BESS at the tipping Point :

The Next Solar or Moment

The market for battery energy storage systems is approaching inflection point. For those ready to ask the key questions and lead the way, answers are here

AN AVALON PERSPECTIVE

CONTEXT

01 SITUATION:

Global energy systems are undergoing their fastest transition yet. Solar and wind (variable sources of energy) are now cheapest and approaching 30% share of grid, yet the systems was never designed for this kind of variability

02 CHALLENGE:

As penetration further rises, balancing grid becomes a core issue. Traditional options like peakers are not fully equipped for this situation and approaching their limits. Batteries are the logical solution but adoption is still nascent, mainly because BESS requires two thresholds to scale: cost parity and structural need

03 KEY QUESTIONS:

- When these dual thresholds are expected to converge?
- And what will be the speed of adoption post that?
- Who captures value and how will value chain transition?
- What are the risks that could derail this transition?

04 OUTCOME:

Analysis using a robust, scenario based model shows inflection is imminent in next 5-10 years, and once crossed, growth is bound to be exponential, similar to solar and Evs

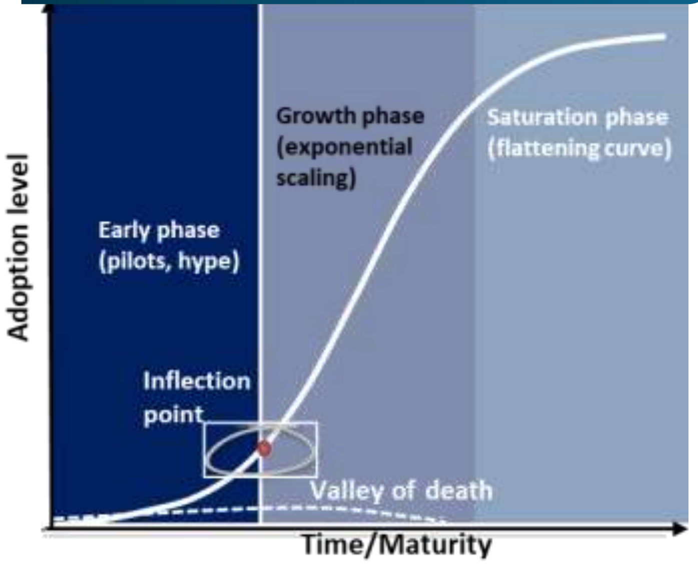
The Power of S-Curves: How Technologies Scale

Energy technologies seldom linearly. They typically follow an S curve, with slow early progress, breakout growth, and eventual saturation.

They struggle in slow gestation phase and remains confined to niche applications. But once they reach economic threshold, growth becomes exponential aided by scale, and network effects, and then it eventually levels off once the addressable market is saturated.

This pattern has been followed by many technologies in the past: from coal overtaking wood, gas displacing coal to the rise of solar PV (Photo voltaic) and EVs (Electric Vehicles) in the past decade.

EXHIBIT 2: FACTORS FOR MANAGING END OF LIFE



S curve typically follows following stages:

Early phase:

Starts with weak signals – pilot projects, hype cycles and limited economics. Many technologies will fall into oblivion into valley of death phase where hype runs ahead of economics.

Only those with supportive policy or addressable markets, even if niche would survive

Growth phase:

Once a tipping point is reached, usually cost parity or a structural need or a certain minimum scale, adoption rapidly accelerates in the market breakout phase.

The slope of this growth is often steep and reflect self reinforcing dynamics – as scale grows, costs fall, and as costs fall, markets expand, and as markets expand, capital flows in, and as capital flows in scale would further grow, creating a virtuous cycle

Saturation phase:

Finally, as the technology starts becoming mainstream, growth would no more be exponential, and the curves starts flattening. Cost decline ceases to be the primary factor.

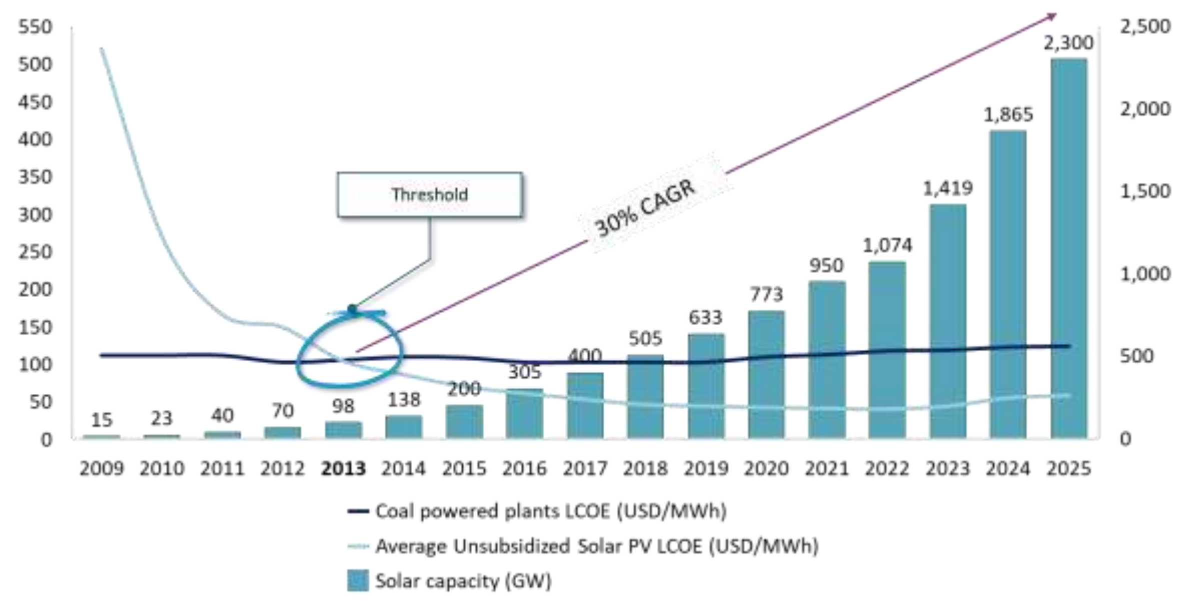
for adoption, and market design, infrastructure would matter more.

Solar’s S-Curve: From Niche to Mainstream

- *Solar energy spent decades struck in early S curve hindered by high cost and dependance on subsidies. In this weak signal phase, projects survived and did not fall into valley of death phase mainly because of government subsidies and not market competitiveness.*
- *This climb also reflects intense growth phase, where falling costs, proven reliability & inducive policies all combined to unlock scale at which it is now*
- *The turning point was in 2013 when solar’s unsubsidized LCOE fell below $100/MWh in key regions which was below LCOE of fossil fuels. This was solar’s market breakout moment and made its entry into the steep middle phase of the S curve. The result was the rapid growth in capacity from 50GW in 2015 to 2300GW in 2025, which is also 2/3 of overall capacity additions in that phase.*
- *Solar PV is now in the upper plateau and already nearing saturation in leading markets like Europe, China and some states of US. Growth is slowing not because of cost dynamics, rather because of saturation dynamics like share of renewables reaching threshold beyond which grid integration limitations starts to emerge, land constraints and diminishing incremental value beyond this penetration level. Curtailment has started to become an issue in some regions, leading to wasted capacity.*

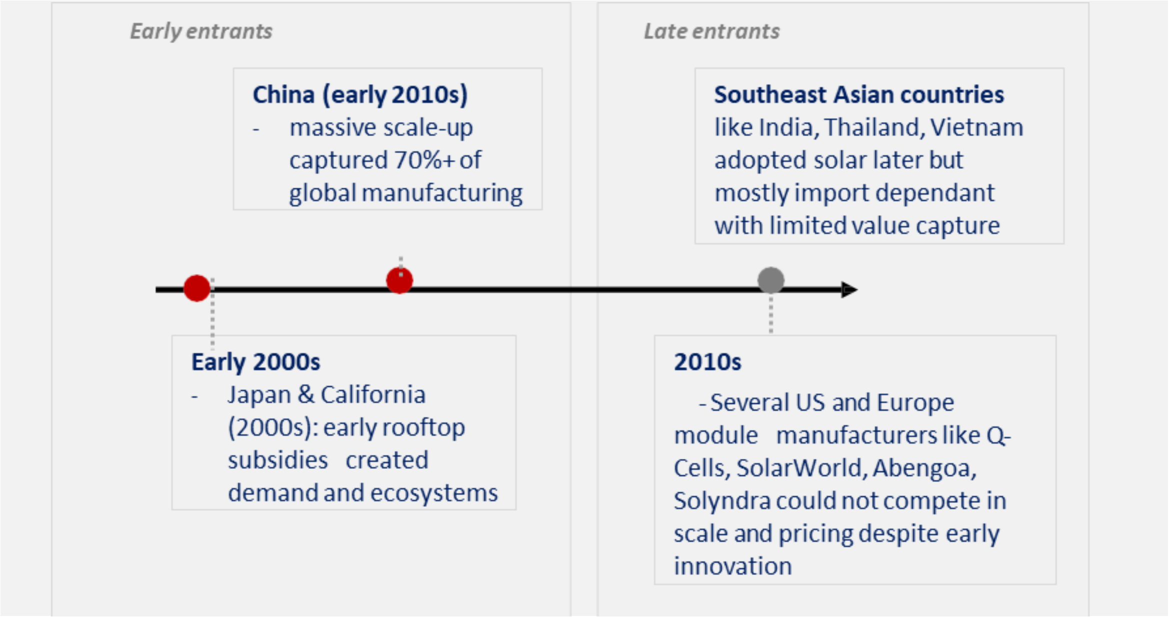
Solar’s Winners and Losers: Early vs. Late Entrants

