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Investor Guidance for Asia Battery Energy Storage Systems (BESS) 2026

Christoph Nedopil, Fabby Tumiwa, Mustafa Amjad, Abdul Rehman

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About this publication

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Abbreviations and acronyms

Abbreviation	Full term
ADB	Asian Development Bank
BESS	Battery Energy Storage System(s)
BTM	Behind-the-Meter
Capex	Capital expenditure
C&I	Commercial and industrial
CfD	Contract for Difference
DSCR	Debt Service Coverage Ratio
ESS	Energy Storage System(s)
FCAS	Frequency Control Ancillary Services
FTM	Front-of-the-Meter
FX	Foreign exchange
GWh	Gigawatt-hour
GW	Gigawatt
IRR	Internal Rate of Return
LCOE	Levelized Cost of Energy
MDB	Multilateral Development Bank
MWh	Megawatt-hour
MW	Megawatt
NEM	National Electricity Market
O&M	Operations and maintenance
PPA	Power Purchase Agreement
SPV	Special Purpose Vehicle
ToU	Time-of-Use

USD	United States dollar
VPP	Virtual Power Plant
WACC	Weighted Average Cost of Capital

Statement on AI Tool Usage

Generative AI platforms were used selectively during the research and review phases of the Battery Energy Storage Systems (BESS) guidance project, with all final editing and analytical decisions performed independently by the author.

- Gemini (Research & Initial Drafting): Utilized as the primary tool for literature synthesis, mapping regulatory frameworks, structuring technical concepts, and generating initial text drafts.
- Perplexity (Final Review & Verification): Utilized to cross-reference technical data, verify citations, and check for recent policy updates prior to finalizing.
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Currency and Financial Data: All financial figures, investment estimates, capital expenditures, and tariff rates presented in this report are denominated in United States Dollars (USD) unless explicitly stated otherwise. Where conversions from local currencies have been performed, they are based on prevailing official exchange rates at the time of data collection and are intended for comparative analytical purposes.

Executive Summary – investing in battery storage in Asia

Battery energy storage systems (BESS) are becoming a core part of Asia's power-sector transition. Growing solar and wind capacity is increasing demand for flexible capacity, frequency control and reliable supply, while battery costs continue to fall. The report estimates around 100 GW of BESS deployment across Asia-Pacific by 2030, in addition to around 160 GW in China.

For investors, the opportunity is highly market-specific. Project returns depend on the services a battery can provide, the rules and tariffs that pay for those services, the ability to combine revenue streams, grid-connection costs, counterparty quality and the availability of suitable finance. A low-cost battery does not compensate for weak tariff design, unavailable market access or an unbankable revenue profile.

Report scope and audience

The *Investor Guidance for Asia Battery Energy Storage Systems (BESS) 2026* is based on a regional survey, expert interviews and desk research undertaken from February to July 2026. It is written for infrastructure and institutional investors, banks, developers, utilities, strategic investors, corporate energy users and policymakers. It assesses business models, market rules, technology and sizing, siting and finance across Australia, Bangladesh, China, India, Indonesia, Lao PDR, Malaysia, Pakistan, the Philippines, South Korea, Taiwan, Thailand and Viet Nam, and includes project cases in Pakistan and Indonesia.

What investors need to test

A BESS project needs a defined system or customer value proposition and a credible path to monetize it. The main value pools are:

- **Energy arbitrage:** charge at low prices and discharge at high prices.
- **Ancillary services:** frequency response, voltage control, reserves and black-start capability.
- **Capacity and availability payments:** contracted revenue for reliable capacity.
- **Renewable firming:** store curtailed or clipped solar and wind output and deliver a more predictable product.
- **Cost avoidance/investment deferral:** defer grid upgrades or relieve congestion at substations and load centres. For industrial and private consumers, reduce demand charges, shift load across time-of-use tariffs, increase solar self-consumption and avoid diesel use or outage costs.

Before committing capital, investors should establish the position in the local policy environment:

- Is **storage legally recognized** and licensed as a distinct asset class.
- Can assets **operate fully** to charge, discharge and participate in energy, ancillary-service, reserve or capacity markets.
- Is **revenue stacking** permitted and operationally feasible through metering, dispatch and settlement rules.
- Do **network fees** apply on charging, discharging or both, and whether these charges undermine arbitrage margins.
- What is the **creditworthiness** of the utility, offtaker, optimizer and EPC/O&M counterparties.

Revenue stacking is a material dividing line. Batteries that can combine energy trading, ancillary services, capacity value and local network support have a more diversified revenue base. The report identifies major constraints on stacking in the Philippines, Taiwan, Malaysia, South Korea and Thailand. In these markets, projects may need a tolling arrangement, availability payment, firm offtake agreement, subsidy or concessional capital.

Front-of-the-meter: where to invest in Asia

Front-of-the-meter (FTM) storage includes standalone utility-scale BESS, renewable-plus-storage projects and batteries providing transmission or distribution support. Its strongest economics are found where price volatility, ancillary-service remuneration, storage market access and grid connection align.

Economy	Investor reading	Main FTM opportunities	Main constraints or risks
Australia	The most developed multi-revenue market in the survey	Reported summer spread of about USD 200/MWh; arbitrage, ancillary and reserve services, capacity mechanisms, hybrid projects, virtual power plants and revenue stacking	Merchant revenues and ancillary-service prices can decline as capacity grows; connection and congestion risks still require site-level analysis
Bangladesh and Lao PDR	Early-stage markets for public or contracted deployment	Hybrid systems, utility-led procurement and grid-support applications	Long-term-contract structures and weak market pricing limit merchant arbitrage
China	Large-scale opportunity with	Hybrid and standalone storage, capacity and ancillary services,	Market rules and price formation vary by province; investors

	substantial policy and market depth	revenue stacking; reported daily spread about USD 110/MWh	require local market and offtake analysis
India	Strong growth market, especially for renewable firming and emerging trading opportunities	Reported daily spread about USD 100/MWh; ancillary and reserve services; virtual power plants; growing real-time trading	Hybrid model and capacity-payment arrangements are not uniformly supported; state-level rules and off-taker risk matter
Indonesia	Selective opportunity rather than broad standalone-BESS market	Hybrid systems, grid support and diesel-displacement applications, particularly remote systems and islands	Long-term contract structure limits arbitrage; standalone projects face constrained economics under current conditions
Malaysia, Taiwan, and Thailand	Focus on defined utility, industrial or hybrid use cases rather than broad merchant strategies	Selected hybrid, ancillary or subsidized applications	Limited support for storage trading, capacity mechanisms, virtual power plants and/or revenue stacking constrains standalone FTM cases
Pakistan	Emerging opportunity where hybridization can be more bankable than standalone merchant storage	Reported daily spread about USD 70/MWh in emerging wholesale market; hybrid projects and revenue stacking; developing bilateral market	Storage trading, capacity and ancillary frameworks remain limited; FX, off-taker and regulatory risks require risk mitigation
Philippines	High potential but execution-intensive	Reported daily spread about USD 170/MWh; arbitrage, ancillary services, reserves, renewable firming and island-grid applications	Revenue stacking constraints identified in the regional assessment; double network fees (buying and selling), island logistics and implementation risk can weaken returns
South Korea	Selective, contract-led market	Hybrid storage and some policy-supported deployment	Reported daily spread around USD 10/MWh; limited support for several BESS business

			models and revenue stacking
Viet Nam	Policy momentum and renewable-integration need, but limited merchant case	Hybrid storage, renewable firming, ancillary and reserve functions; mandated storage requirements for some renewable projects	Minimal reported arbitrage spread; single-buyer characteristics and incomplete stacking rules favour contracted rather than merchant models

For investors, this analysis has the following implications

1. **Easy picking in multi-revenue markets:** Australia, China and selected parts of India offer the broadest combination of price spreads, permitted business models and potential for stacking.
2. **Use contracted structures in regulated markets:** Viet Nam, Indonesia, Bangladesh, Lao PDR, Taiwan, Malaysia and Thailand are more suitable for utility procurement, renewable firming, tolling or public-supported projects than pure merchant arbitrage.
3. **Treat the Philippines and Pakistan as high-upside, higher-structuring markets:** value can be substantial, but returns depend on regulatory implementation, network charges, counterparty protections and finance.
4. **Co-location can reduce development cost:** sharing land, substations, transformers and connection rights with renewable generation can reduce CAPEX and capture curtailed output.
5. **Demand-side locations can offer higher value:** batteries near congested cities, industrial zones and substations may access peak prices, local network-support contracts and grid-deferral value, although land, permitting and connection costs are often higher.

Behind-the-meter: customer-led returns

Behind-the-meter (BTM) storage serves industrial, commercial and residential customers, often combined with rooftop solar, backup generation or both. It can be more viable than FTM storage where wholesale markets are limited because returns arise from avoided customer costs.

Economy or market group	Investor reading	BTM value drivers
Australia	Strong residential, commercial and industrial market with enabling tariffs and aggregation potential	Time-of-use optimization, demand-charge reduction, solar self-consumption, virtual power plants and reliability
China	Large commercial and industrial opportunity where tariffs and demand profiles support storage	High electricity-cost exposure, time-of-use optimization, peak shaving and onsite renewable integration

India	Attractive C&I opportunity in locations with demand charges and high peak-cost exposure	Peak shaving, demand-charge avoidance, onsite solar and reliability for energy-intensive users
Philippines	High retail prices and reliability needs strengthen C&I and island-system cases	Load shifting, backup power, diesel displacement, solar integration and avoided outage costs
Pakistan	High tariffs support customer-side storage, especially where reliability and self-generation matter	Time-of-use savings, solar-plus-storage, generator displacement and resilience
Taiwan	Industrial peak and voltage penalties can support targeted BTM deployment	Peak shaving, power-quality management and demand-charge reduction
Indonesia	Best opportunities are remote, island and diesel-hybrid settings	Fuel savings, generator optimization, microgrids, renewable integration and avoided fuel logistics
Viet Nam, Malaysia, Thailand and South Korea	Targeted C&I opportunities, conditional on tariff design, customer load profile and local installation rules	Time-of-use shifting, rooftop-solar self-consumption, peak control and resilience

These results have the following investment implications:

1. **Focus on customers with high demand charges**, large time-of-use spreads, expensive diesel generation or material outage costs.
2. **Underwrite savings from actual interval load data and tariff bills,** rather than average national electricity prices.
3. **Assess four customer value streams**: demand-charge savings, energy shifting, solar self-consumption, and reliability or avoided-outage value.
4. **Use smart contracts** like energy-as-a-service, leasing, shared-savings contracts, solar-plus-storage PPAs or battery-as-a-service to reduce customer upfront CAPEX.

