage and the other has ten.

The same 122.8 GW development universe represents roughly 491 GWh at 4 hours, 982 GWh at 8 hours and 1,228 GWh at 10 hours before allowing for attrition. If only half the pipeline is realised, the eight-hour case falls to about 491 GWh. Duration and project conversion therefore matter as much as the announced MW number.

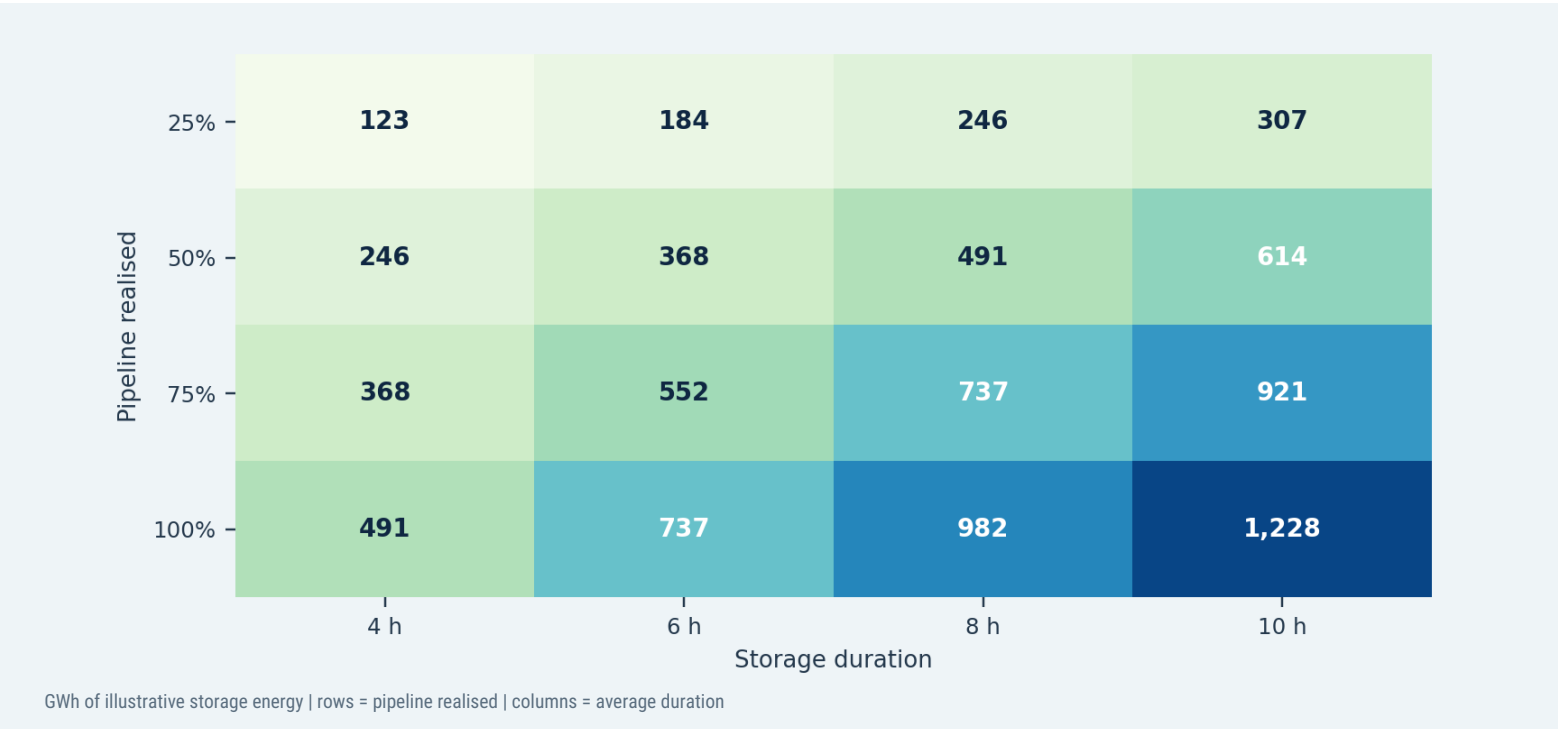
Storage procurement should specify MW, MWh, duration, round-trip efficiency, response time, availability, cycling expectations and delivered ₹/MWh. Those parameters describe the service the grid is buying and create a more meaningful basis for comparing PSP with batteries or hybrid renewable portfolios.