EXHIBIT 2: EXPONENTIAL GROWTH OF SOLAR CAPACITY POST THRESHOLD



Solar had reached its inflection point in 2012 and had managed to grow rapidly beyond

EXHIBIT 3: EARLY AND LATE ENTRANTS IN SOLAR PV



China (early 2010s)
- massive scale-up captured 70%+ of global manufacturing

Southeast Asian countries like India, Thailand, Vietnam adopted solar later but mostly import dependant with limited value capture

Early 2000s
- Japan & California (2000s): early rooftop subsidies created demand and ecosystems

2010s
- Several US and Europe module manufacturers like Q-Cells, SolarWorld, Abengoa, Solyndra could not compete in scale and pricing despite early innovation

Solar’s S-curve inflection around 2012 shows how early movers captured high value and how late entrants could not compete. On the adoption side, California and Japan piloted the model through rooftop programs by providing incentives when economics were still weak. On the supply side, China scaled rapidly after 2010, securing >70% of global manufacturing of the PV cells, emerging as a price setter

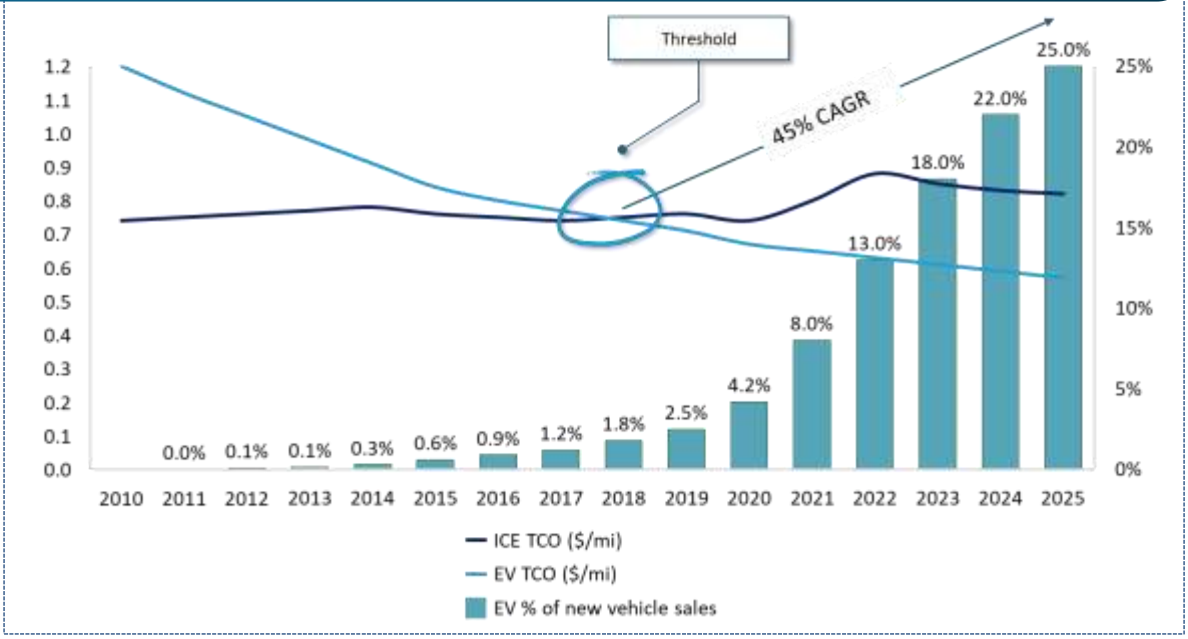
By contrast, many of the early innovators from US and Europe who failed to scale like Solyndra, SolarWorld, and Q-Cells had exited the market due to cost pressures. Late entrants after 2012, such as India, Southeast Asia, and parts of Europe, became import reliant, thereby missing the opportunity to capture upstream value capture even as adoption grew.

EV’s S-Curve:
Road to mass adoption

- EVs followed a similar S curve trajectory. For many years it followed the weak signal phase - it was dismissed as a niche application and hindered by high battery costs and range anxiety.
- In 2010s, it was less than 0.01% of total auto sales, and was surviving more on policy support and early adopters than cost competitiveness
- However, post that, Li-ion battery which constitutes upto 60% of EV cost saw steep decrease in cost (~ 90%) from 2010 to 2020 from $1000/kWh to $130/kWh, leading to a market breakout moment, bringing TCO towards parity with Internal Combustion Engine (ICE) vehicles.
- By 2018 it entered steep growth phase of S curve with sales doubling in just 2 years as customers started realising that EVs are not only greener but are increasingly cheaper and simpler to operate. Charging networks expanded, number of choices expanded, and whole automotive ecosystem started adopting for electrification at scale.
- As of 2025, EV has captured 25% of global auto sales, being in intensive growth phase of S curve. Eventually it is expected to lead to eventual saturation plateau, where EVs becomes a default option, which is already the case in countries like Norway (90% of new car sales in is electric), Sweden – 58% and China – 48%.

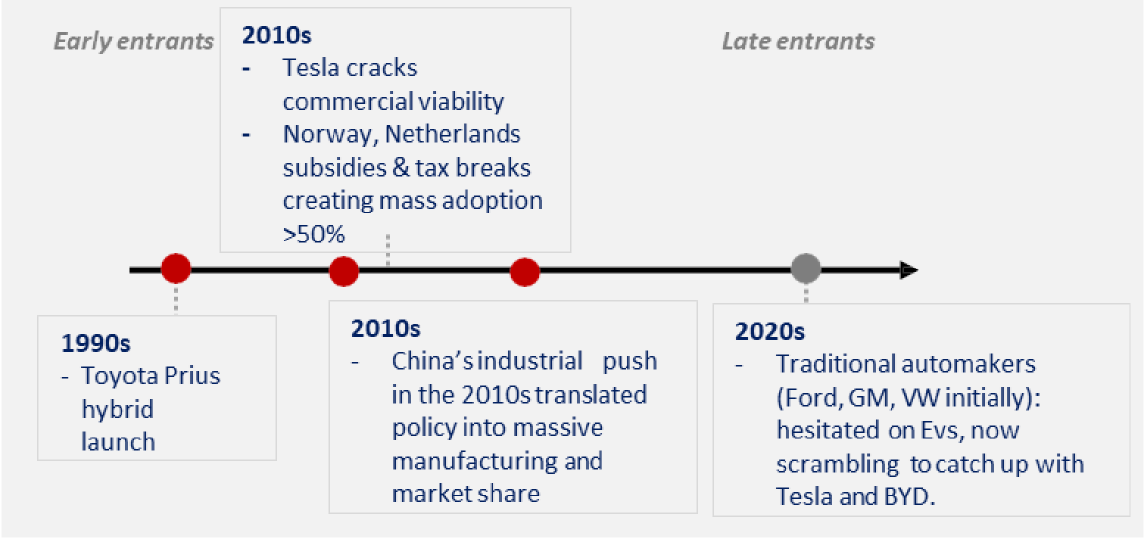
EV's Winners and Losers: Early vs. Late Entrants

Exhibit 4: Global Exponential growth of EV post threshold



EV had reached its inflection point in 2018 and had managed to grow rapidly beyond

Exhibit 5: Early and late Entrants in EV



Early entrants

Late entrants

2010s
- Tesla cracks commercial viability
- Norway, Netherlands subsidies & tax breaks creating mass adoption >50%

1990s
- Toyota Prius hybrid launch

2010s
- China's industrial push in the 2010s translated policy into massive manufacturing and market share

2020s
- Traditional automakers (Ford, GM, VW initially): hesitated on Evs, now scrambling to catch up with Tesla and BYD.

EV transition followed a similar pattern. Toyota's Prius in the 1990s established viability, Tesla's breakthrough in early 2010s made EVs aspirational, and on the country level, Norway and Netherlands scaled demand through subsidies.

