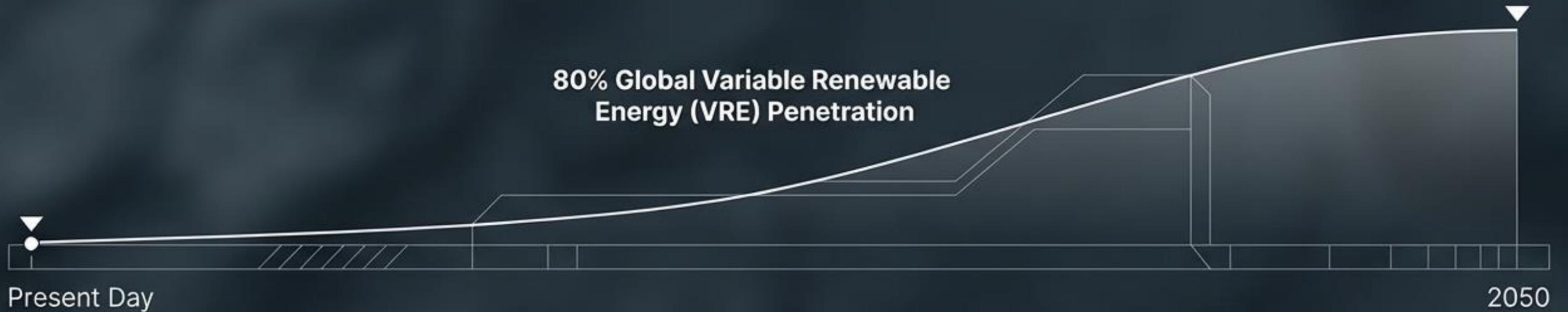




The Decisive Decade

Capital Allocation for 60 GWh Grid-Scale Storage.

80% Global Variable Renewable Energy (VRE) Penetration



THE PHYSICAL NEED

Mitigating the inherent intermittency of solar PV and wind. Replacing lost conventional synchronous inertia with millisecond-fast frequency regulation.

THE POLICY CATALYST

Bankable legislative signals, notably the US Inflation Reduction Act (IRA) and the UK's Cap and Floor mechanism, are fundamentally de-risking standalone storage investments.

THE SECURITY MANDATE

Providing a critical, physical infrastructure buffer against geopolitical fuel price shocks and the increasing frequency of extreme weather events.

Procuring a 60 GWh storage system reveals a dramatic **100x** capital expenditure spread.

Lithium-ion BESS

\$17.64 Billion

Total Installed CAPEX for 60 GWh

Pit Thermal Storage (PTES)

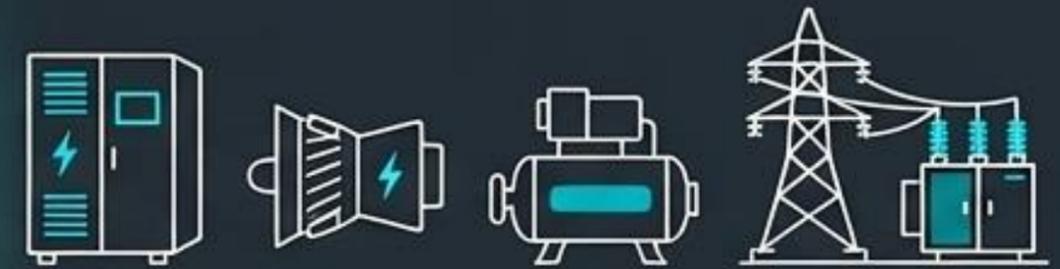
\$177 Million

Total Installed CAPEX for 60 GWh

Total system cost is fundamentally defined by the duality of power and energy hardware.

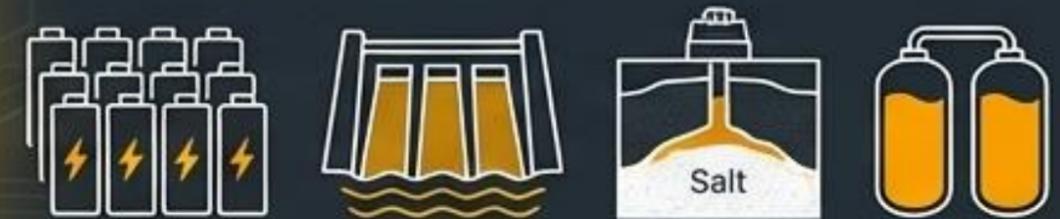
Power-Related Costs (\$/kW)

Dictates the rate of charge/discharge.