Illustrative energy asset; not a case-study site.

Evidence / model: Firstgreen duration sensitivity using 122.77 GW media-reported pipeline.

04 How the opportunity changes



491 GWh
50% of pipeline realised at 8 hours

982 GWh
100% of pipeline realised at 8 hours

1,228 GWh
100% of pipeline realised at 10 hours

1

A scenario is not a forecast

The heatmap is a sensitivity framework rather than a forecast. Each cell asks a simple question: if a given share of the reported pipeline is realised, and if the average usable duration is a stated number of hours, how much energy capacity would that imply? Project-level reservoir studies are still required.

2

Duration is a bankability variable

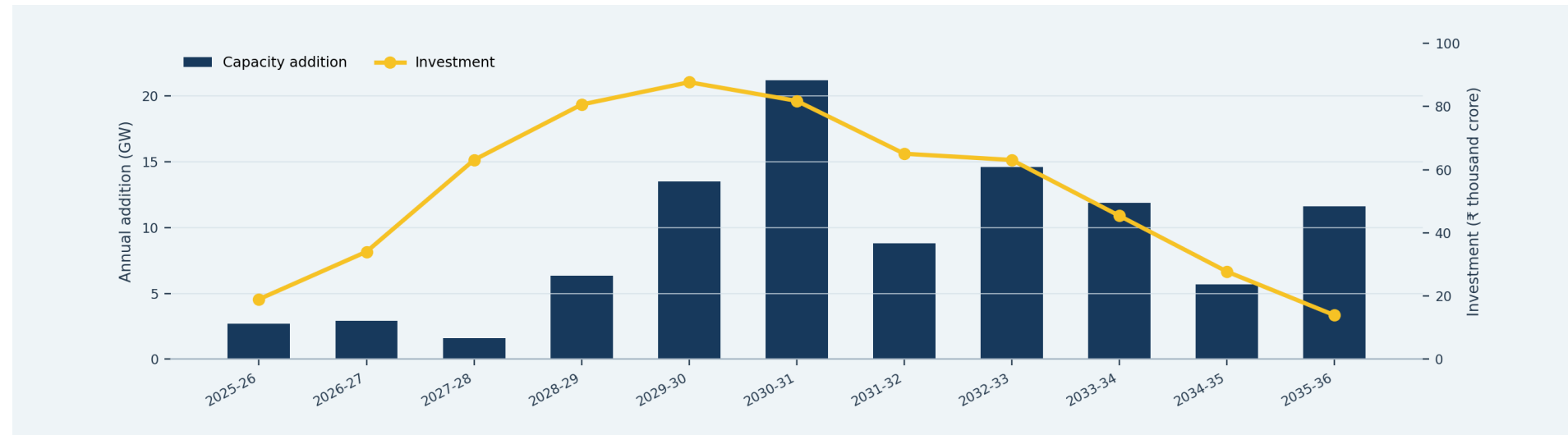
Longer duration can increase the value of renewable shifting, but the asset must physically sustain that service. Usable reservoir volume, hydraulic head, pumping and generating efficiency, water management constraints and the expected operating regime all affect whether the assumed hours are technically and commercially credible.

Delivery is back-loaded. Execution becomes the constraint.

CEA's roadmap implies a sharp build-out after FY2028-29, with annual investment peaking before the largest commissioning year.

The roadmap is not a smooth construction programme. It implies a clustered delivery wave in which civil works, electro-mechanical packages, transmission bays and environmental clearances must all mature in parallel. That makes execution capacity as important as capital availability.