By 2020s, China's push and Europe's policy shifts led to exponential growth. Several legacy automakers from Ford and GM to European luxury players entered quite late and are scrambling in a crowded market with thinner margins. Once again, timing of entry defined the winners.

A Familiar S-Curve, with a Twist: BESS Has Two Inflection Points

Battery Energy Storage systems (BESS) is approaching on similar lines as solar and EVs. For years it was promising and working well in pilots but not economically scalable over alternatives.

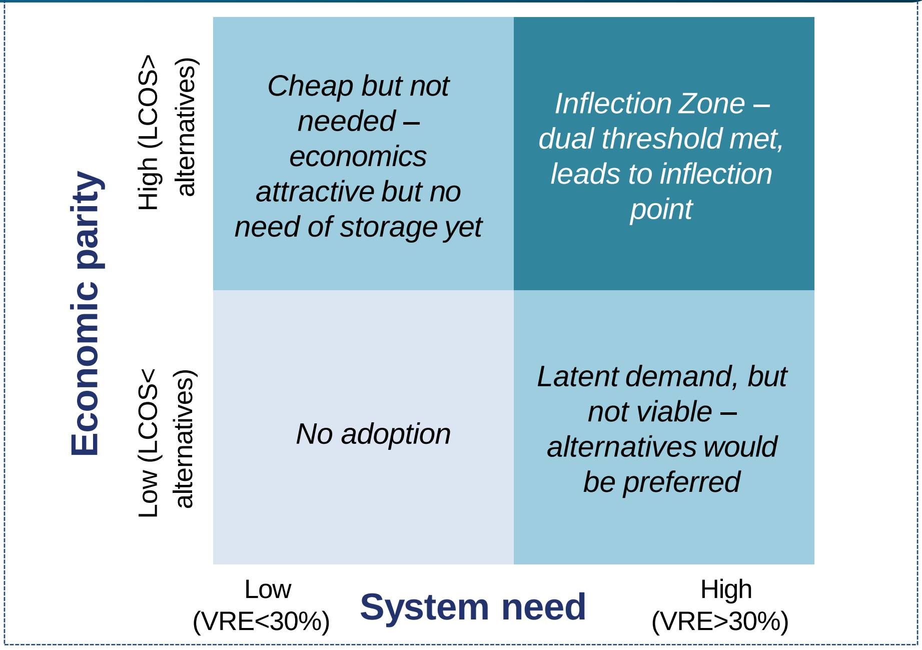
For most of 2010s, storage was viewed as technology for the future, but prohibitively expensive. But now this scenario is changing, with Li-ion battery pack projected to fall below $100/kWh by 2030 and other more efficient alternative battery sources like Sodium ion and flow batteries fast developing,

However, unlike solar and EV, which reached breakout primarily on cost parity, storage requires dual threshold for growth:

Economic threshold	When LCOS<LCOE of Alternatives
System threshold	When Variable Renewable Energy (VRE) >30%, creating volatility, ramping eds which only storage can solve

Growth could be driven by system requirements not just economic parity

Exhibit 6: Global Exponential growth of EV post threshold



	Low (VRE<30%)	High (VRE>30%)
High (LCOS> alternatives)	*Cheap but not needed – economics attractive but no need of storage yet*	*Inflection Zone – dual threshold met, leads to inflection point*
Low (LCOS< alternatives)	*No adoption*	*Latent demand, but not viable – alternatives would be preferred*

Solar/EV needed only economic parity (single threshold) but BESS requires two thresholds simultaneously (cost and system need).
Examples:

California	India	Germany/Spain
Crossed both thresholds	Cheap, but system need yet to fully emerge	High need, but economic parity yet to be reached

Managing Grid Balance: Traditional Levers Before Storage

Every power systems has to efficiently handle demand - supply spikes in real time. These spikes in demand could be:

- ***Predictable and seasonal peaks:*** Regular demand peaks in summer, daily peak energy demand in nights etc.
- ***Unexpected spikes:*** Demand peaks in heat wave/ cold waves

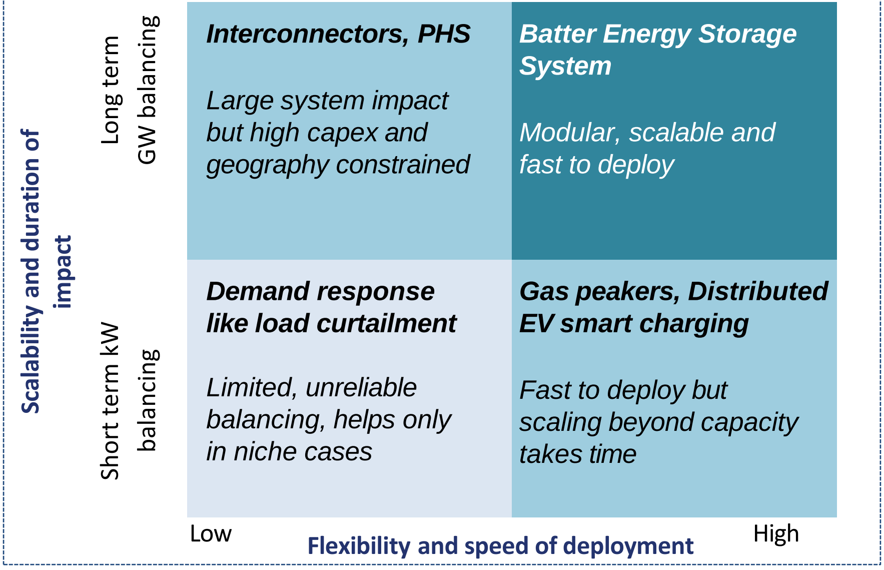
Historically, fossil fuel led grids handled these mismatches with dispatchable generation (coal, gas, oil) that can be ramped up and down on demand. But with variable renewable energy (VRE) like solar, wind increasing share, mismatch has become structural.

Ex: In California, where VRE share is >30%, solar generation peaks at midday while demand peaks in the evening producing the infamous duck curve wherein intra-day ramps become sharper, and traditional solutions start breaking down.

Ways of Grid Balancing

Deman-side flexibility	Flexible supply	Transmission	Storage
• Time-of-use pricing, load shifting • Useful but limited impact and variable based on consumer behavior	• Gas peakers to cover demand spikes. • Increasingly uneconomic due to low utilization (<10–15%) & high emissions	• Interconnectors to move power between surplus and deficit regions • Capital intensive, politically complex, and cannot fully substitute local balancing.	• Pumped Hydro Storage (PHS) has higher storage duration (~8hrs) but constrained by geography, BESS relatively smaller storage capacity (~4hrs) but modular and scalable • This is the only lever that can decouple generation from consumption.

Exhibit 7: Four levers of grid balancing



	Low	High
Long term GW balancing	***Interconnectors, PHS*** *Large system impact but high capex and geography constrained*	***Batter Energy Storage System*** *Modular, scalable and fast to deploy*
Short term kW balancing	***Demand response like load curtailment*** *Limited, unreliable balancing, helps only in niche cases*	***Gas peakers, Distributed EV smart charging*** *Fast to deploy but scaling beyond capacity takes time*

- *Each lever addresses a specific challenge in grid balancing and comes at their own cost, but none is a silver bullet, and typically a portfolio of these levers are required*
- *Relative attractiveness of a solution is region specific*
- *BESS is the only option if fast deployment and scalability is the primary factor*

Why and When Storage Is Needed: The Case for BESS

Traditionally, demand was predictable (industrial base load + minor peaks).and supply was readily dispatchable (coal, gas).

But with high VRE share, supply is now:

Variable (depends on sunlight, wind)	*Non-dispatchable (zero solar generation at night)*	*Mismatched with demand (solar peaks midday whereas demand peaks evening)*

This results in curtailment, high volatility, zero/negative spot prices, and grid instability. Storage is the only option that can time-shift generation of energy from renewables to period when it is needed.