Energy-Related Costs (\$/kWh)

Dictates the physical volume of stored energy.



$$\text{Total CAPEX} = (\text{Energy Cost} \times \text{Energy Capacity}) + (\text{Power Cost} \times \text{Power Capacity})$$

Assumed discharge duration dictates the required power rating and drives total infrastructure scale.



All three systems hold exactly 60 GWh of energy. The duration mandate dictates the scale of the expensive power conversion equipment.

Lithium-ion systems dominate high-power ancillary services but scale poorly for bulk energy shifting

Duration:

4 Hours

Power Rating:

15.0 GW

Total CAPEX:

\$17.64 Billion

Effective Unit Cost:

\$294 / kWh

Chemistry

Transitioning rapidly to Lithium Iron Phosphate (LFP) for safety and supply chain stability.

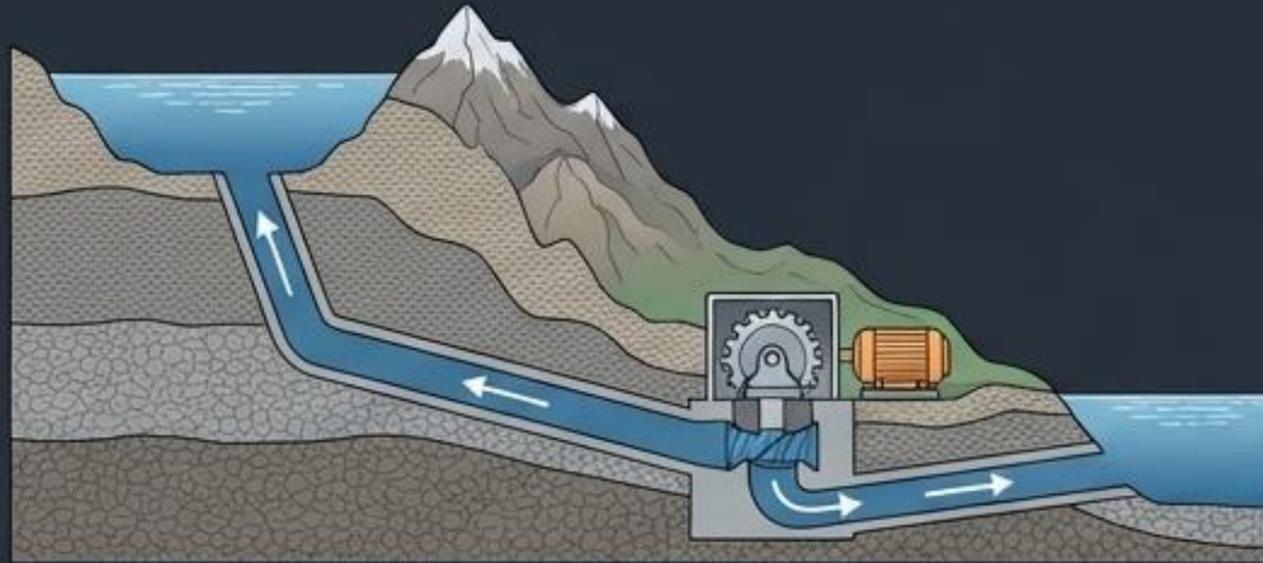
Economics

Highly modular but capital costs remain tethered to global electric vehicle (EV) supply chain volatility

Hidden Costs

Initial CAPEX excludes future augmentation cycles required to combat persistent cell degradation

Mechanical storage provides highly cost-effective daily arbitrage by leveraging natural topography.