05 Build-out and investment: two explicit axes

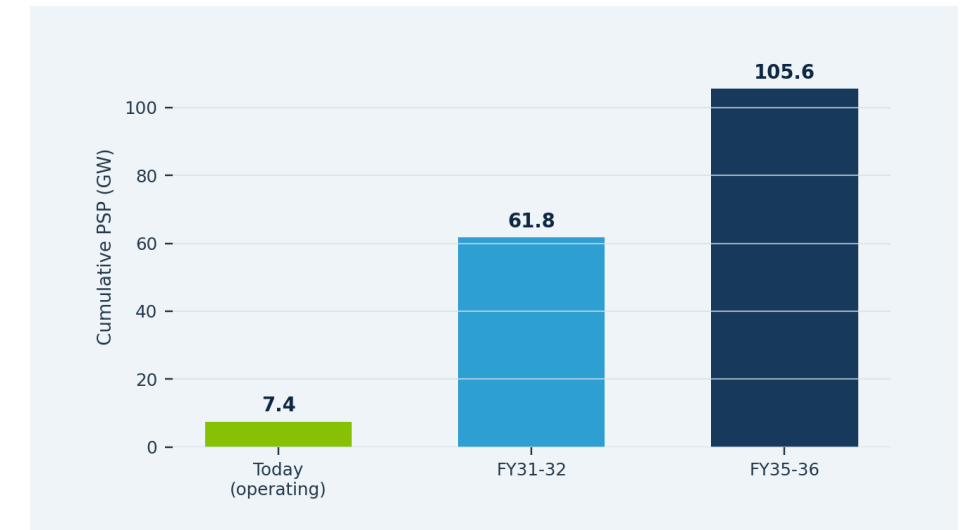


Why the curve steepens. Capacity additions rise sharply after FY2028-29. The programme therefore shifts from a project-by-project challenge to a portfolio delivery challenge. Experienced hydro EPC capacity, tunnelling resources, turbines, generators, switchyards, transmission bays and specialist engineering teams all need to scale together. A delay in any one of these interfaces can push commissioning into a later year, so the apparent annual MW profile should be interpreted as an execution dependency map as much as a capacity forecast.

Roadmap checkpoints and analytical interpretation

Across the roadmap, average annual addition is about 9.2 GW, while the single-year peak reaches 21.19 GW in FY2030-31. Annual investment peaks one year earlier at about ₹87,690 crore, and the cumulative investment requirement represented by the roadmap is about ₹5.81 trillion. The mismatch in timing is important: capital, equipment orders and civil works must be committed before commissioning. The practical question is whether India can create enough simultaneous project-management, contracting and grid-connection capacity to prevent a back-loaded pipeline from becoming a back-loaded delay queue.

06 What the roadmap accumulates to



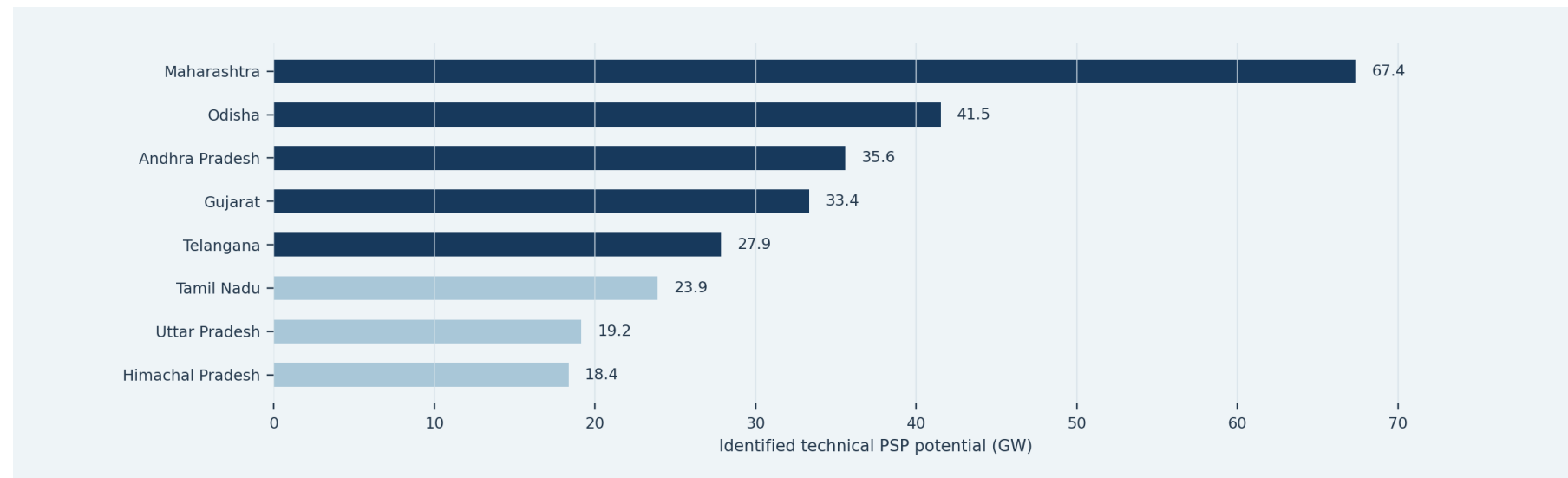
Why investment peaks earlier. Investment can precede commissioning by several years because excavation, water-conductor systems, civil structures and long-lead electro-mechanical packages are funded before COD. The annual investment curve should therefore be read as a financing and supply-chain signal, not merely as a commissioning proxy. Lenders and developers will need visibility on construction milestones, offtake or market revenues and transmission synchronisation well before the final MW appears on the system.