There are two main storage options at scale:

Pumped Hydro Storage (PHS)

Pros	Cons	Use case:
Has very large capacity (GW) and can support long-duration (8–12+ hrs) and becomes cheaper at scale.	Highly geography dependent as it requires reservoirs & elevation difference, has environmental impact and inflexible	Useful for seasonal/bulk storage in countries like China, India, Switzerland

Battery Energy Storage Systems (BESS) is the emerging alternative

Pros	Cons	Use case:
Modular and can be deployed anywhere, has instant response time, costs are declining and has multiple revenue streams (energy arbitrage, ancillary).	Can support only shorter duration (typically 2–6 hrs), battery degrades over time and highly concentrated supply chain	Fast ramping and short to mid duration balancing

Why BESS is becoming the default option

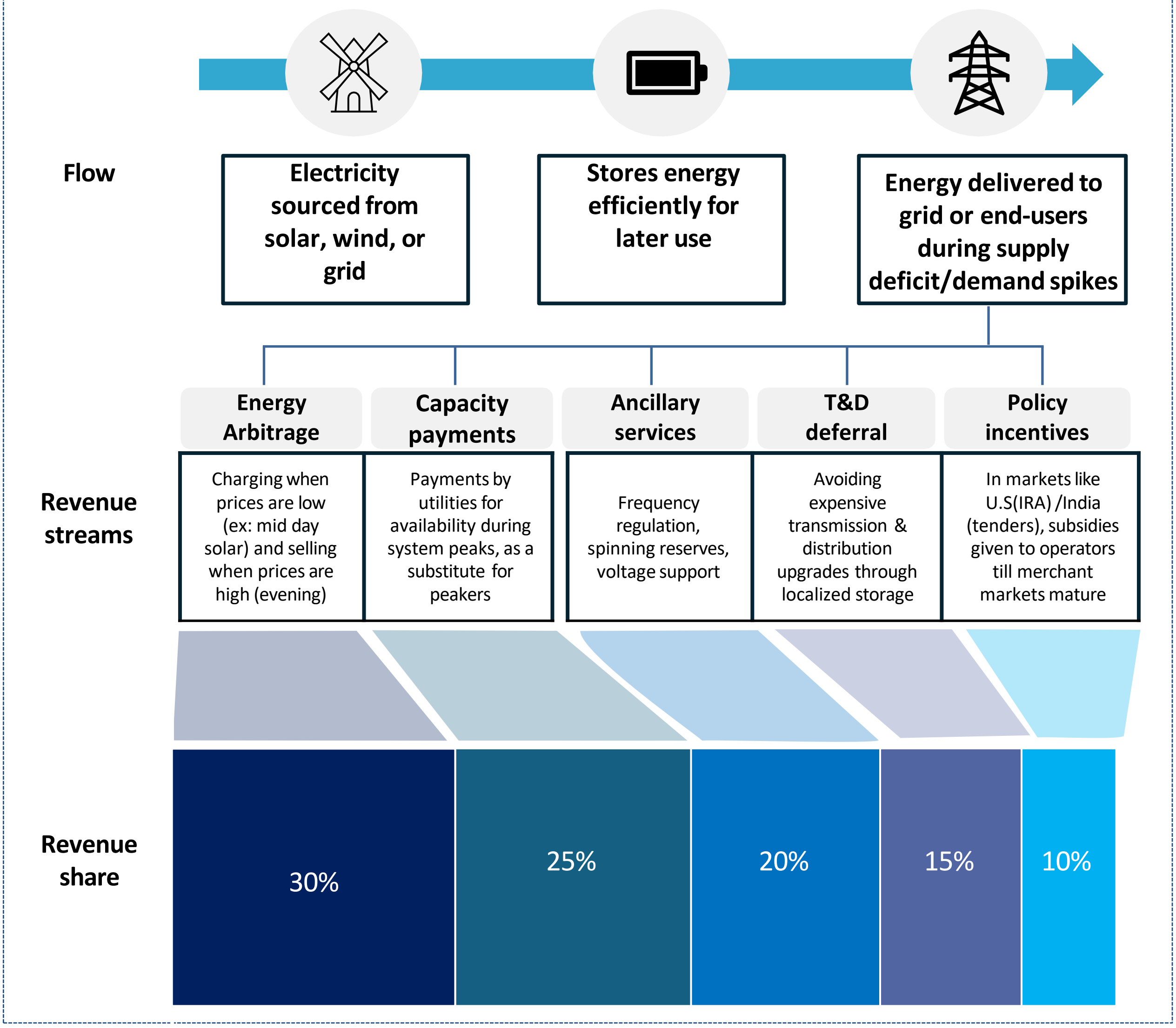
- ***Geography agnostic:*** Unlike PHS, BESS can be setup near demand centers
- ***Scalable:*** Deployable in MW–GW ranges with short lead times
- ***Economic:*** Costs are declining fast due to reduction in price of Li Ion battery (main cost driver), has more revenue streams

PHS will continue to remain relevant in geography suited places with bulk storage needs like China, India. But globally, BESS is expected to shape as dominant force as it can address the marginal need of balancing for 2– 6 hrs at ~30%+ VRE.

Inside BESS:
What It Is and How It Works

Battery Energy Storage System (BESS) is a technology solution that stores electrical energy (usually from renewable or grid sources) in batteries packs (typically Li ion) for later use. It enables grid stability, peak shifting, backup power. It is mainly used with Variable Renewable Energy sources like wind and solar, where there are higher intermittencies in supply

Exhibit 8: BESS revenue stacking



Flow	**Electricity sourced from solar, wind, or grid**		**Stores energy efficiently for later use**		**Energy delivered to grid or end-users during supply deficit/demand spikes**
	Energy Arbitrage	**Capacity payments**	**Ancillary services**	**T&D deferral**	**Policy incentives**
Revenue streams	Charging when prices are low (ex: mid day solar) and selling when prices are high (evening)	Payments by utilities for availability during system peaks, as a substitute for peakers	Frequency regulation, spinning reserves, voltage support	Avoiding expensive transmission & distribution upgrades through localized storage	In markets like U.S(IRA) /India (tenders), subsidies given to operators till merchant markets mature
Revenue share	30%	25%	20%	15%	10%

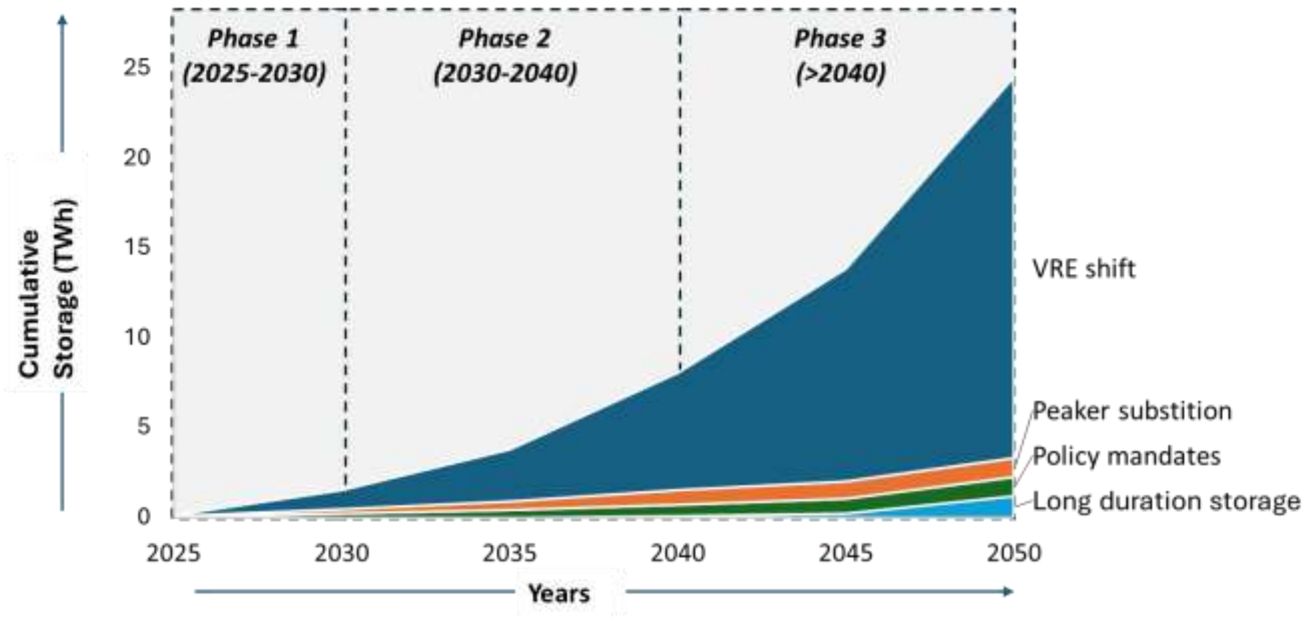
The real differentiator of BESS is not the hardware alone but the unique business model. Unlike other energy sources, which sell a single product (MWh of generation), storage earns revenue from multiple services across energy, capacity, and grid management

BESS economics depend on revenue stacking, and how this mix shifts over time as VRE penetration rises and market needs evolve. Early players who master optimizes revenue from ancillary services, will eventually dominate the downstream profit pool.