Financing and risk allocation

The capital structure should match the reliability of project revenues.

- **Traditional project finance:** appropriate for assets supported by long-term utility tolling, capacity contracts, firm PPAs or energy-service agreements with creditworthy counterparties. Such projects can support roughly 60–80% debt, subject to strong EPC, O&M, warranty, insurance, reserve-account and debt-service protections.
- **Merchant debt:** suited to mature and liquid markets with high price volatility and capable optimizers. Expect shorter tenors, lower leverage—typically

around 40–50%—high debt-service coverage requirements, cash sweeps and refinancing risk.

- **Corporate finance:** useful for utilities, developers, industrial groups and large customers in earlier-stage markets. Corporate balance sheets can absorb merchant volatility and fund strategic projects that are not yet suitable for non-recourse debt.
- **Green and sustainability-linked bonds:** most suitable for large, creditworthy sponsors or aggregated BESS portfolios rather than small standalone projects.
- **Blended and public finance:** relevant where FX exposure, utility credit risk, uncertain regulation or weak market mechanisms prevent commercial financial close. Concessional debt, first-loss capital, guarantees, technical-assistance grants, local-currency finance and political-risk cover can make otherwise marginal projects financeable.

Type of energy storage system (ESS) project	Type of finance	Country examples
• Publicly mandated or demonstration FTM/BTM project	Public finance	Laos, Bangladesh, Indonesia
• Higher risk environments with wholesale electricity price uncertainty for FTM	Blended finance/ concessional finance	Bangladesh, Pakistan, Viet Nam
• Co-located/hybrid FTM, commercial & industrial BTM	Corporate finance (possibly with green/ sustainable bonds)	Australia, China, India, Pakistan, South Korea, Taiwan, Viet Nam
• Multi-revenue FTM arbitrage, • energy trading (FTM and BTM with virtual power plants)	Merchant debt facilities	Australia, China, India, Philippines, Taiwan, Viet Nam
• Co-located FTM PPAs, • long-term FTM utility contracts, • direct purchase agreements (DPPs) for FTM	Project finance (possibly with green/ sustainable bonds)	Australia, China, India

FTM: Front-of-meter
BTM: Behind-the-meter
PPA: power purchase agreement

Investors should contract or hedge the risks that cannot be borne efficiently in the equity case: offtake and utility payment risk, delay of engineering/ procurement/ construction (EPC), battery performance and degradation, optimization performance, FX exposure, curtailment, network charges and regulatory change.

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Introduction: Asia's energy storage opportunity and challenge

As Asia's electricity markets switch from fossil fuels to intermittent renewable resources, energy storage systems (ESS), such battery energy storage systems (BESS) are playing an increasingly important role in maintaining the stability and flexibility of the power grid.

Global energy storage additions reached an estimated 273 GWh in 2025, with forecasts indicating 359 GWh in 2026, representing 31.5% year-over-year growth. China alone projects 182 GWh additions in 2026, accounting for approximately 50.7**%** of global installations[1] and plans another 180 GW for 2027[2] – equaling investments of about USD35.2 billion. Australia's home battery scheme aims to install 40 GWh of batteries across 2 million homes with a value of about USD 20-25 billion by 2030.

Much of this growth was driven by rapidly declining cost of BESS with price drops of 9% between 2024 and 2025 alone (see Figure 1). This price drop has made renewable energy stack consisting e.g., of intermittent solar electricity generation with battery storage to provide 95% firm energy cheaper than gas and nuclear on a levelized cost of energy (LCOE) basis (see Figure 2). Indeed, the price drop for the green stack has been between 30% and 35% between 2020 and 2025, and again for 2025 to 2030, while the expected price drop 2030 to 2035 is 40%[3].

Figure 1: Lithium-ion battery price drop 2010-2025[4]

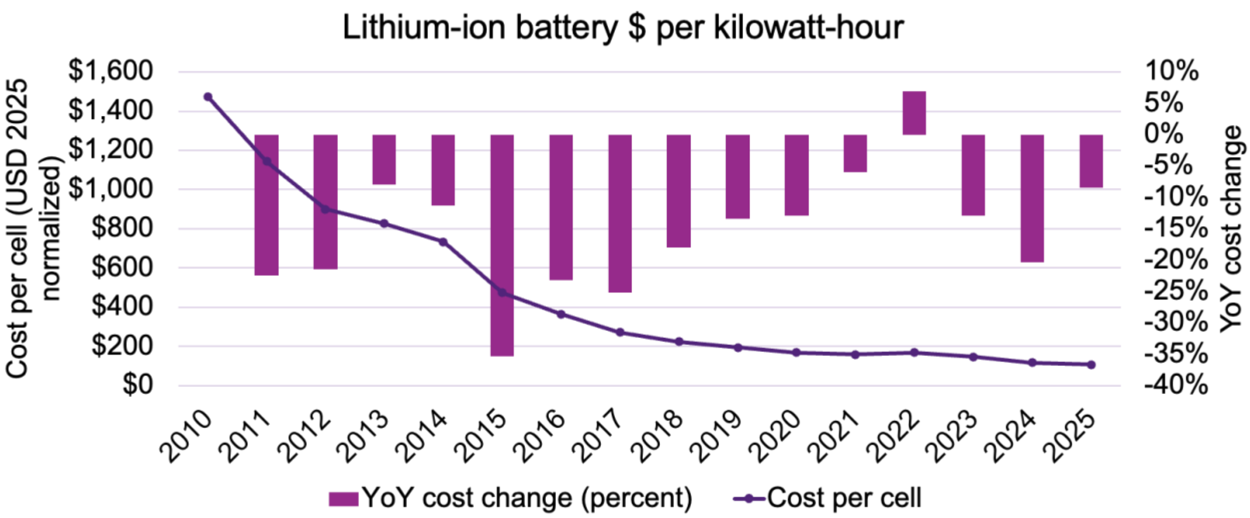
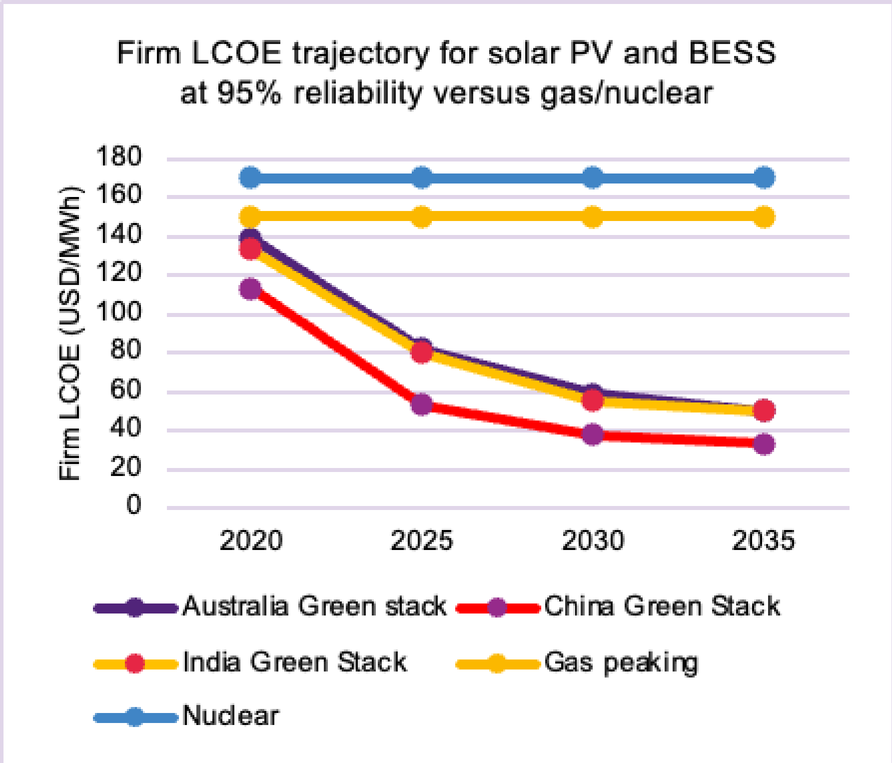


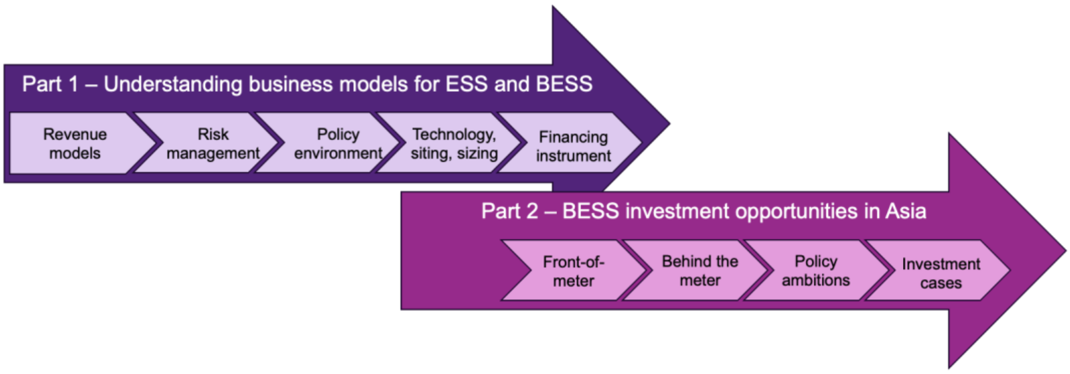
Figure 2: Levelized cost trajectory for solar PV and BESS 2020-2035[3,5]



However, while China and India are leading Asia's green energy investments, ASEAN economies are diverging with moderate ESS growth trajectories putting the value of BESS investment to a cumulative USD 5.43 billion by 2031[6]. Despite the relatively moderate growth projection in ASEAN economies, significant opportunities for ESS (and BESS, in particular) investments exist across different Asian markets[7,8], including in various ASEAN economies.