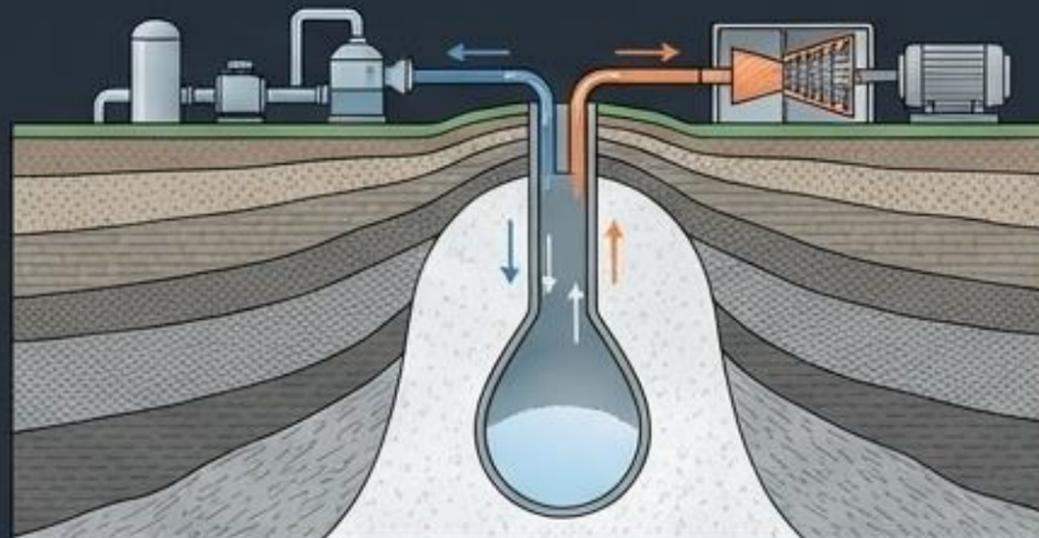


Pumped Storage Hydro

10 Hours | 6.0 GW

Total CAPEX: **\$9.60 Billion**

Effective Cost: **\$160 / kWh**



Compressed Air (CAES)