The Four Growth Levers Shaping Adoption

- Traditionally, grids have mainly relied on gas peakers and pumped hydro storage plants at scale for managing demand supply gap
- Peakers address short duration spikes but comes at high cost and emissions; PHS is more suited for long duration flexibility but constrained by geography and long cycles for development. As grid transition towards renewables, both these options are increasingly being complemented and eventually substituted by batteries.
- The first major growth lever is **peaker substitution.** Peakers are still cheaper at scale in most markets (~$150/MWh), compared to levelized cost of storage (LCOS) of BESS (>$200/MWh today). But this situation is expected to flip as BESS costs are expected to fall below $150/MWh by 2030, thereby becoming the cost-efficient option. With ~450 GW of peakers operating globally, even if 60% are replaceable, it represents 1 TWh substitution opportunity. Replacing peakers are the early anchor for BESS adoption
- The second driver which is the most dominant is the **rising share of variable renewable energy (VRE)** sources, from ~17% of generation today to ~30% by 2030. This is expected to create daily energy shifting - leading to structural needs, whereby BESS being the most scalable become indispensable.
- Third, **policy mandates** are driving deployment across the globe with California, China and India already procuring multi-GW of storage annually, creating the initial ecosystem and a demand floor, irrespective of how economics pans out
- Final lever, **long duration storage** will emerge only post 2035-40, as the system reaches maturity, PHS will be substituted or complemented by BESS as per the geography
- Together, these four forces - peaker substitution, VRE integration, policy mandates, and long-duration solutions, are expected to drive the growth of BESS and set the tone for three distinct phases of expansion.

EXHIBIT 9: BESS GROWTH PHASES



Phase 1 (2025–2030)*: growth anchored by peaker substitution; policy creates floor for early adoption*
Phase 2 (2030–2040): *VRE shift becomes dominant as VRE to grid rises to >40%, peaker substitution flattens* ***Phase 3 (2040+),*** *long-duration solutions emerge, and peakers decline, with storage transitioning to be backbone of the grids of future*

Three Scenarios for Growth: Consensus, Breakthrough, Conservative

Forecasting any transition is never about predicting a single future, but rather mapping levers that drive adoption and their uncertainties across scenarios.

For BESS, the four forces can move at different speeds depending on market, technology, and regulation. And to capture these variabilities, 3 scenarios are modeled:

Conservative Case

VRE penetration rises slowly (<25% by 2030), Cost parity occurs in mid 2030s. BESS still grows but not upto expectations.

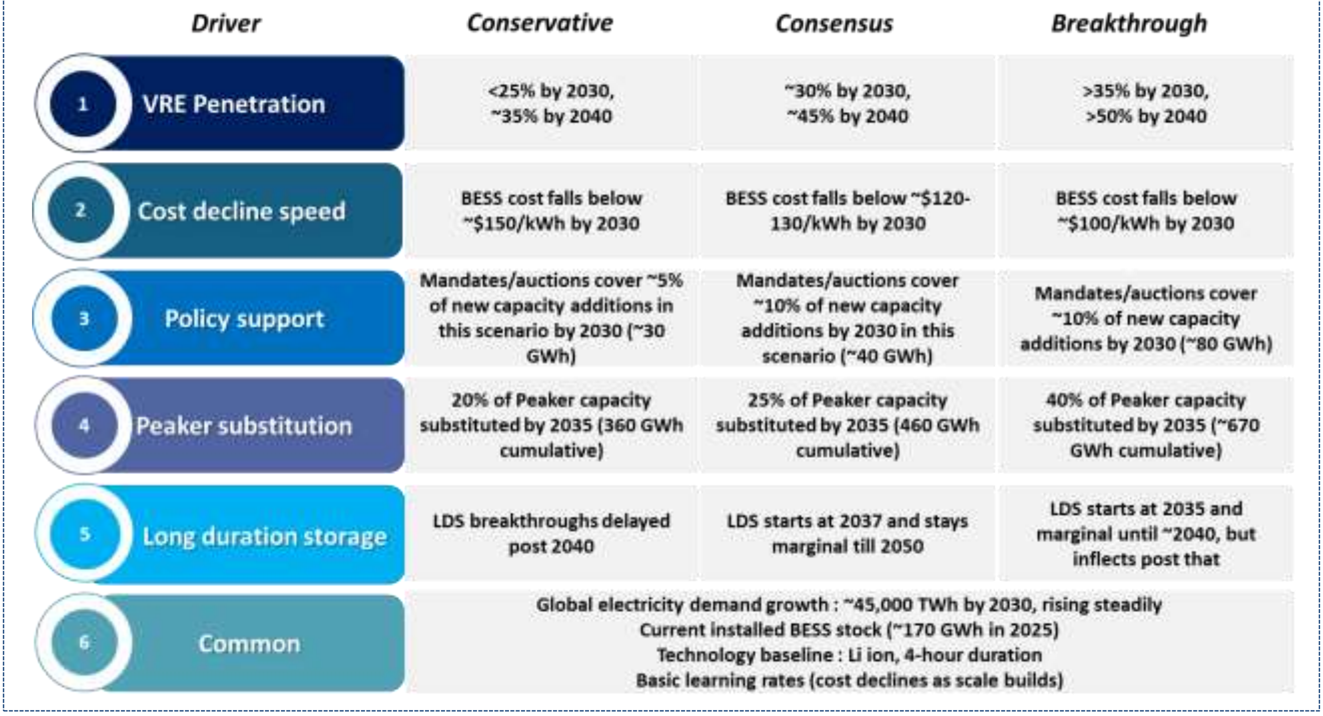
Breakthrough Case

Costs fall faster (parity achieved by 2028), and policy support attracts private capital. VRE reaches 35% by 2030

Consensus Case

Central pathway with highest probability. VRE reaches ~30% and battery LCOS falls to ~$120–130/MWh by 2030, achieving cost parity with peakers in most regions. Supported by steady policy mandates, global BESS grows in line with market forecasts

EXHIBIT 10: BESS SCENARIO WISE GROWTH DRIVERS AND ASSUMPTIONS

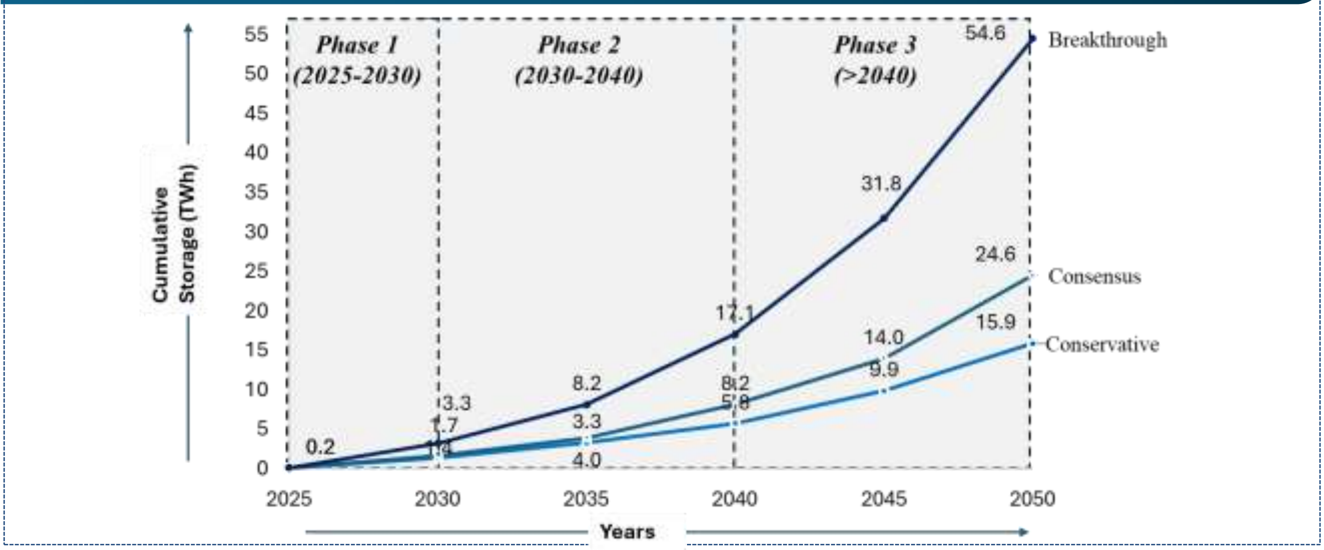


Driver	Conservative	Consensus	Breakthrough
1 VRE Penetration	<25% by 2030, ~35% by 2040	~30% by 2030, ~45% by 2040	>35% by 2030, >50% by 2040
2 Cost decline speed	BESS cost falls below ~$150/kWh by 2030	BESS cost falls below ~$120-130/kWh by 2030	BESS cost falls below ~$100/kWh by 2030
3 Policy support	Mandates/auctions cover ~5% of new capacity additions in this scenario by 2030 (~30 GWh)	Mandates/auctions cover ~10% of new capacity additions by 2030 in this scenario (~40 GWh)	Mandates/auctions cover ~10% of new capacity additions by 2030 (~80 GWh)
4 Peaker substitution	20% of Peaker capacity substituted by 2035 (360 GWh cumulative)	25% of Peaker capacity substituted by 2035 (460 GWh cumulative)	40% of Peaker capacity substituted by 2035 (~670 GWh cumulative)
5 Long duration storage	LDS breakthroughs delayed post 2040	LDS starts at 2037 and stays marginal till 2050	LDS starts at 2035 and marginal until ~2040, but inflects post that
6 Common	Global electricity demand growth : ~45,000 TWh by 2030, rising steadily Current installed BESS stock (~170 GWh in 2025) Technology baseline : Li ion, 4-hour duration Basic learning rates (cost declines as scale builds)		