This guidance was thus developed for investors to understand ESS and BESS investment opportunities across major Asian economies. The guidance first explains viable business models of ESS such as arbitrage, ancillary services and revenue stacking as well as policy determinants allowing for different business models. It then describes ESS technologies and their evolution, as well as technological considerations relevant for investing in ESS and in particular siting and sizing considerations. Finally, the guide provides different financing instruments that can be applied in different investment scenarios.

Figure 3: Structure of Asia BESS Investor Guidance



Part 1: Understanding business models for ESS and BESS in Asia

Revenue models for ESS

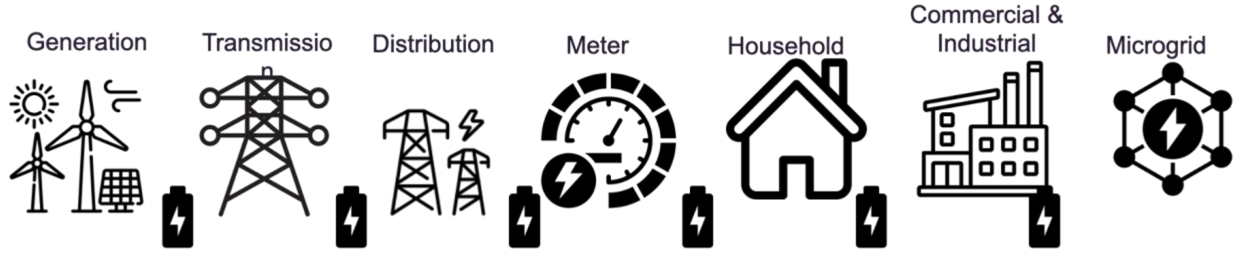
Energy storage systems (ESS) are typically used to temporarily store excess electric power and then release this power as electricity once power demand exceeds power supply in the grid (**front-of-the-meter/FTM**) or at the relevant consumer (**behind-the—meter/BTM**). It is thus an asset that can balance the load in an energy neutral way by either "consuming" electricity in times of short or long-term overcapacity or by "producing" electricity in times of higher load. This makes ESS an essential feature to balance intermittent power supply of some renewable energy sources, and in particular wind and solar. At the same time, this makes ESS distinct from either generating or grid assets – as it has multiple functions.

Multiple ways exist for ESS to generate revenues and investment returns – and in particular arbitrage, ancillary services and cost reduction as well as investment deferral which are described in the following section.

These revenues and investment returns can be generated "front-of-the-meter" and "behind the meter" as shown in Figure 4:

- Front-of-the-meter (FTM)
  - co-located with generation for hybrid or co-located business model
  - balancing services for transmission and distribution
  - Pure trading providing storage for electricity
  - Reducing electricity cost from grid for households or commercial operations by storing own electricity (e.g., in combination with rooftop solar)
- Behind-the-meter (BTM)
  - Use in microgrids independent of major grids
  - industrial and residential consumers to load shift or utilize differentiated tariffs

Figure 4: ESS across the power system



	Front-of-the-Meter (FTM)			Behind-the-Meter (BTM)		
	Generation	**Transmission/ distribution**	**Trading**	**Household**	**Commercial**	**Microgrids/ virtual power grids**
Role of ESS	• Co-locate with electricity generation (e.g., solar, wind) to store local excess electricity and discharge to grid	• Frequency containment • Grid balancing (e.g., capacity balancing)	• Buy from generation and sell to transmission/ distribution or final consumers	• Home battery storage	• Emergency services, energy storage, frequency containment (e.g., in high precision factories)	• Combining multiple energy sources including home batteries
Business model	• Combined generation plus storage (hybrid model or co-located model*) • Capacity payments • Abritrage • Firming • Curtailment mitigation	• Ancillary services • Cost avoidance (e.g., reduction of grid investment)	• Arbitrage • Capacity payments	• Cost avoidance (for buying electricity from grid) • Backup power	• Cost avoidance (for buying electricity from grid) • Backup power • Higher production efficiency	• Arbitrage - sell electricity to market at higher price than buying price • Cost avoidance for grid investment (for microgrids)

*The primary difference between these designations is that hybrids are modeled as a single resource, whereas the market software treats the different components of co-located facilities as separate resources, for example in the California Energy Market

Arbitrage

For ESS to generate revenue, the most common model is **arbitrage**, where ESS “buy low and sell high”, or in other words utilize the price differences of electricity during the day to charge at low electricity price times and discharge at times of higher electricity prices while compensating for efficiency losses in storage and variable operation costs to make a profit. A typical arbitrage application for batteries is thus to consume and store excess energy of intermittent sources such as solar or wind during peak production hours and release them during peak load times (e.g., in the evenings), which is also referred to as “**load-shift**”. This can take several forms as shown in Table 1.

This simple application has two immediate positive effects on the grid: it reduces curtailment of intermittent sources where the grid would otherwise not be able to absorb the electricity and reduces the peak capacity required from non-intermittent sources, which is also referred to as “**peak shaving**”.

Table 1: Arbitrage Business Models

Dayahead trading (DA)	The ESS participates in the day-ahead auction (i.e., 24 hours of the next day) agreeing to buy (charge) during a projected low-

	price hour and sell (discharge) during high-price hours, locking in a financially binding delivery and pricing schedule for the next day for both buying and selling.
Realtime trading (RT)	The ESS exploits immediate supply-and-demand shocks in the spot market, which is priced closer to delivery. It captures sudden, intense price spikes caused by unexpected power plant failures or rapid weather shifts.
Intraday trading (Renewables Forecast Variations)	The ESS capitalizes on short-term market imbalances caused by errors in wind and solar forecasts as delivery time approaches. It makes a profit by quickly stepping in to supply power when renewable output drops below expectations, or by buying excess power when renewables overproduce.

A prerequisite for arbitrage is the existence of a wholesale electricity market that allows for electricity price movements.

Ancillary services

ESS can generate revenues by providing **ancillary services** and benefits to the grid based on their fast response times. In particular BESS are ideal for providing services used to balance very short-term differences in supply and demand, such as frequency regulation and flexible ramping product. Similarly, ESS can provide ancillary services by providing capacity reserves, for example for emergencies or for compensating for more extreme weathers. Some of the ancillary service business models are described in Table 2.

Table 2: Ancillary services business models

Balancing Mechanism (BM)	The ESS submits continuous offers to the grid operator to increase or decrease generation in real time to keep the grid stable. Because these interventions handle immediate, localized emergencies, the prices paid are often much higher than standard wholesale rates.
Spinning reserves	The BESS keeps a specific amount of capacity available to discharge within seconds or minutes to replace a major power plant that has suddenly gone offline. It receives a steady standby payment for being synchronized to the grid and prepared to respond instantly.
Non-spinning reserves	The BESS reserves capacity to respond to longer-term grid disruptions, usually requiring deployment within 10 to 30 minutes. Because it does not need to react instantly, this service typically commands a lower premium than spinning reserves but accommodates longer-duration storage systems.

Regulation up	The BESS stands ready to discharge power instantly to the grid when frequency drops due to an unexpected shortage. It is paid primarily for holding this capacity in reserve, plus a payment for the actual energy delivered when called upon.
Regulation down	The BESS stands ready to charge quickly and absorb excess electricity from the grid when frequency rises too high. This allows the battery to get paid for charging its system while helping the operator prevent grid over-generation.

A prerequisite for revenues through ancillary services are policies with service definitions and prices to compensate for the provision of ancillary services.

Capacity payments

Capacity payments have often been used for generating assets, such as fossil-powered power plants to “firm” the grid and ensure reliability of the grid in peak demand times.

ESS can similarly provide fixed capacity and reserve capacity and can receive fixed payments for ensuring system reliability – both in the regulated grid and in private grids (e.g., direct power purchase agreements between IPP and industrial/commercial offtaker). Capacity payments are ideally structured to provide a long-term investment incentive for ESS by providing predictable revenues.

Capacity payment schemes can also support investors through providing different revenue streams, for example through a contract for differences (CdF) structure. Australia’s Capacity Investment Scheme (CIS), for example, provided a revenue floor for eligible zero-emission projects (including standalone BESS, hybrid storage). In this scheme, the government guaranteed a revenue floor independent of revenues from arbitrage or ancillary services, as well as a revenue ceiling where operators had to pay back profits above an agreed ceiling.[i]

Cost avoidance and investment deferral

In addition to direct revenue generation, ESS can also generate financial returns by decreasing cost, for example in grid expansion. An example is that ESS can store energy close to the consumer to provide intermittent peak capacity – where without the battery the grid would need to be expanded to transmit electricity from further away generating assets.

Additionally, industrial and residential consumers can benefit from storing energy in ESS reducing electricity cost by taking advantage of differentiated tariffs (e.g., buy at low tariff and use at high tariff times) or by storing surplus energy created through rooftop solar. This allows them to reduce cost from buying electricity of the grid.