Resource abundance. Bankability concentration.

India has ample technical potential, but it is geographically concentrated - and a resource map is not a bankability map.

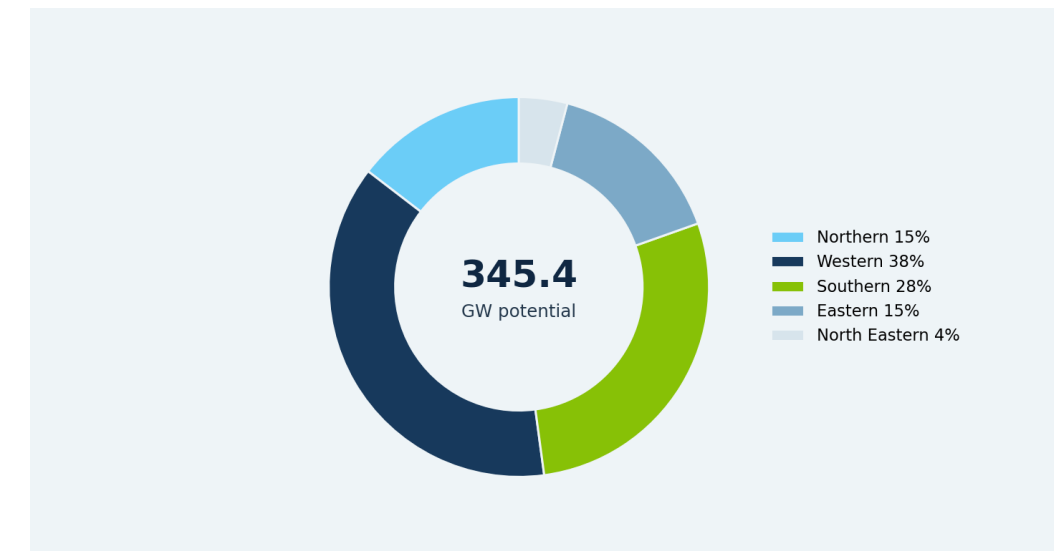
Technical potential is only the first screening layer. The bankable subset depends on reservoir configuration, head, geology, land and forest constraints, water-use permissions, charging access and the distance to strong transmission. Those filters can materially reorder the state ranking.

07 Where the technical potential sits



State concentration matters. Maharashtra is the largest identified state resource in this dataset, while Odisha, Andhra Pradesh, Gujarat and Telangana form a second tier. The ranking is useful for understanding where the technical opportunity is concentrated, but it should not be read as an investment ranking. Each state has different land, forest, water, grid-access and permitting conditions. Developers therefore need state-specific screening playbooks that connect reservoir geometry and head with transmission availability, construction logistics and a credible route to monetising charging and discharge cycles.

08 Regional concentration



Regional concentration matters for the grid. Western and Southern regions together account for roughly two-thirds of identified potential. That concentration affects where charging energy can be sourced and where discharge can relieve evening or seasonal constraints. A technically attractive PSP can still be commercially weak if it sits behind transmission congestion or far from the renewable surplus it is expected to absorb. Resource mapping therefore needs to be integrated with transmission planning, market nodes and the evolving location of solar and wind build-out.