Each of the key drivers modelled differently for different scenarios. However there are also some common factors which are considered to be universally same and projections are sensitive to any deviation in those factors

How the Four Levers Interplay in different Sc

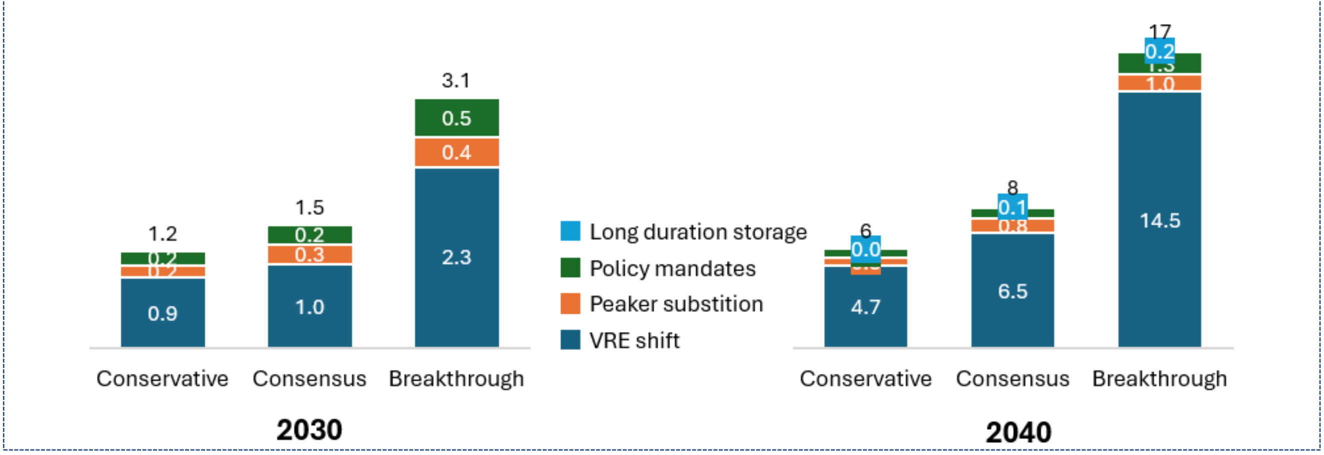
EXHIBIT 11: BESS SCENARIO WISE GROWTH



Global BESS adoption will accelerate across all cases, but the **level of growth is asymmetric** Even in **Conservative case**, installed capacity is expected to rise nearly tenfold by 2040, underlining the eventuality of storage adoption. In **Consensus case**, which is aligned with market forecasts, expansion is faster, reaching ~6 TWh at 30x by 2040. In the most optimistic **Breakthrough case**, cost parity is reached couple of years earlier due to stronger policy support, doubling adoption by 2030 and crossing an enormous 50 TWh by 2050.

Across scenarios, investors and grid operators face significant upside if adoption accelerates, though there is also a limited downside. This makes early entry and positioning critical ahead of the 2030 inflection point.

EXHIBIT 12: SHARE OF GROWTH DRIVERS – 2030 VS 2040



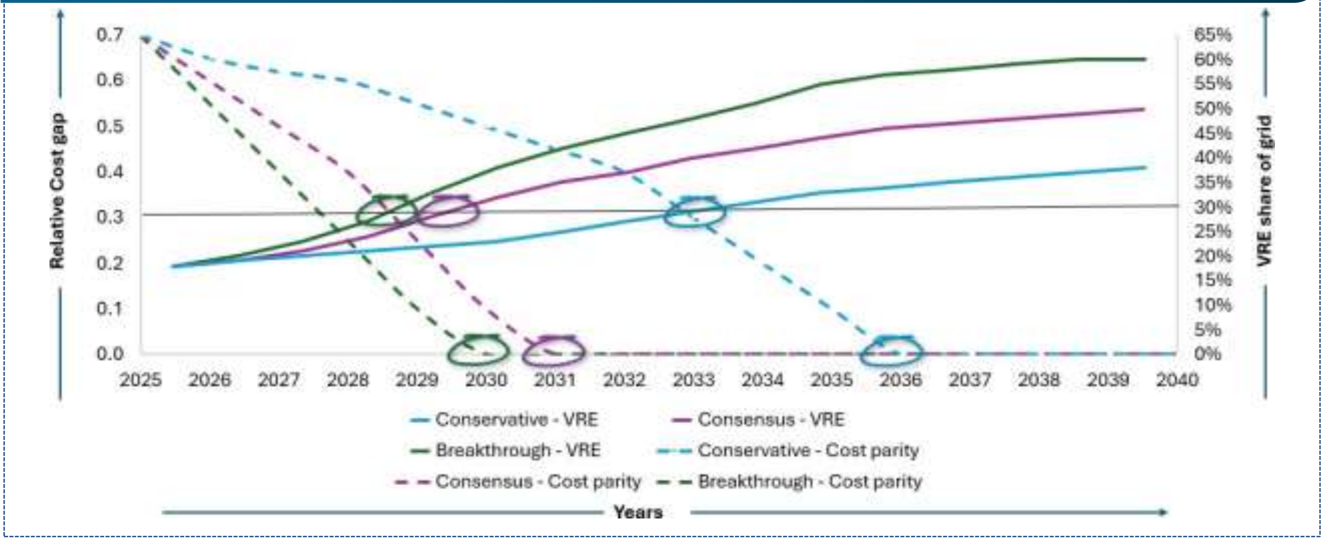
- By 2030, VRE integration already emerges as the single largest driver of storage demand, contributing ~65% of capacity. However, peaker substitution & policy mandates remain critical anchors in driving growth

- By 2040, VRE gains share, reaching ~80% of installed base. Peaker substitution plateaus and flattens, and relative share of policy mandates shrinks. Long-duration storage begins to emerge from the sidelines in high-adoption markets

Scenario divergence mainly reflects intensity of VRE scaling: in Conservative Case, VRE penetration is slower and peakers persist longer (~6 TWh total by 2040), while in Breakthrough Case, rapid addition of renewables & early cost parity propel storage to ~17 TWh

The S-Curve of BESS: Inflection Ahead

EXHIBIT 13: INFLECTION POINT IN DIFFERENT SCENARIOS



Across all scenarios, VRE share crosses the structural threshold of 30% slightly before BESS achieves cost parity with peakers.

Breakthroug

VRE ~30% by 2029, cost parity by ~2030

Consensus

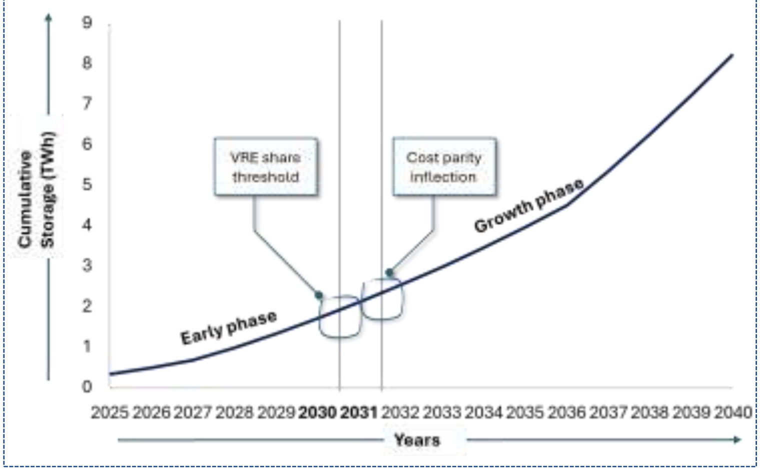
VRE ~30% by 2030, cost parity next year

Conservative

VRE ~30% by ~2033, cost parity reached in 2036

This creates a gap in some regions, where the structural limitation creates need for storage, but economics delay adoption, leading to curtailment, daily ramps, and reliability pressures on grid operators before BESS becomes cost competitive. Alternative flexibilities (peakers, interconnectors, demand response) are expected to dominate in this brief window, and policymakers would face mounting pressure to accelerate storage adoption through subsidies

EXHIBIT 14: CONSENSUS SCENARIO – INFLECTION POINTS AND S CURVE BREAKOUT



Once cost parity catches up, adoption enters growth curve. When both the inflection points are triggered, growth becomes steep, investors enter, EPCs scale, downstream profit pools increase.