[i] The success of Australia’s CIS has been mixed with strong bidding for battery projects but slow implementation of batteries. The scheme also undermined a pure merchant’s market by increasing reliance on government guaranteed returns.

Revenue stream summary table

Table 3 provides a summary of basic revenue streams of ESS as described above

Table 3: Basic revenue streams for ESS

Business model	Details	Risks examples
Arbitrage/energy trading	Buying low (mid-day solar) and selling high (evening peak). Wholesale market arbitrage in day-ahead and intraday markets typically represents 20 to 50 percent of the full storage revenue stack today and is expected to increase to more than 60 percent by 2030 in some markets[9]. Arbitrage also works for co-located/hybrid models (e.g., ESS co-located with energy production such as solar or wind) where non-contracted energy is stored locally when prices are low and released when prices are higher.	• Spread between buying and selling price too low due to weak market • Volatility of price differential not predictable (e.g., weak market signals) • Curtailment of renewable energy sources/ESS • Growing ESS competition leading to lower spreads
Ancillary Services	Provision of frequency regulation, voltage control, back-up energy, and black-start capabilities. Ancillary services that stabilize the power grid typically represent 50 to 80 percent of the full storage revenue stack of energy storage assets deployed today. This is observed across multiple mature storage markets but is expected to decrease to less than 40 percent by 2030. This change is driven by the predicted saturation of these markets as ESS become widely deployed in the future.[9]	• Competition leads to lower prices for ancillary services • Regulatory changes
Capacity payments	Fixed payments for ensuring system reliability. Capacity payments or similar regulated incentives can represent an average of 20 to 30 percent of the total storage revenue stack in selected geographies (for example, Italy and Poland), with some cases reaching almost 100 percent when supported by infrastructure-like incentive schemes, such as the Italian MACSE auctions[9]. In CAISO's[5] Resource Adequacy program and the UK's National Grid Electricity System Operator (ESO) capacity market, this is achieved by contracting resources,	

	including BESS, to ensure sufficient capacity availability.	
Investment deferral	generating savings from not investing in other generation or grid upgrades (e.g., transmission lines, substations) by balancing grid (e.g., building battery storage in substations to service higher peak loads rather than expanding grid plus installing new transformer).	• Changing demand structures leading to oversupply (e.g., growing home batteries lead to lower utilization of substation batteries)
Cost avoidance	generating savings from not buying electricity from grid and under slab-based tariffs, limiting exposure to higher-priced consumption bands (e.g., utilizing BTM solar and ESS)	• Changing price structures (e.g., electricity prices) might reduce cost avoidance benefits

Box 1 looks at emerging ESS business models

Box 1: Emerging ESS business models

ESS business models are continuously evolving, often depending on emerging domestic and international regulations.

An example is generating renewable energy credits (RECs) through ESS, which would require the implementation of the hourly clean power matching requirements in the greenhouse gas protocol, rather than the current annual matching: this shift would increase the demand for nighttime clean electricity provision.

Similarly, ESS can generate carbon credits if they replace fossil fuel power generation. This would require a clearer pathway for domestic or international carbon accounting and carbon trading.

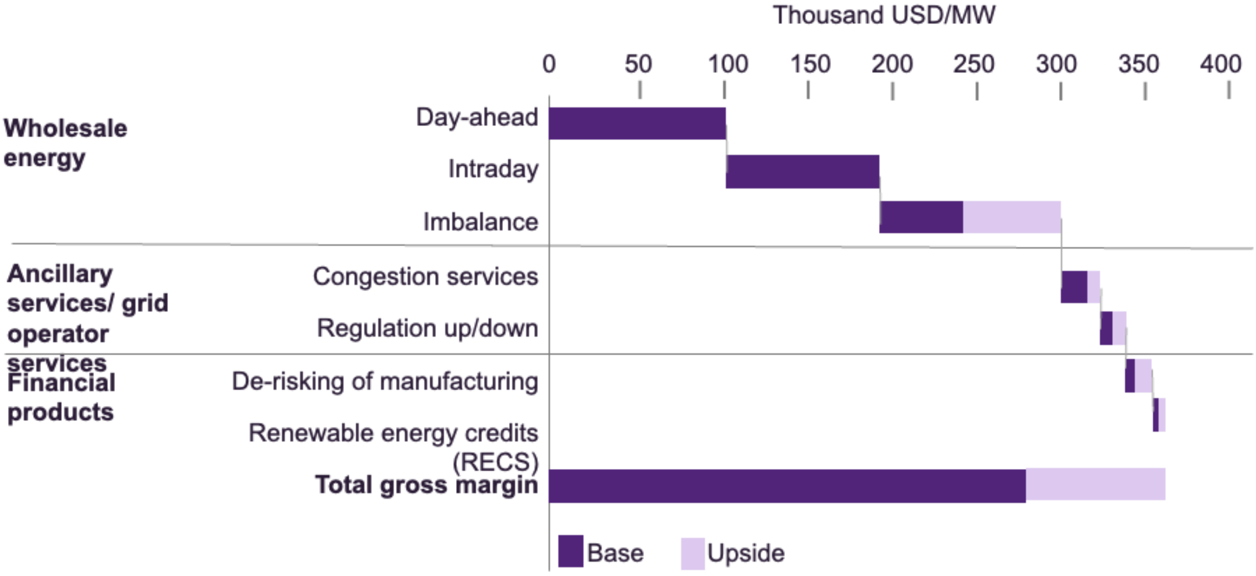
Battery as a Service (BaaS)— when applied to stationary setups—decouples hardware ownership from energy utilization. Under this framework, a third-party service provider retains asset ownership and manages the entire operational lifecycle, including installation, degradation monitoring, and eventual recycling

Revenue stacking

Relying on a single business model (e.g., arbitrage) may be insufficient to meet investor's return requirements[9]. Typically, ESS investors would therefore want to "stack" revenue from diverse sources to strengthen the business case of ESS.

Figure 5 shows an example of how operators can improve gross margin by combining revenue from different business models. As can be seen, arbitrage might make up 70% of revenue, while ancillary services might make up 20-30%.

Figure 5: Value from energy storage revenue stacking (based on McKinsey[9] on an example from Eastern Europe)



Revenue stacking is not possible in many Asian markets due to lacking regulation or outright bans. This severely undermines merchant's models of ESS investment.

Risk management in ESS

To reduce risks of ESS business models particularly of price volatility, curtailment or changing demand structures, different options have emerged to share risks among different stakeholders, e.g., by splitting ownership, operation and revenues of assets. Table 4 provides an overview of some of those models.

Table 4: Revenue models and revenue volatility (Source: Macquarie)[7]

Model	Description and key features	Revenue characteristics
Pure tolling	Owners lease the asset to a third party, transferring dispatch rights in return for fixed revenues. Asset owners retain ownership but give up operational control	Fixed revenue stream regardless of market conditions
Rate-based cost recovery	Transmission/distribution operators own energy storage as grid assets, providing services and recovering costs through regulated cost-based rates	Regulated cost recovery ensures stable returns, market-based rate services may also be used if compliant with regulations
Contracted revenue	Asset owners secure long-term contracts with offtakers, such as power purchase agreements (PPAs) or capacity-based payments. Asset owners retain dispatch and capacity rights under auction-based contracts	Stable, predictable revenue stream over the contract tenor

Floor-plus share	Optimizers (e.g., trading firms) guarantee a revenue floor and share profits above it, blending features of merchant and tolling models (hybrid). Like contract-for-difference (CfD) structure	Minimum guaranteed revenue or profit with additional upside potential. Optimizers cover shortfalls if revenues fall below the threshold
Pure merchant	Owners charge/discharge electricity based on price signals in competitive markets (can use optimizers to support operation)	Revenue depends on price volatility. Owners benefit from price swings and face downside risks. May use revenue insurance to mitigate risks

Policy environment requirements for ESS investment

For ESS to be a viable investment, electricity markets and related policies require a relatively high level of sophistication. Table 5 provides an overview of policy requirements to allow for different ESS business models

Table 5: Policy requirements for ESS business models

Business model	Policy requirement
Legal definitions	Legal definitions of energy storage as a third asset class opposed to generation and consumption
Licensing frameworks	Utility-scale systems require independent generation/storage licenses and market participant registration. Behind-the-meter (BTM) or commercial systems usually only require local distribution network permits or simplified deemed-consent registrations
Grid connection code	Legally binding technical standards (e.g., IEEE 1547, regional grid codes) governing how the ESS interacts with the network. It dictates bidirectional power quality, fault ride-through capabilities, autonomous voltage regulation, and automated reactive power support to maintain grid stability.
Electricity markets	Enabling wholesale electricity markets that have an efficient price finding mechanism based on supply and demand, thus allowing for arbitrage (buying low, selling high)
Metering and settlement rules	Highly accurate, time-segmented bidirectional smart meters capable of tracking high-frequency intervals (e.g., 5-minute or 15-minute settlement periods). This ensures precise, synchronized financial settlement for energy drawn versus energy injected for residential, commercial and utility scale owners.
Revenue stacking	Legal frameworks allowing a single ESS asset to layer multiple service contracts simultaneously (e.g., prioritizing local backup power, while selling excess capacity into frequency markets). Rules define strict priority hierarchies and telemetry tracking to prevent "double counting" or conflicting dispatch instructions

Charging of network fees	Regulates whether the ESS pays grid transmission/ distribution tariffs. A regulatory goal is eliminating "double taxation," ensuring independent ESS assets are exempt from retail network fees while charging, paying fees only on net energy consumed or via wholesale-only tariffs[ii].
Procurement and Payment	Governs how different business models are compensated. Front-of-the-Meter (FTM) / Utility-Scale: Paid via wholesale arbitrage, capacity market availability payments, or ancillary services (frequency response). Behind-the-Meter (BTM) / Commercial: Paid via demand-charge reduction, peak shaving, or virtual power plant (VPP) aggregation contracts.
Behind-the-meter (BTM) installations	Consumers (residential and/or industrial) being allowed to install BTM storage

Multiple jurisdictions across Asia have implemented integrated renewable-storage procurement in 2025, including India, Philippines, Australia, and Malaysia. Consequently, these mechanisms require ESS components within renewable projects. Yet, many Asian jurisdictions often lack aspects of the policy environment to enable different ESS business models, including arbitrage, ancillary services or capacity payments. Rather, many jurisdictions rely on tenders, subsidies, regulated tariffs, and state-supported procurement for project bankability.[1]

Box 2 highlights policy environment differences between Philippines and Vietnam.