Illustrative grid imagery from the supplied Firstgreen template.

Source: CEA, Potential of Pumped Storage Projects in the Country, September 2026; Firstgreen analysis.

1

65.9% sits in West + South

Two regions hold roughly two-thirds of identified national PSP technical potential. This creates a clear concentration of development opportunity, but also a concentration of transmission and permitting dependencies.

2

Top five states hold ~59.6%

The top five states account for nearly three-fifths of the identified potential. Their project pipelines will therefore be especially sensitive to state-level land, water, forest and approval frameworks.

3

Location must meet the grid

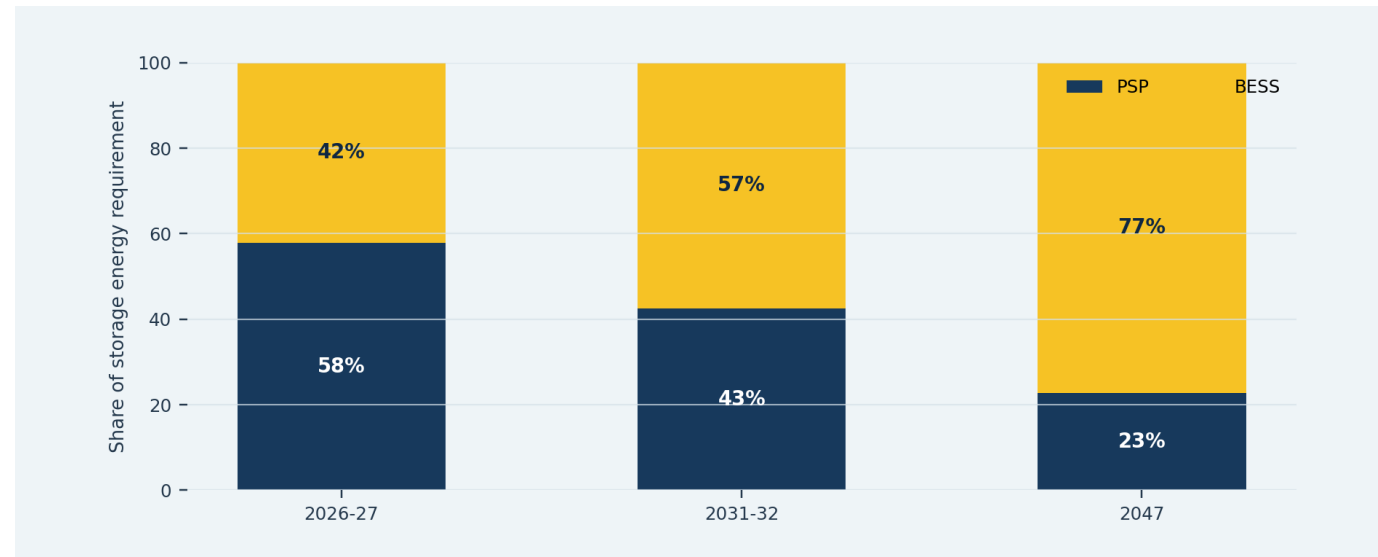
The best resource is not necessarily the best project. Evacuation capacity, charging access, market value at discharge hours and network constraints determine whether technically attractive storage can be monetised.

Both technologies grow. The job split changes.

BESS takes a larger share of storage-energy requirements over time, while pumped storage still expands materially in absolute GWh.