The critical question is not if storage is needed. But rather who bridges the gap when structural needs appear before economics align. Stakeholders (policymakers, investors, utilities) actions in this window shape whether adoption is delayed (Conservative) or accelerated (Breakthrough)

Regional growth pathways

Exhibit 15: Region wise pathways

High VRE led markets		Cost parity led markets	
Market led breakout **(Ex: UK, US)**	**Policy led shift** **(Ex: EU)**	**Tender driven** **(Ex: India, Middle East, Africa)**	**Supply led** **(Ex: China)**
• 7 GW+ already installed in California, where peaker substitution already started • These are strong merchant markets where storage is viewed as a bankable asset class	• Curtailment rising in Germany and Spain, but market is fragmented which dilutes value capture • Ancillary services are underdeveloped • Scaling depends on reforms like Net Zero Industry Act	• In countries like India, tenders hitting record lows at $50–60/MWh • These countries have their own renewables target, which would drive BESS growth • Revenue streams beyond tariffs undeveloped	• In China, Domestically growth is led by curtailment pressures • China achieving 70% global cell/module manufacturing share in 2030 will globally help reach the scale to drive fall of LCOS

Global adoption of BESS is to be ultimately driven by the same four levers: peaker substitution, VRE integration, policy mandates, and long-duration solutions, however growth will not be uniform,

1-High VRE - Market-led (ex: US, UK)

In these geographies, VRE integration is already dominant, which leads to daily ramps and curtailment, necessitating need for BESS. California, has 7 GW+ BESS online and replaces peakers often. Australia have strong ancillary markets for BESS. Because economics is already strong, growth is market-led and provide good returns for investors, who see BESS as a bankable asset class, just like wind and solar were in last decade. Peaker substitution still contributes, but the breakout is primarily VE-driven.

2- High VRE - Policy-led shift (ex: EU)

Europe also has high VRE share but markets are fragmented, diluting value captured, leading to rising curtailment in Germany & Spain, and under developed ancillary markets. Policy mandates like EU-level Net Zero Industry Act will drive BESS growth beyond energy arbitrage. But post maturity, VRE integration will grow rapidly

3-Tender-driven growth (ex: India, Middle East & Africa)

These markets follow same policy playbook they do for renewables like solar and wind. India's recent tenders at global lows ($50–60/MWh) are driving capacity growth. However, revenue streams beyond the tariffs are undefined, because of which ancillary services contributions are limited, but the policy lever substitutes for weak merchant markets. Peaker substitution lever also remains relevant as India plans to ramp down fossil plants. Middle East also follows similar government led tender procurement strategy.

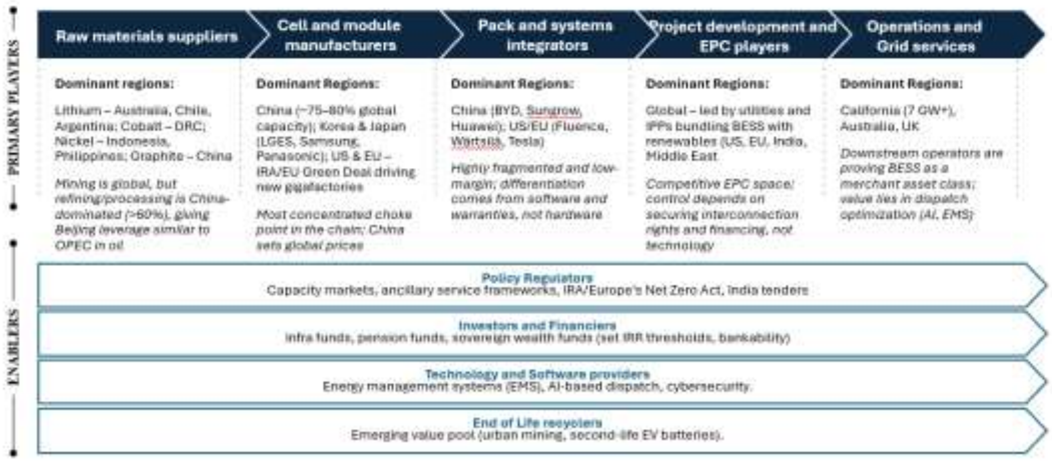
4- Supply-led scale (e.g., China)

In China, domestic growth is primarily driven by policies and curtailment. But globally, China would contribute 70% of battery manufacturing capacity by 2030 which would drive LCOS declines, enabling peaker substitution & VRE economics elsewhere.

- In conservative case, growth remains limited to tender and policy led markets.
- In Consensus case, both market-led breakouts and policy-led drive growth, ably supported by supply-side scale of China.
- In Breakthrough Case, rapid LCOS decline powers all levers across all regions

Who Controls the Value Chain: Shifting Profit Pools

EXHIBIT 16: BESS VALUE CHAIN: DOMINANT PLAYERS IN EACH STAGE



PRIMARY PLAYERS

Raw materials suppliers	Cell and module manufacturers	Pack and systems integrators	Project development and EPC players	Operations and Grid services
Dominant regions: Lithium – Australia, Chile, Argentina; Cobalt – DRC; Nickel – Indonesia, Philippines; Graphite – China *Mining is global, but refining/processing is China-dominated (>60%), giving Beijing leverage similar to OPEC in oil*	**Dominant Regions:** China (~75–80% global capacity); Korea & Japan (LGES, Samsung, Panasonic); US & EU – IRA/EU Green Deal driving new gigafactories *Most concentrated choke point in the chain; China sets global prices*	**Dominant Regions:** China (BYD, Sungrow, Huawei); US/EU (Fluence, Wartsila, Tesla) *Highly fragmented and low-margin; differentiation comes from software and warranties, not hardware*	**Dominant Regions:** Global – led by utilities and IPPs bundling BESS with renewables (US, EU, India, Middle East *Competitive EPC space; control depends on securing interconnection rights and financing, not technology*	**Dominant Regions:** California (7 GW+), Australia, UK *Downstream operators are proving BESS as a merchant asset class; value lies in dispatch optimization (AI, EMS)*

ENABLERS

Policy Regulators
Capacity markets, ancillary service frameworks, IRA/Europe's Net Zero Act, India tenders

Investors and Financiers
Infra funds, pension funds, sovereign wealth funds (set IRR thresholds, bankability)

Technology and Software providers
Energy management systems (EMS), AI-based dispatch, cybersecurity.

End of Life recyclers
Emerging value pool (urban mining, second-life EV batteries).

Today, upstream (raw materials, cells) players dominate the value chain, but profit pools are expected to migrate downstream (integration, operations, services) with scale

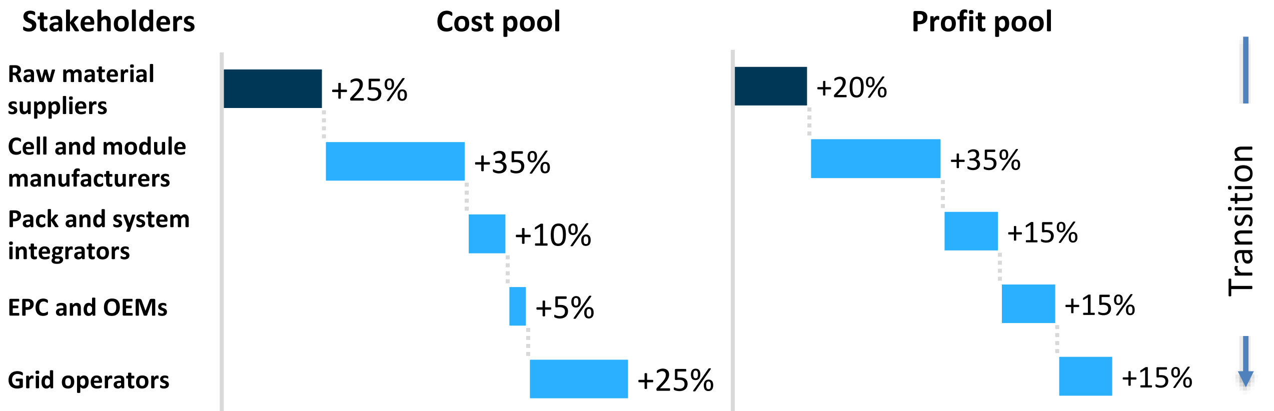
Despite global mining sources being distributed, refining is dominated by China, leading to cells being the most concentrated choke point in the value chain with supply chain risks

Enablers like policymakers, investors impact whether reinforcing or defensive loops take hold. Without an aligned policy and sufficient returns, cost parity alone cannot unlock scale

End of life recycling is nascent but would start emerging as key focus area and potentially an additional profit pool, as large volumes of batteries begin reaching retirement in 2030s

Operators in advanced markets starting to prove storage as a bankable asset, stakeholders mastering dispatch & revenue optimization from ancillary services will own next profit pool.