Box 2: Policy environment for BESS in the Philippines and Vietnam[8]

The Philippines:
The Philippines BESS policy environment is governed by the Department of Energy (DOE), the Energy Regulatory Commission (ERC), the Independent Electricity Market Operator of the Philippines (IEMOP), and the National Grid Corporation of the Philippines (NGCP).

Philippine regulations recognize BESS as a flexible grid asset capable of serving multiple functions across generation, transmission, distribution, and end-user tiers. However, rules still blur the line between treating a standalone BESS as a generator and a wholesale load customer in certain market clearing contexts.

Permitted and regulated BESS services/business models in the Philippines:

1. Ancillary services: BESS facilities can supply three primary reserve categories in the Wholesale Electricity Spot Market (WESM):
    - Regulating Reserve (Up/Down for continuous frequency correction),
    - Contingency Reserve (rapid response to generator trips), and

[ii] In the Philippines in August 2026 still charged network charges on both sides of ESS, decreasing viability of arbitrage business models despite the existence of a functioning electricity market.

- Dispatchable/Replacement Reserve (slower start-up replacement).
2. Wholesale energy arbitrage: BESS can draw power from the grid during low-demand or low-price hours and discharge into the 5-minute WESM spot market during peak demand hours or price spikes.
3. Renewable integration and firming: BESS co-located with solar or wind helps smooth power output, mitigate ramping issues, and reduce curtailment. In February 2026, DOE issued Department Circular DC2026-02-0008, mandating 20% BESS with minimum 4-hour duration for all new renewable energy plants exceeding 10 MW capacity.
4. Distribution and off-grid support: BESS is permitted for peak shaving, transformer deferral at distribution levels, and replacing expensive diesel generation in island microgrids under the Microgrid Development Act.
5. Revenue stacking is officially permitted and technically facilitated through the WESM Reserve Market, which operates co-optimization between spot energy dispatch and ancillary services on a 5-minute clearing basis

A key structural issue for standalone BESS globally is double charging—paying transmission/distribution wheeling fees both when charging from the grid and when discharging back into it.

Particularly for many islands of Philippines, BESS installations require additional support due to high logistics cost and lack of qualified personnel for installations and maintenance.

Viet Nam

The regulatory environment for BESS in Vietnam is rapidly evolving under the Ministry of Industry and Trade (MOIT), Vietnam Electricity (EVN), and the National Power System and Market Operator (NSMO). Driven by Power Development Plan VIII (PDP8) targets of 10,000 MW to 16,300 MW by 2030, recent policy interventions have established formal pricing and PPA frameworks.

Permitted and regulated BESS services/business models in Vietnam:

1. Ancillary services: Utility-scale BESS facilities provide frequency regulation, voltage control, and spinning reserves directly managed by NSMO to stabilize grid frequency amidst high variable solar and wind penetration.
2. Renewable integration and firming: Under MOIT regulations (including Circulars 09/2025/TT-BCT, 12/2025/TT-BCT, and Decision 988/QD-BCT), centralized solar power projects are required to integrate a BESS with a minimum capacity equivalent to 10% of plant capacity and a 2-hour discharge duration.
3. BTM peak shaving: Commercial and industrial (C&I) customers can deploy BESS to optimize Time-of-Use (TOU) tariff differentials, reducing electricity charges during peak hours and ensuring uninterrupted power supply for industrial facilities.

Importantly, wholesale energy **arbitrage** is restricted in practice for grid-connected assets due to Vietnam's single-buyer electricity market structure, where off-take prices are determined via regulated PPAs with EVN rather than an open merchant spot market.

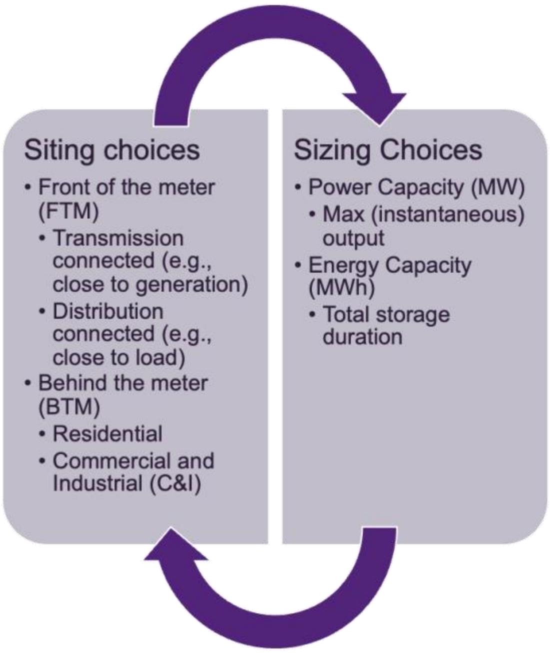
All utility-scale BESS projects connected at 110 kV or higher sell capacity/energy directly to EVN/NSMO under regulated tariffs rather than paying independent wheeling fees to access spot markets. This also includes direct power purchase agreements (DPPAs) that permits private renewable generators to sell power to large end-users via the national grid. However, EVN would buy the electricity at spot market prices from the producer/BESS with the off-taker and the producer/BESS balancing the difference between EVN's offtake price and the DPPA price through a contract for differences rather than a power wheeling charge.

Currently, definitions or regulations are also lacking for revenue stacking in Vietnam.

Technology, Siting and Sizing choices for ESS and BESS

Siting (where to put the ESS) and sizing (how much power and energy capacity it should have) are interconnected choices that determine a BESS project's technical viability and financial return (see Figure 6).

Figure 6: The interconnection between sizing and siting choices for ESS



To decide on siting and sizing, it is fundamental to understand ESS technologies and their characteristics, which are described in the next section.

Technology and prices of ESS

A foundation of ESS and BESS technologies is that no ESS generates electricity, but only consume electricity, stores energy and releases electricity.

Different ESS have important physical or technical properties that determine how the systems rapidly or slowly consume and release electricity or store energy. This includes mechanical form (e.g., pumped hydro, flywheels, gravity energy storage, compressed air storage), electro-chemical form (e.g., most BESS such as lithium batteries, iron-air technology), chemical (e.g., hydrogen), or thermal (e.g., molten salt).

ESS, depending on their physical capability, can consume or release electricity with almost no delay (within milliseconds for some batteries) or with some delay (e.g., pumped hydro). The use cases vary accordingly: low-delay ESS can provide ancillary services such as grid balancing, ESS with some delay can provide long term energy storage.

Furthermore, ESS vary significantly in their storage power measured in Watts (or kilowatts (kW), megawatts (MW), gigawatts (GW)) that determines how fast their can charge and discharge, and their energy capacity measured in Watt-hours (or Kilowatt-hours (kWh) etc.) – the amount of power the battery can hold and deliver over time.

Finally, an ESS is determined by its ability to store energy over a shorter or longer period that distinguishes its applicability for short-duration storage (e.g., 0-4 hours) and long-duration energy storage (LDES) (typically 6-12+ hours).

Table 6 provides an overview of different ESS and their physical capabilities. For a more detailed analyses of different ESS, their physical properties and applications, refer to Appendix 1,

Appendix 2, and

Appendix 3.

Table 6: Overview of different ESS technologies and their technological capabilities

Technology	Physical type	Reaction time	Power (e.g., MW)	Capacity (e.g., MWh)	Discharge duration in hours[10]	Price per kWh in USD[10]
Lithium-ion batteries	Electro-chemical	Short	Low-medium	Low-high	0-6	125[11]
Sodium-ion batteries[12]	Electro-chemical	Short	Low-medium	Low-medium	0-4	55-70[13]
Flywheels	Mechanical	Short	Low-medium	Medium	Typically, less than 15 minutes, but up to few hours possible	
Gravity energy storage	Mechanical	Medium	Low-medium	Medium	4-24	100-1500
Hydrogen	Chemical	Medium	Low-high	Low-high	Long-term	
Pumped hydro	Mechanical	Medium	Medium-high	Medium-high	8-35	300-350
Compressed air storage	Mechanical	Medium	Medium-high	Medium-high	Long-term	100-600

Today, most large-scale storage systems in operation use lithium-ion technology, which is currently preferred over other battery technologies because it provides fast response times and high-cycle efficiency (low energy loss between charging and discharging), while still being cost-effective.

With each technology having different technology advantages and disadvantages, investors need to understand the how the ESS needs to perform and how to optimize revenue streams to choose the right technology or technology mix, the right size for a specific site.

Sizing choices

Sizing choices, the choice between a battery's power (MW) – also referred to as output, and its energy capacity (MWh) – also referred to as storage duration, dictate how a battery can operate and thus impact the business model. **Box 3** gives background on the relationship between power and capacity.

Box 3: Battery charging and discharging speeds and ratios
The metric that describes the speed at which a battery charges or discharges relative to its total capacity is the **C-rate**. A 1C battery empties in 1 hour; a 0.25C battery empties in 4 hours; a 4C battery empties in 15 minutes.

The physical sizing of the battery cells relative to the inverter determines the maximum C-rate, which automatically locks the asset into or out of specific markets.