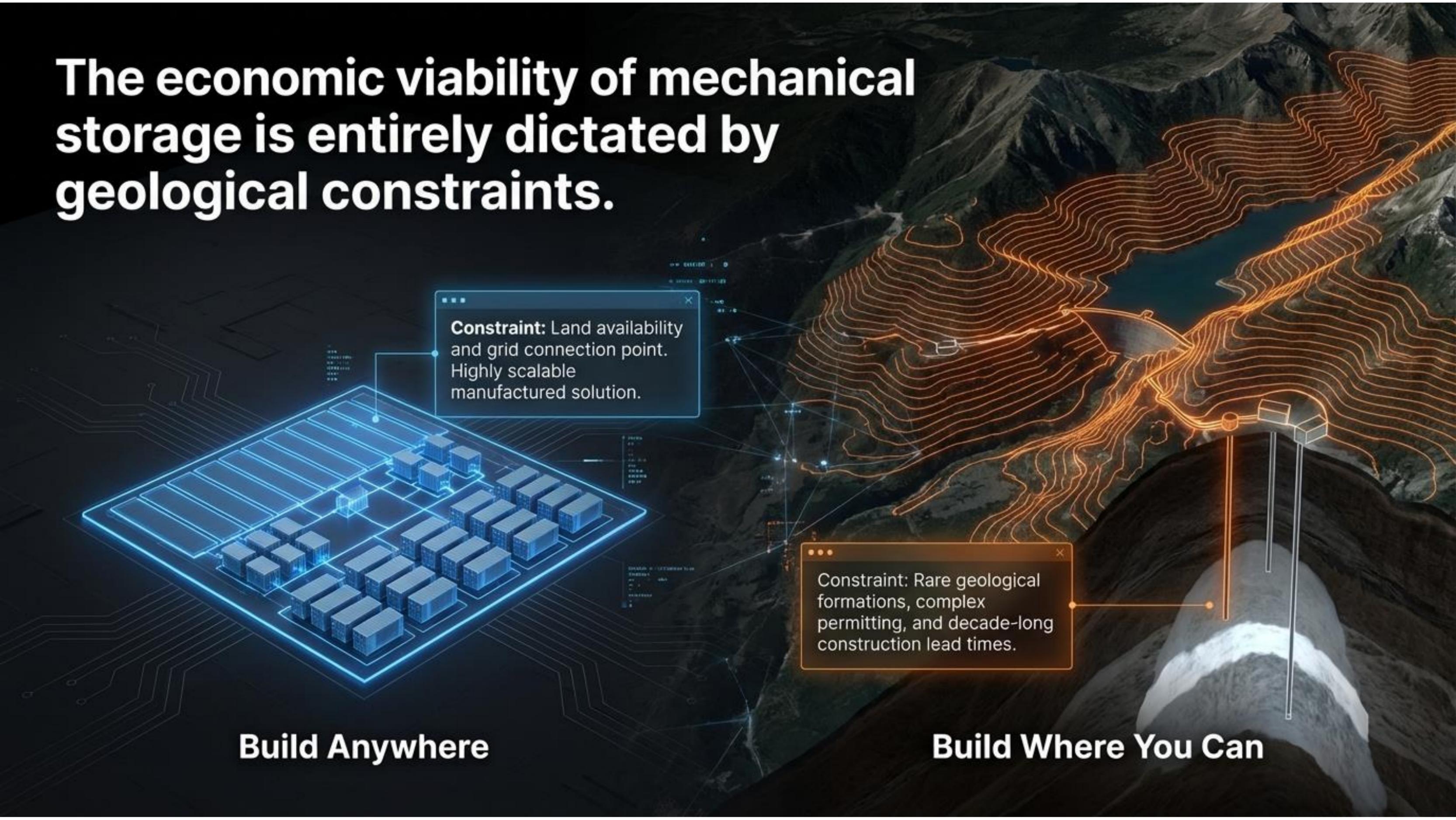
16 Hours | 3.75 GW

Total CAPEX: **\$5.30 Billion**

Effective Cost: **\$88 / kWh**

Insight: The energy component (\$/kWh) is **remarkably cheap**.
Capital is **heavily concentrated** in the civil works and turbomachinery.

The economic viability of mechanical storage is entirely dictated by geological constraints.



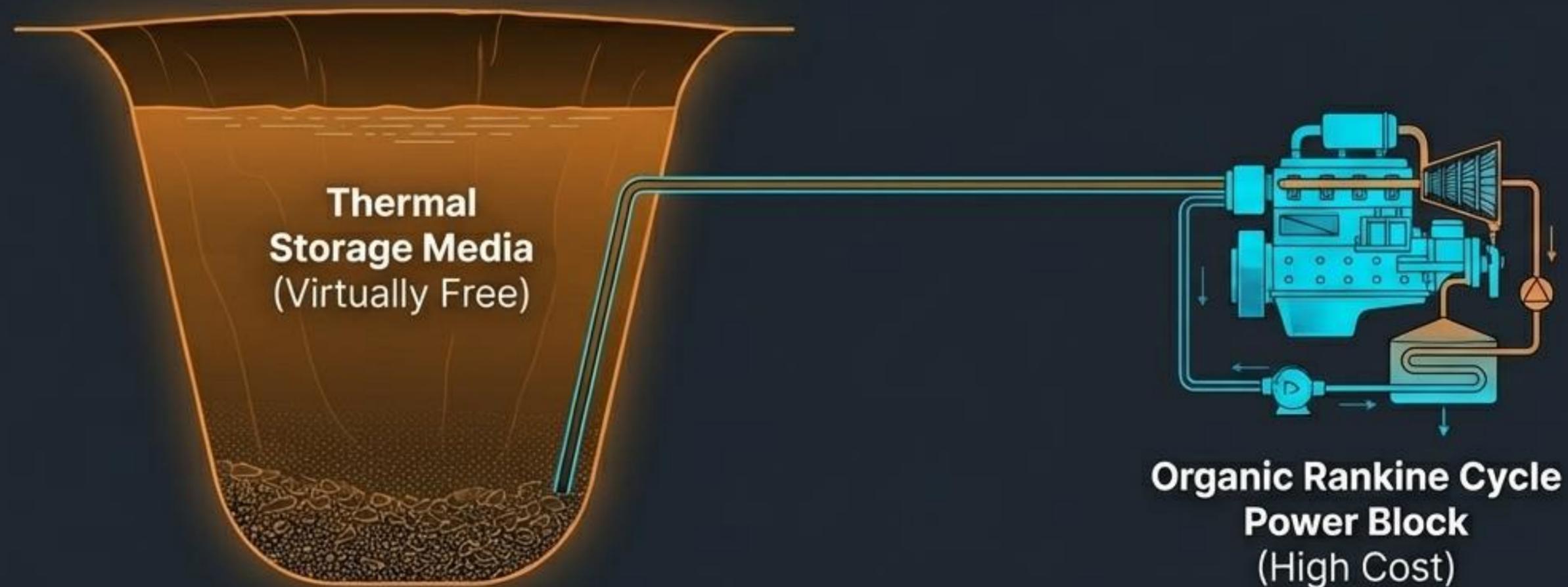
Constraint: Land availability and grid connection point. Highly scalable manufactured solution.