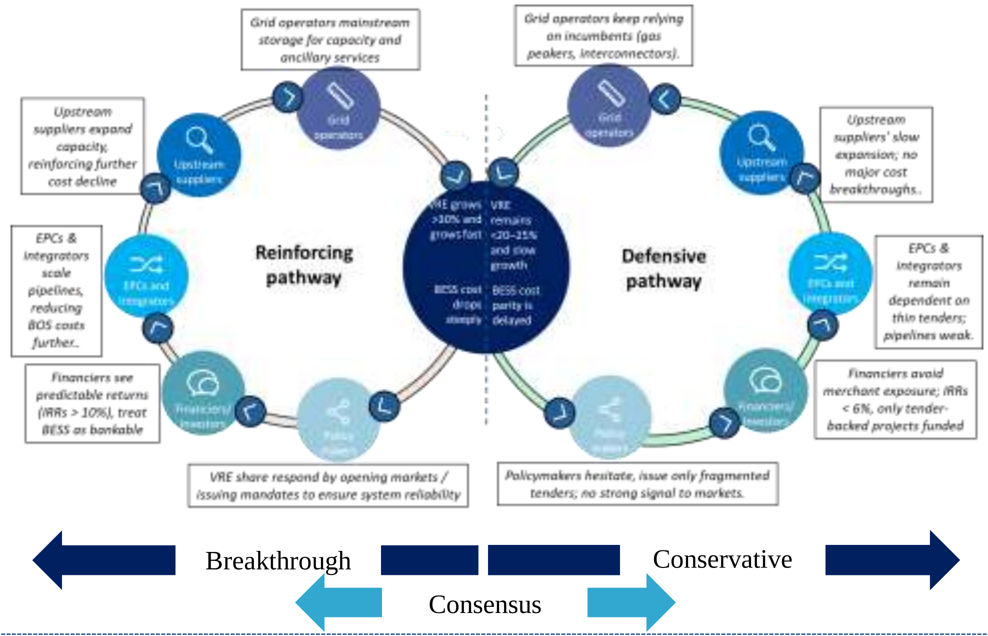
EXHIBIT 17: BESS COST AND PROFIT POOL OF DIFFERENT STAKEHOLDERS



BESS industry exhibits barbell profit structure, with highest share of money sitting upstream (raw materials, cells) and also downstream (operators). In mid stream, Integrators & EPCs are stuck with shrinking margins; and for them differentiation requires moving from commoditized construction towards integrated solution driven offerings. As cell costs further fall, the relative profit pool start shifting downstream and value will get concentrated in operators, traders, and platform players that optimize BESS dispatch

Stakeholder dynamics: Reinforcing vs Defensive pathways

EXHIBIT 18: REINFORCING AND DEFENSIVE PATHWAYS



While the cost pool and profit pool in the BESS value chain define where value is created, it is stakeholder interaction that ultimately determines when and how fast this value is unlocked. Energy system is not a passive market. Each actor, shapes the pace and direction of adoption. Two contrasting pathways illustrate the dynamics:

Reinforcing Pathway (Breakthrough Case):

When VRE penetration rises above ~30% and BESS costs fall steeply. Policymakers, facing curtailment and ramping pressures, respond by opening markets and issuing mandates to ensure system reliability. Investors gain confidence, treating BESS as a bankable asset class with IRRs > 10%. EPCs scale, reducing balance-of-system costs further. Grid operators make storage mainstream for capacity adequacy & ancillary services. Upstream suppliers expand battery capacity, reinforcing further cost decline. This alignment pulls S-curve inflection point forward, with downstream players capturing increasing share of profit pool

Defensive Pathway (Conservative Case):

When VRE penetration stalls below ~25% and cost parity is delayed, curtailment remains limited and flexibility need is catered by alternatives. BESS costs remain above parity, preventing merchant projects from taking off. Financiers avoid merchant exposure, funding only tender-backed projects (IRRs<6%). EPCs remain dependent on thin pipelines, while grid operators continue to rely on incumbents. Upstream suppliers, seeing weak demand signals, slow expansion, which in turn delays cost breakthroughs. In this pathway, adoption is shallow, inflection is pushed beyond 2035, and profit pools remain concentrated upstream. **Consensus case** follows moderate case scenarios from both these pathways

Takeaways:

- Only when all move together does the S-curve steepen.
- Upstream benefits in defensive loops; downstream gains in reinforcing loops.
- Cost curves set boundary, but stakeholder choices set pace.

Risks and gamechangers: What could alter the trajectory

WHAT COULD DRASTICALLY ALTER TRAJECTORY

Every disruptive technology can face not only headwinds but also shocks that can throw it off the planned trajectory altogether. For BESS, there are a few scenarios we need to be wary about:

Chemistry disruption: Li ion batteries are still dominant. But a breakthrough in long-duration chemistries like iron-air, sodium-ion could accelerate substitution of peakers, pulling the S-curve much forward. On the contrary, if no use cases beyond Li ion come to fruition, adoption would be capped to four-hour use cases, & long duration storage substitution scenario would cease

Safety setbacks: High-profile or multiple fire incidents linking to BESS could trigger a political and systemic backlash, and may lead to blanket insurance exclusions and moratoriums. In such a case, growth timelines could be thrown off track, as seen in South Korea over past few years

Faster degradation: Most of the installed BESS is yet to reach end of life, but if real world capacity degrades faster than modeled assumptions, or if end of life management becomes tricky, investors may slash IRR expectations. Even a 5% higher annual degradation can erode ~$10–15/MWh in LCOS and reduce few years of operation, delaying cost parity

Policy reversal: Subsidies and storage targets are highly policy sensitive. Any change in priorities of major energy consuming nations, or rollback of incentives can bring adoption down even if economics are favorable

Supply chain risks: Critical minerals and upstream domination by China pose a geopolitical risk, and any major disruptions can could rise LCOS 20–30% overnight

STRESS TESTS ON THE MODEL

01

Electricity demand growth:

A ±5% swing in global electricity load by 2030 can shift cumulative BESS needs by ~200–300 GWh.

02

VRE penetration:

A ±5% deviation in VRE share by 2030 can affect inflection point by 2 years.

03

Capex trajectory:

A ±20% swing in capex influences LCOS by roughly ±20–25 $/MWh, shifting cost parity year.

04

ROUND-TRIP EFFICIENCY:

If RTE improves from 80% to 90%, it improves economics by 10 $/MWh,

05

POLICY SCALING FACTOR:

If mandates only attribute to 5% instead of 15% of new capacity by 2030, adoption could be ~300 GWh lower.

06

PEAKER SUBSTITUTION:

A ±10% assumption shift in peaker replacement due to change in peaker costs, equates to ~200 GWh change by 2030

Conclusion: Ride the wave – BESS Inflection is near

The lesson from past energy transitions are clear. Whoever anticipated inflection early and acted on it became eventual winners. For BESS, both cost and structural inflection points are expected to be crossed within the next 5-10 years, and growth post that will be exponential, not linear.

As consultants, conversation with clients is no longer going to be about only cost competitiveness. Market players would need inputs on parts of value chain to focus, ways and means to scale and assess their risks and payoff.

Scenario-based planning with stress tests depending on the stakeholder role and ambition is the need of the hour to help clients manage their risks.

And further, should try to move away from just advisory to act as architects in this transition by getting involved in shaping tenders, market rules and profit pools to remain indispensable.

The implications for each stakeholders are:

Policymakers & regulators:

- Well defined capacity markets, fire safety standards and streamlining permitting can help accelerate adoption
- Well designed tenders can help attract private capital. Focus should also be on ensuring monetization of ancillary services of BESS
- De-risk supply chain by diversifying sourcing, and ensuring the country is a dominant player in at least one part of the value chain

Investors & financiers:

- Bet on early entrants, especially downstream and account for exponential adoption, and not linear curves in IRR models
- Focus on optimizing revenue stacking across capacity, arbitrage and ancillary services

Industry players (Developers, EPCs, grid operators):

- Focus on optimizing towards downstream including dispatch optimization, warranties, software, end of life recycling as profit pool will eventually transition towards it
- Even if margins are thin today, entering early helps build scale and bankability with investors once growth picks up

For energy systems, BESS is no longer a promise. Future is going to be a flexible, renewable-dominated grid. Stakeholders who anticipate the inflection and start building capacity, shaping policy, invest in this are bound to reap disproportionate rewards. Those who wait on the sidelines, risk missing another bus, just as many did in the previous solar and EV transitions

Our Values

The Avalon EDGE

E

ENTREPRENEURSHIP

Enterprising ownership to transform ideas into pragmatic and profitable solutions

D

DEDICATION TO EXCELLENCE

Commitment to premier quality and highest standards in everything we do

G

GREAT VALUE CREATION

Focus on delivering maximum client impact through innovation and collaboration

E

ETHICAL APPROACH

Respect, fairness, and transparency in all our interactions

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