High power / Short duration	High Energy/Long duration
• High C-Rate (e.g., 2C) • Fast frequency response • Continuous micro-cycling (charging and discharging) • Low cell-to-inverter cost	• Low C-Rate (e.g., 0.25C) • Arbitrage & Energy Shifting • Deep daily cycling (1-2 full cycles) • High cell-to-inverter cost
Example: 200 MW/100 MWh (0.5 hours)	Example: 200 MW/800 MWh (4 hours)

BESS are therefore bound to sizing choices, mostly between short-duration/high-power and long-duration/high-energy profiles:

Short-duration/high-power profiles – ancillary battery

Short-duration/high power profile BESS have a high C-rate capability and can consume or release high amounts of power (e.g., to provide electricity for highly power consuming applications or support large parts of grids). They often have sub-second reaction times to grid anomalies.

Typically, this type of BESS is used for fast frequency response, regulation up/down, requiring the battery to consume or inject power for a short time only (e.g., seconds or minutes).

Long-duration/high energy profiles – arbitrage battery

Long-duration/high energy profile BESS have a low C-rate and can sustain a steady output over a prolonged period. It is more suited for wholesale energy arbitrage, peak shaving and capacity markets.

The battery must survive more regular 4-hour discharge windows (where short-duration/high-power BESS do not compete).

Box 4 provides the key takeaways for sizing of ESS.

Box 4: Key take-away for ESS sizing

An under-sized asset (e.g., trying to arbitrage with an ancillary battery) will have to cycle multiple times a day, thus quickly depleting the guaranteed charging cycles and reducing the lifetime of the battery.

An oversized asset (e.g., trying to provide ancillary services with an arbitrage battery) will fully underutilize the asset as charging and discharging takes more time, and a short window for ancillary services will leave significant amounts unused, dragging down the financial value.

Siting choices

Siting BESS close to generation sources (such as large wind or solar farms) and thus connected to the transmission, versus close to urban or industrial load centers and thus connected to the distribution alters the project's risk profile, construction costs, and revenue potential.

Siting Close to Electricity Generation (Co-location / Hybrid)

This approach involves placing the BESS at or near the point of electricity generation, typically rural areas where large-scale wind or solar farms are built. This has several advantages

- **Reduced Interconnection Costs:** By co-locating with an existing or planned renewable asset, the battery can share the same substation, transformers, grid connection agreement, and physical land. This eliminates a massive percentage of the capital expenditure (Capex) required for independent grid connection.
- **Capturing Clipped and Curtailed Energy:** Solar arrays are frequently oversized relative to their inverter capacity, leading to "clipped" energy that is lost during peak afternoon sun. Additionally, grid operators frequently order wind and solar plants to shut off or reduce output during periods of oversupply (curtailment). A co-located battery can capture this otherwise wasted energy for free and store it for later use.
- **Streamlined Permitting:** Rural generation sites usually have favorable zoning laws, lower land costs, and fewer local community objections compared to urban areas. The environmental and civil engineering approvals are often bundled with the generator's existing permits.
- **Green Power Firming:** It allows a variable asset like wind or solar to act more like a traditional baseline power plant, transforming volatile, unpredictable generation into a steady, reliable, and higher-value energy product that can be sold via Power Purchase Agreements (PPAs).

Siting Close to Load Centers (Demand-Sited / Urban-Sited)

This approach involves placing the BESS close to the end consumers of electricity—near cities, industrial parks, or congested urban distribution substations. This has several advantages:

- **Capturing Localized Transmission Congestion:** High electricity prices during peak hours are often caused by physical bottlenecks on the transmission lines trying to move power into a crowded city. A battery sited inside the city lines can buy cheap power before the bottleneck occurs, or discharge during peak grid strain, capturing massive real-time price spikes that rural batteries cannot access.
- **Deferring T&D Infrastructure Spending (Non-Wires Alternatives):** Utilities will pay a premium to battery operators whose systems can reduce peak demand on local infrastructure. Siting a battery directly behind a stressed urban substation allows it to provide "peak shaving," preventing the utility from having to spend tens of millions of dollars upgrading physical wires and transformers.
- **Premium Ancillary Service Performance:** Certain critical reliability services, such as dynamic voltage support or localized black-start capabilities, must be delivered

directly where the grid strain occurs. Urban batteries are perfectly positioned to capture these high-value local network service contracts.

- **Lower Transmission Losses:** Moving electricity over long distances results in power loss due to line resistance. Discharging a battery directly into a local distribution network minimizes these efficiency losses, ensuring more of the stored energy reaches paying customers.

Box 5 provides the key takeaways for siting choices.

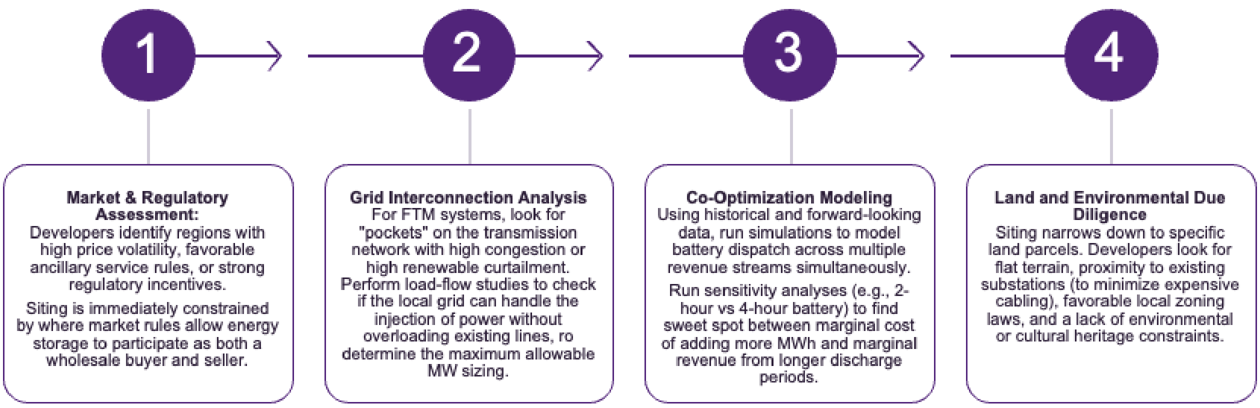
Box 5: Key take-away for ESS siting
When evaluating these options, the trade-off can be summarized as capital expenditure (Capex) efficiency versus revenue flexibility:

- **Production-sited batteries** have advantages at reducing initial project development costs (capital expenditures) and solving the localized grid issue of renewable curtailment. However, they lack access to high-value urban markets if the main transmission lines heading toward the load centers (e.g., cities, industrial areas) become congested.
- **Load-center-sited batteries** face severe bottlenecks in land availability, high connection costs, and intense local permitting hurdles. However, they gain access to a wider portfolio of stacked revenue streams, including local utility grid-support contracts and the highest real-time wholesale price peaks.

Process for Siting and Sizing

Developers and planners use a rigorous multi-step engineering and financial modeling process to finalize these parameters.

Figure 7: Process for Siting and Sizing



Step 1: Market & Regulatory Assessment

Developers identify regions with high price volatility, favorable ancillary service rules, or strong regulatory incentives. Siting is immediately constrained by where market rules allow energy storage to participate as both a wholesale buyer and seller.

Step 2: Grid Interconnection Analysis

For FTM systems, developers look for "pockets" on the transmission network with high congestion or high renewable curtailment. They perform load-flow studies to check if the local grid can handle the injection of power without overloading existing lines, which determines the maximum allowable MW sizing at that specific site.

Step 3: Co-Optimization Modeling

Using historical and forward-looking data, developers run software simulations to model battery dispatch across multiple revenue streams simultaneously. They run sensitivity analyses (e.g., comparing a 2-hour battery versus a 4-hour battery) to find the sweet spot where the marginal cost of adding more MWh of lithium-ion cells matches the marginal revenue gained from longer discharge periods.

Step 4: Land and Environmental Due Diligence

Siting narrows down to specific land parcels. Developers look for flat terrain, proximity to existing substations (to minimize expensive cabling), favorable local zoning laws, and a lack of environmental or cultural heritage constraints.

Financing instruments for energy storage systems

Financing ESS requires matching the asset's risk profile with the correct financial instrument. Because batteries often rely on volatile wholesale spot markets and short-term ancillary service contracts, standard long-term infrastructure project debt can be difficult to secure. A further challenge in parts of Asia is the lack of revenue stacking options, decreasing revenue potentials and thus limiting ESS financing options.

Nevertheless, across Asia, the financial landscape is evolving to bridge this gap, shifting from venture capital and equity or corporate finance toward specialized debt, corporate facilities, and state-backed frameworks. Also blended finance as well as community finance are options for specific projects.

Public finance

In emerging Asian markets, electricity markets are often under-developed or lack formal revenue mechanisms (such as capacity payments, ancillary service markets, or time-of-use arbitrage tariffs). Commercial banks avoid financing the high CAPEX for ESS for the risks associated with such markets, including unproven cash flows, off-taker credit risks, and grid integration uncertainties as unbankable.

Public finance - through concessional loans, direct sovereign equity, fiscal guarantees, and policy-backed co-investment – can act as a catalytic bridge in these markets by absorbing first-mover risks, extended tenor debt based on stronger credit rating and access to capital markets of the sovereign lenders.

Key Players in the Public Finance Ecosystem

1. Development Finance Institutions (DFIs)

- **Multilateral development banks (MDBs),** such as Asian Development Bank (ADB), Asian Infrastructure Investment Bank (AIIB), World Bank (including IFC)**:**

MDBs function as anchor lenders for regional megaprojects and blended finance structures. They leverage specialized climate vehicles (such as the Clean Technology Fund or Climate Investment Funds) to layer soft debt on top of sovereign or non-sovereign commercial tranches. They are also active in structuring public-private partnership (PPP) frameworks, guarantee facilities, and sector-wide policy loans tied to power grid modernizations.