Constraint: Rare geological formations, complex permitting, and decade-long construction lead times.

Build Anywhere

Build Where You Can

Pit Thermal Storage offers near-zero energy containment costs but suffers high re-electrification penalties.



Duration:
2,500 Hours

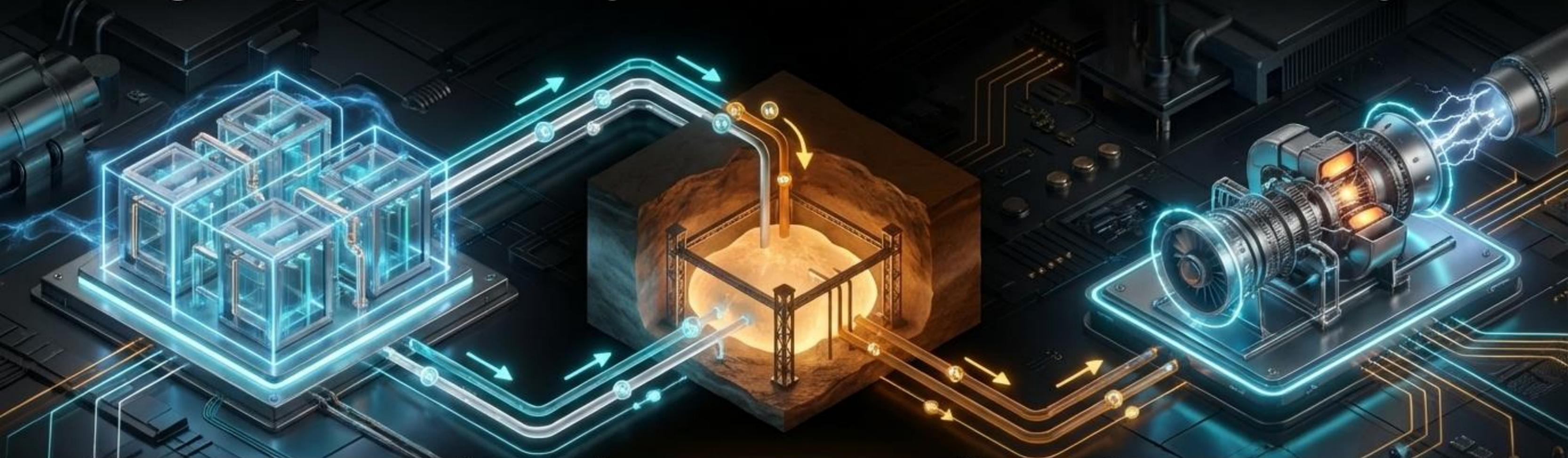
Power Rating:
24 MW

Total CAPEX:
\$177 Million

Effective Unit Cost:
\$2.95 / kWh

Insight: To deliver 60 GWh_e at 40% round-trip efficiency, the system must store a massive **150 GWh_{th}** of thermal energy. **Viable exclusively for seasonal durations** where the power block is amortised over months.

Green hydrogen acts as a seasonal strategic reserve, though though capital is heavily locked in conversion machinery.



Production: 220 MW PEM
Electrolyzer Plant (\$374M)

Storage: Cavern holding
4,800 tonnes of H₂ (\$320M)

Re-electrification: 60 MW
Gas Turbine (\$66M)