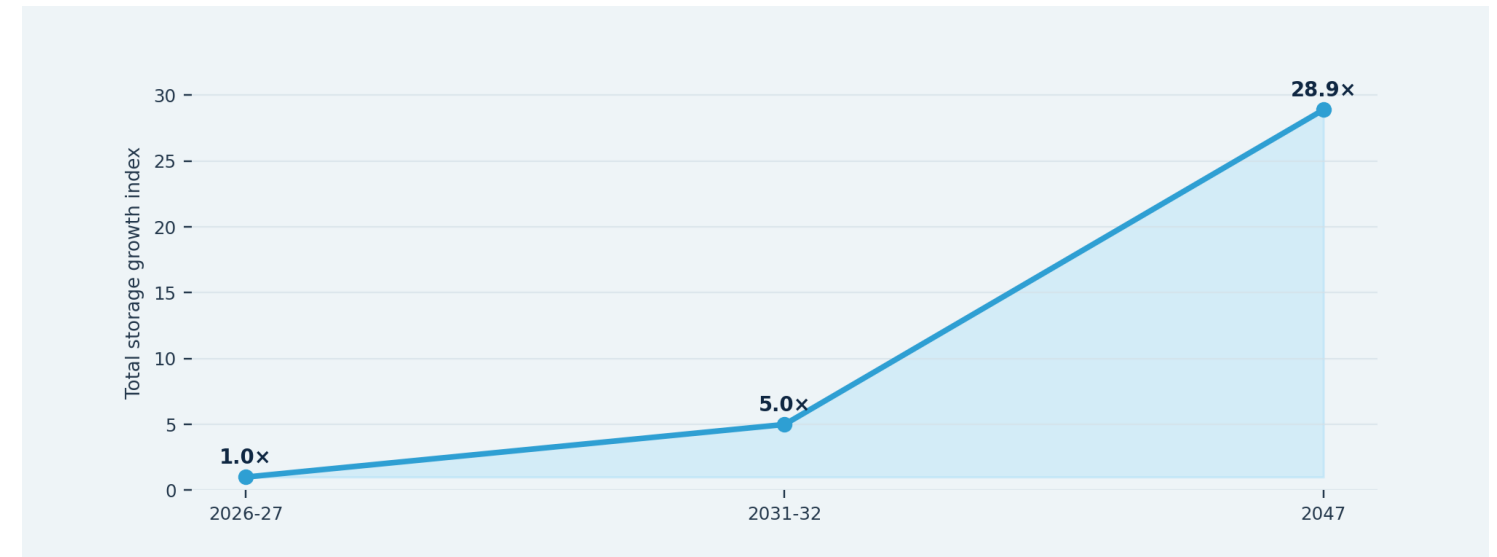
India's storage pathway is better viewed as technology segmentation than substitution. Batteries increasingly dominate short-to-medium duration requirements because they are modular and fast to deploy, while pumped storage remains relevant where long duration, large energy volumes and long asset life justify the longer development cycle.

09 The storage mix shifts toward batteries



Mix shift. The modelled share of storage energy met by PSP falls over time, but this does not imply declining PSP demand. Absolute PSP requirements still rise as the entire storage market expands. The chart should therefore be read as a change in functional mix: batteries capture more of the rapidly growing short- and medium-duration requirement, while PSP continues to serve large-volume, long-duration applications where site conditions and project economics support it. Market share can fall even while deployed GWh rises materially.

10 Total storage need expands nearly 29x



Scale effect. The combined storage requirement expands far faster than either technology can be considered in isolation. In the scenario shown, total storage energy grows from about 82 GWh to roughly 2,380 GWh. That scale makes technology-neutral service definitions increasingly important. Procurement should describe the grid need - duration, response time, availability, cycling pattern, location and delivered energy - and then allow competing technologies or hybrid portfolios to demonstrate the lowest-risk way to meet it.



The storage race will be decided by duration, dispatchability, location and ₹/MWh.

Procurement Implication round-trip efficiency + response time + availability. A four-hour BESS and a ten-hour PSP deliver different grid services; comparing them on MW or capex/MW alone can misprice flexibility. Procurement should also define the required dispatch window, cycling frequency, degradation or refurbishment assumptions, charging constraints and performance penalties. That converts the tender from a technology purchase into a clearly specified flexibility service and makes the economic comparison more transparent.

Bankability Implication as an opportunity envelope, not committed capacity. Rank candidate PSPs by development stage, usable reservoir hours, geology, civil-work intensity, capex, transmission access, approvals, construction schedule and the revenue stack available to the project. The strongest projects will be those where a technically robust site, a realistic delivery plan and a bankable dispatch value align. This is the bridge from national potential to investable storage capacity.