- **Bilateral DFIs:** International development finance arms—such as Japan International Cooperation Agency (JICA), Korea Development Bank (KDB), and Germany's KfW/DEG—frequently co-finance Asian storage projects to de-risk export pathways for their domestic technologies or engineering firms.
- **National Development Banks (NDBs),** such as the Industrial Finance Corporation of India (IFCI), Indian Renewable Energy Development Agency (IREDA), Development Bank of the Philippines (DBP), and Pakistan's state development institutions provide direct local-currency debt and sub-market interest rates to sovereign-backed power utilities.

Example (Pakistan): The ADB supported a $250 million financing package (including $50 million in concessional ordinary capital) for Pakistan's National Transmission & Despatch Company (NTDC) to install 1,000 MW / 2,000 MWh of grid-integrated BESS along the North-South corridor to mitigate transmission bottlenecks.

2. State-owned holding companies and funds

- **Sovereign asset holders,** such as Danantara and INA in Indonesia, Temasek in Singapore, or Khazanah in Malaysia act as flexible, equity-oriented arms of the state. They consolidate state-owned assets to raise capital, invest as anchor equity partners in high-impact national priorities, and de-risk emerging sectors through asset recycling and blended equity facilities.
- **State climate funds** such as national green funds and transition funds (e.g., those attached to the Just Energy Transition Partnership / JETP frameworks in Indonesia and Vietnam) can step in as catalytic co-investors to absorb early-stage tech and execution risk.

3. Direct fiscal spending (e.g., ministries of finance or energy)

- **Fiscal policy:** Ministries of Finance sit at the top of the domestic financial hierarchy, providing sovereign credit wraps, default guarantees, and viability gap funding (VGF) for storage projects. They lower developer cost-of-capital by backstopping national utility payment obligations and offering tax incentives, long-term tax holidays, or tariff subsidies.

4. State-Owned Enterprises (SOEs) in Grid and Energy

- **Off-takers**, such as national power utilities and grid operators (e.g., PLN in Indonesia, State Grid Corporation of China (SGCC), or CPPA-G in Pakistan) deploy direct balance-sheet CAPEX to procure and operate grid-connected battery systems. They also provide public finance support indirectly by signing long-term power purchase agreements (PPAs), capacity contracts, and ancillary service agreements that guarantee project cash flows.

Example (Philippines - EDC): The Energy Development Corporation (EDC) in the Philippines deployed over 100 MW of BESS capacity using a mix of internal balance-sheet capital and concessional debt from MDB programs to provide frequency regulation and ancillary services to the national grid

Expectations of public finance providers

Public finance institutions operate under a dual mandate: financial sustainability paired with high social and environmental impact. When deploying capital into Asian ESS projects, public finance players expect:

- **Additionality:** financing projects for common good that would not be financed under pure commercial financial conditions.
- **Demonstration for scaling:** Proving the commercial viability of storage applications (such as solar-plus-storage load shifting, frequency regulation, or cross-border grid firming) to encourage commercial banks to step in for future iterations.
- **Policy reform:** Mandating structural electricity sector reforms, such as unbundling state utilities, establishing time-of-use tariffs, or implementing competitive bidding frameworks, as pre-conditions for loan disbursements or capital injections, for example through policy-based loans.
- **Environmental and social safeguards:** Enforcing strict standards around battery supply chain transparency, land acquisition, safe disposal/recycling, and environmental impact assessments in line with World Bank/IFC environmental and social safeguards (ESS).
- **Crowding-in private capital:** Achieving a high leverage ratio where every dollar of concessional debt or state equity mobilizes multiple dollars of private commercial debt or equity.

Risks mitigation through public finance

Public finance has specific functions in reducing risks of ESS in Asia, including

- **Bankability:** public finance including those with sub-market interest rates and long grace periods significantly reduce debt-servicing burdens, turning marginal BESS projects into financially viable ones.
- **Off-taker/counterparty credit risk:** In markets where national state-owned utilities suffer from circular debt or weak credit ratings, [public finance can protect developers against non-payment or breach of contract.
- **Technology and execution risk:** Public finance often subsidizes the early-stage engineering, battery degradation risks, and integration uncertainties inherent in deploying new BESS tech in weak grids.
- **Foreign exchange (FX) risks:** International MDBs and domestic state funds can offer local currency financing or currency-hedging facilities, protecting projects that earn revenue in local electricity currencies while servicing foreign currency capital costs.

While public finance reduces risks, it is important for policy makers and public finance agencies to reduce unintended side effects, including

- **Market distortion** where developers rely on deeply subsidized public capital or state utility balance sheets to make projects viable

- **Moral hazard slowing reform** where state-owned power utilities rely indefinitely on sovereign bailouts or guarantees for grid-firming assets, and local governments may delay establishing real, market-based ancillary service or capacity pricing frameworks.
- **Bureaucratic lead times:** MDB, NDB, and government ministry approval processes, environmental/social compliance audits, and sovereign consent requirements can add 12 to 24 months to project development timelines and thus increase capital cost of project
- **Sovereign debt strain** where concessional loans routed through sovereign channels increase the overall national debt burden of developing Asian nations, potentially conflicting with fiscal consolidation targets.

Blended finance

Blended finance layers non-commercial capital (from philanthropic, donor, and multilateral sources) with commercial finance to lower the overall weighted average cost of capital (WACC) and bring an otherwise commercially non-viable ESS project to commercial viability. It thus ideally gets ESS projects implemented that would otherwise fail while mobilizing private sector capital.

Key mechanisms of blended finance

Several financial mechanisms can support blended finance development

- **First-loss capital (concessional equity / junior debt):** Donor capital accepts a subordinate position, absorbing initial revenue shortfalls or defaults before senior commercial lenders take losses.
- **Concessional / soft loans:** MDBs provide long-term debt at sub-market interest rates with 5–10 year grace periods, lowering overall debt service requirements.
- **Guarantees:** Partial credit guarantees and political risk insurance backstop state utility payment obligations.
- **Technical assistance grants:** Non-repayable grants fund pre-construction grid modelling and legal PPA structuring.

Key players in blended finance

Several public institutions provide the concessional part of the capital stack in blended finance:

- **Philanthropic foundations**, such as GEAPP (Global Energy Alliance for People and Planet) that deploys first-loss grants and soft capital across Southeast Asia.
- **Specialized multilateral climate** funds such as Climate Investment Funds (CIF) / Clean Technology Fund (CTF) that deliver deeply concessional co-financing through major MDBs.
- **Dedicated blended vehicles** such as the commercial Climate Fund Managers & Private Infrastructure Development Group (PIDG) provide local-currency guarantees and blended debt platforms.

Guarantees

Guarantees act as credit enhancement tools that bridge the gap between commercial risk profiles and bankable assets for ESS in emerging Asian markets. They can be a core element of blended finance (see above).

Guarantees do not remove technical or market risks; instead, they reallocate specific financial and sovereign risks to higher-rated balance sheets (such as Multilateral Development Banks (MDBs), export credit agencies (ECAs), or host governments).

In BESS projects, guarantees generally operate across four main structures:

1. **Off-taker payment/sovereign liquidity guarantees** support BESS assets in markets like Vietnam, Indonesia, or the Philippines that often rely on capacity payments from state-owned utilities (e.g., EVN, PLN). If the utility defaults on these availability payments, a Partial Risk Guarantee (PRG) or a Political Risk Insurance (PRI) policy issued by MDBs (like ADB, MIGA, or World Bank) step in to backstop debt service.
2. **Partial Credit Guarantees (PCGs) for long-term debt** support developers in developing Asian economies where commercial banks are unwilling to extend debt tenors beyond 5–7 years compared to the required 10–12 years for BESS projects needed to recover investments. A development finance institution provides a PCG covering debt service defaults on the back-end years of the loan.
3. **Performance/degradation backstops (ECA / OEM Guarantees)** provided by manufacturers (OEMs) and potentially supported by ECA reduces BESS revenue risks from decreasing battery performance (e.g., maintaining minimum round-trip efficiency and cycle life).
4. **Foreign exchange (FX), currency convertible guarantees** support BESS operators whose capital costs are incurred in foreign currency (e.g., USD for financing or system acquisition cost) compared to revenues earned in local currency by reducing FX risks and protecting lenders if a host country enacts capital controls.

Corporate finance

Corporate finance relies directly on the balance sheet of a sponsor company—such as a renewable energy developer, industrial conglomerate, or utility—to finance BESS projects rather than relying on standalone, non-recourse project finance.

Under this approach, the parent organization funds BESS assets using internal cash reserves, general corporate credit facilities, or corporate green bonds. Because loan repayment depends on the overall financial strength and credit rating of the corporate entity rather than the isolated cash flows of a single BESS asset, corporate finance allows companies to bypass complex revenue structure negotiations and rapidly deploy storage assets in markets where standalone merchant storage mechanisms remain underdeveloped.

Core mechanisms of corporate finance

Corporations tap into several primary channels to finance storage directly:

- **General corporate debt and credit lines:** Large balance-sheet sponsors issue corporate-level senior unsecured bonds or utilize revolving credit facilities. Because creditors look to the parent company's total cash flows across all business lines, interest rates reflect the overall corporate credit rating rather than the asset-specific risks of the battery.
- **Corporate green and sustainability-linked bonds:** Energy companies issue earmarked green bonds to fund decarbonization portfolios. Storage assets easily qualify for green bond frameworks, allowing sponsors to potentially lock in lower pricing (greenium) from institutional ESG investors
- **Retained earnings/ internal free cash flows:** Cash-rich entities—such as large utilities, mining majors, or hyperscale data centre operators—frequently fund BESS directly out of working capital or annual CAPEX budgets to avoid financial structuring friction.