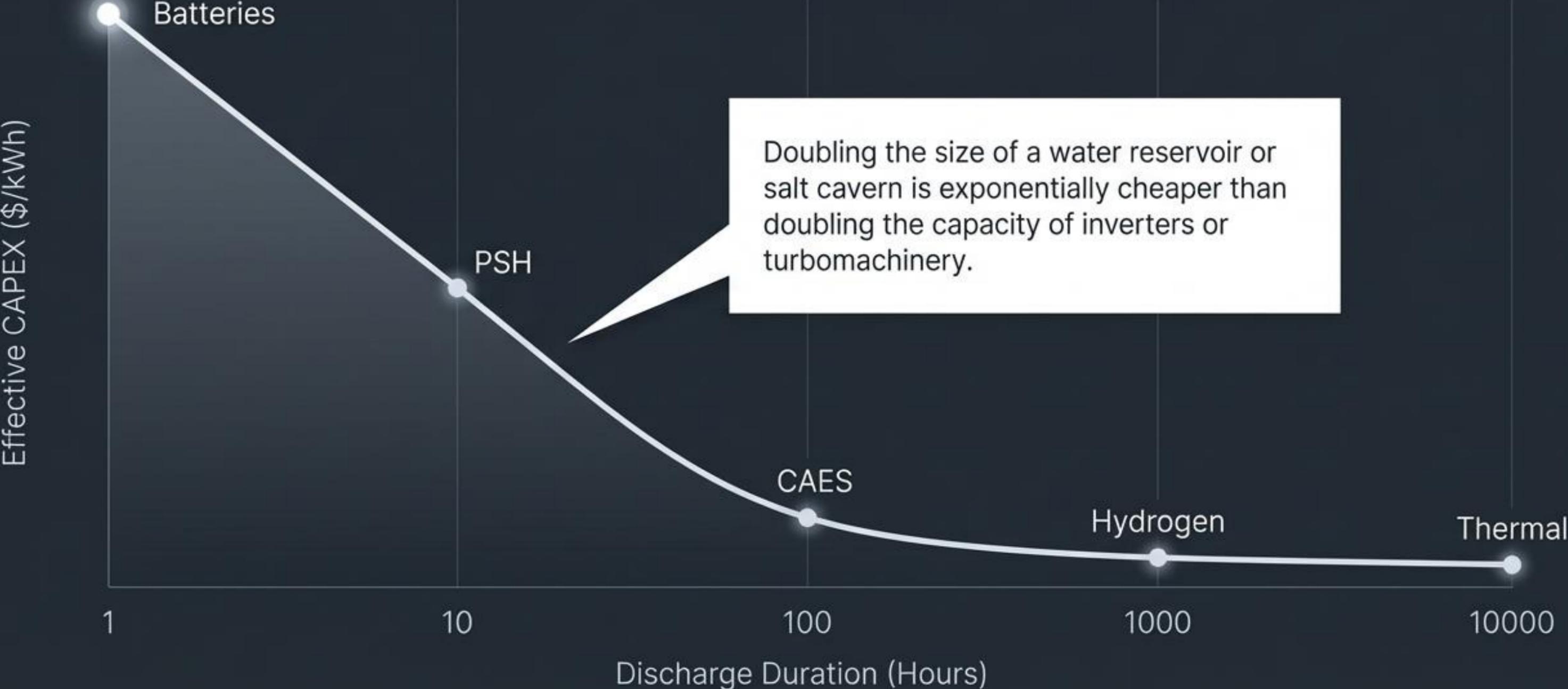
Total Scale: 1,000 Hours | 60 MW | Total CAPEX: \$760 Million | \$12.67 / kWh

Insight: The physical storage cavern is the minority cost. Hydrogen's true economic value lies in its versatility as a chemical feedstock rather than round-trip electricity storage.

The 60 GWh Comparative Blueprint

Technology	Discharge Duration (hrs)	Power Rating (GW)	Effective CAPEX (\$/kWh)	Total CAPEX (Billion USD)
Batteries (Li-ion)	4	15.0	\$294	\$17.64
Pumped Storage Hydro	10	6.0	\$160	\$9.60
Compressed Air (CAES)	16	3.75	\$88	\$5.30
Hydrogen (Green)	1,000	0.06	\$12.67	\$0.76
Pit Thermal (PTES)	2,500	0.024	\$2.95	\$0.18

The Amortisation Curve: Extending discharge duration exponentially lowers the effective unit cost of energy.



Capital allocation must align the technological cost structure with the specific grid application.



The Precision Portfolio: A resilient, low-carbon grid demands a blended infrastructure footprint.

Smoothing moment-to-moment spikes

Shifting the daily solar curve

The ultimate winter safety net

The 60 GWh scale represents nation-building infrastructure. There is no single silver bullet. Strategic investment requires matching the right asset class to the precise duration mandate of the grid.