Comparison of corporate and project finance

Corporate finance approaches can have some advantages over project finance (see below), while also increasing some risks for the corporate investor (see Table 7):

Table 7: Comparison of corporate and project finance advantages

Advantages of corporate finance	Disadvantages of corporate finance
Speed: Project finance typically requires extensive due diligence, battery degradation warranties, complex PPA/tolling negotiations, and lengthy lender audits. Corporate balance-sheet funding eliminates these third-party hurdles	**Balance sheet contamination:** Project underperformance or asset loss directly impacts the parent company's credit rating and leverage metrics (where a project finance is non-recourse with no direct impacts on parent companies).
Absorbing merchant volatility: Project finance lenders rarely accept high merchant exposure without aggressive debt-service coverage ratios (DSCR) or low leverage caps. Corporate balance sheets can more easily absorb revenue fluctuations across broader portfolio earnings.	**Capital allocation constraints:** BESS projects must compete directly with other internal corporate investments for limited CAPEX dollars.
Capturing BTM synergies: For industrial sites or renewable developers co-locating BESS with existing wind/solar, the primary value often comes from avoiding peak-demand charges, reducing curtailment, or optimizing grid connections. These internal operational benefits are difficult to ring-fence for project finance lenders	**Lower leverage limits:** Corporate debt limits are bound by overall corporate leverage thresholds, whereas project finance can often achieve higher gearing on contracted assets.
Reduced transaction costs: Avoids expensive legal fees, independent engineer	

reports, and advisory costs associated with ring-fenced SPVs.

Project Finance Debt (Term Loans & Non-Recourse Debt)

Project finance relies on a non-recourse or limited-recourse debt structure, where commercial lenders extend loans to a dedicated Special Purpose Vehicle (SPV) created solely to own and operate BESS. Typically, an SPV would rely on a debt-to-equity ratio of 70/30 (meaning 70% of the project volume is financed through commercial debt, and 30% through equity).

Core mechanisms in project finance

In project finance, the full risk including debt repayments are linked only to the cash flows generated by the ESS asset itself, with the physical equipment, contracts, and revenue streams pledged as collateral. Because lenders have no direct recourse to the parent sponsors' balance sheets, this structure transfers operational, technical, and market performance risks directly to the project entity.

For financial institutions providing loans, this type of financing comes with specific requirements:

- **Ring-fenced cash flows/ waterfall mechanics:** All project revenues flow through strict SPV bank accounts. The loan agreement enforces a rigid waterfall mechanism: operating expenses and maintenance reserves are paid first, followed immediately by senior debt service, reserve fund top-ups, and degradation replacement funds. Equity distributions to sponsors occur only at the very bottom.
- **Reserve accounts and degradation funding:** Given capacity degradation over time, lenders require sponsors to maintain major maintenance reserves or pre-funded cell-replacement accounts to ensure battery augmentation occurs on schedule without threatening debt service.
- **Comprehensive insurance:** The SPV must maintain comprehensive insurance coverage, including Business Interruption, Property Damage, and Third-Party Liability, alongside liquidated damages clauses within the engineering/construction contract to cover grid connection delays.

Key requirements for project finance

Commercial banks enforce stringent structuring criteria before extending non-recourse senior debt to BESS projects:

- **Predictable long-term revenue assurance:** Commercial lenders require cash-flow visibility over the loan term (typically 7–12 years). Bankable revenue models include utility Tolling Agreements, Capacity Contracts, Long-Term Energy Service Agreements (LTESAs), or long-term Fixed-Price Arbitrage PPAs. Pure merchant BESS projects struggle to secure traditional project finance without floor-price guarantees.

- **Tier-1 technology and system performance guarantees:** Lenders mandate Tier-1 battery cell manufacturers and system integrators. Financing packages require comprehensive Engineering, Procurement, and Construction (EPC) turnkey contracts, backed by multi-year Long-Term Service Agreements (LTSAs) that guarantee round-trip efficiency (RTE), availability rates, and degradation limits.
- **Conservative Debt Service Coverage Ratios (DSCR):** Because battery revenue stacks carry market or operational volatility, commercial banks set strict DSCRs—typically ranging from 1.20x to 1.35x for fully contracted revenues, and pushing above 1.50x to 1.80x for any merchant-exposed cash flow tranches.
- **Clear regulatory and grid interconnection frameworks:** Non-recourse debt is restricted to mature electricity markets with transparent grid-code standards, unbundled market rules, non-discriminatory dispatch, and clear asset classifications for energy storage.

Strategic trade-offs in project finance

The following Table 8 provides an overview of trade-offs project developers and investors must consider when engaging in project finance for ESS.

Table 8: Trade-offs in project finance for ESS

Advantage	Disadvantage / Risk
High leverage: Allows sponsors to fund up to 60%–80% of project CAPEX with senior debt, preserving corporate equity and maximizing Return on Equity (ROE).	**High transaction costs including lead times:** Structuring requires extensive legal drafting, independent engineering reports, market consultant audits, and battery health modelling, adding 6–12 months to financial close.
Balance sheet protection: Non-recourse structure shields the parent company's balance sheet and credit rating from project-level failure or asset loss.	**Restrictive operating covenants:** Lenders impose strict operational controls, limiting battery cycling rates, dispatch flexibilities, or trading strategies to prevent accelerated degradation.
Capital efficiency: Enables developers to construct large-scale portfolios without exhausting corporate credit lines.	**Limited availability in emerging markets:** Almost impossible to achieve without government revenue underwriting (e.g., floor schemes or CFDs) in markets lacking deep ancillary or capacity markets.

Merchant debt facilities (flexible mini-perms)

Merchant debt facilities represent a specialized adaptation of project finance designed specifically for BESS assets operating without long-term off-take contracts or fixed-price capacity agreements.

Rather than relying on contracted revenue, merchant facilities allow storage developers to finance assets against spot market price spreads (energy arbitrage) and real-time frequency control ancillary services (FCAS). To manage this inherent market exposure, commercial lenders replace rigid debt service schedules with conservative leverage, shorter loan maturities, and dynamic repayment structures that adapt to grid volatility.

Key features of merchant debt facilities

- **Shorter tenors and accelerated amortization:** While traditional contracted project finance extends debt out to 10–15 years, merchant facilities restrict loan tenors to 3–7 years. Lenders structure aggressive amortization schedules during early operational years to pay down principal rapidly while battery degradation is low and market pricing remains favourable.
- **Flexible repayment and cash sweeps:** Debt service incorporates dynamic mechanisms such as seasonal repayment schedules and cash sweeps. During periods of extreme grid volatility (e.g., summer demand peaks), excess revenues above a baseline DSCR are automatically swept to pay down loan principal early. During low-volatility periods, lower fixed debt service prevents default.
- **Conservative gearing and high DSCR requirements:** Merchant debt facilities maintain lower debt-to-equity ratios, typically offering 40% to 50% leverage compared to 70% to 80% for fully contracted assets. Lenders enforce higher Debt Service Coverage Ratio (DSCR) covenants, often 1.50x to 1.80x or higher, calculated against conservative, downside-case price forecasts.
- **Floor-price risk wraps and revenue stacking limits:** Lenders often mandate synthetic revenue hedges, such as merchant floor contracts, short-term swap agreements, or cap-and-floor structures for a portion of the capacity (e.g., 30% to 50%) to guarantee a baseline income stream while leaving the remaining capacity unhedged to capture market spikes.

Key market requirements for merchant debt

Merchant facilities are restricted to highly liquid, transparent, and deregulated electricity markets. Key prerequisites include:

- **High price volatility and dynamic settlement:** Markets with wide spreads between minimum (or negative) solar-trough prices and evening demand peaks, alongside short settlement intervals (e.g., 5-minute settlement in Australia's NEM).
- **Deep ancillary service markets:** Transparent, unbundled markets for fast frequency response (FFR) and spinning reserves that allow BESS to monetize instant response capabilities.
- **Sophisticated merchant analytics and automated bidding:** Lenders require developers to partner with proven algorithmic trading platforms and battery optimizers capable of real-time co-optimization across energy arbitrage and FCAS markets.

Strategic trade-offs in merchant debt

The following Table 9 provides an overview of trade-offs investors and ESS project developers must consider when engaging in merchant debt options.

Table 9: Trade-offs in merchant debt for ESS

Advantage	Disadvantage / Risk
Revenue upside: Allows asset owners to capture 100% of merchant price spikes and volatility without capping returns via fixed tolling or PPA rates.	**Higher cost of debt:** Lenders charge higher interest margins and upfront fees to compensate for merchant price and volume risks.
Merchant flexibility: Eliminates the need to find creditworthy off-takers willing to sign long-term contracts in rapidly evolving power markets.	**Refinancing risk:** Short 3–5 year tenors expose the project to refinancing risk if market volatility drops or power market rules change prior to debt maturity.
Faster commercialization: Enables developers to deploy assets quickly when market spreads broaden, bypassing lengthy PPA negotiations.	**Strict cash distribution lockup:** High DSCR triggers and cash sweep mechanics mean equity holders may receive little to no cash distributions during low-volatility years.

Green Bonds and Sustainability-Linked Bonds (SLBs)

Green bonds and sustainability linked bonds can support ESS development in Asia particularly for corporate financed assets and, to a limited extent, project financed ESS (particularly when bundling multiple SPVs to create a larger bond issuance as bond issuances under USD 200 million don't attract sufficient international investors).

- **Green Bonds:** The proceeds are strictly earmarked for specific eligible green projects (many major regional developers, such as Ørsted or regional Asian IPPs, have updated their Green Finance Frameworks to explicitly include BESS).
- **Sustainability-Linked Bonds (SLBs):** These provide general corporate funding, but the interest rate (coupon) adjusts based on whether the company meets specific Key Performance Indicators, such as hitting a regional grid decarbonization or storage MWh deployment target.

Both bond instruments are typically only available for large established and low-risk ESS project companies with existing credit ratings and access to capital markets to finance utility ESS with stable revenue streams.

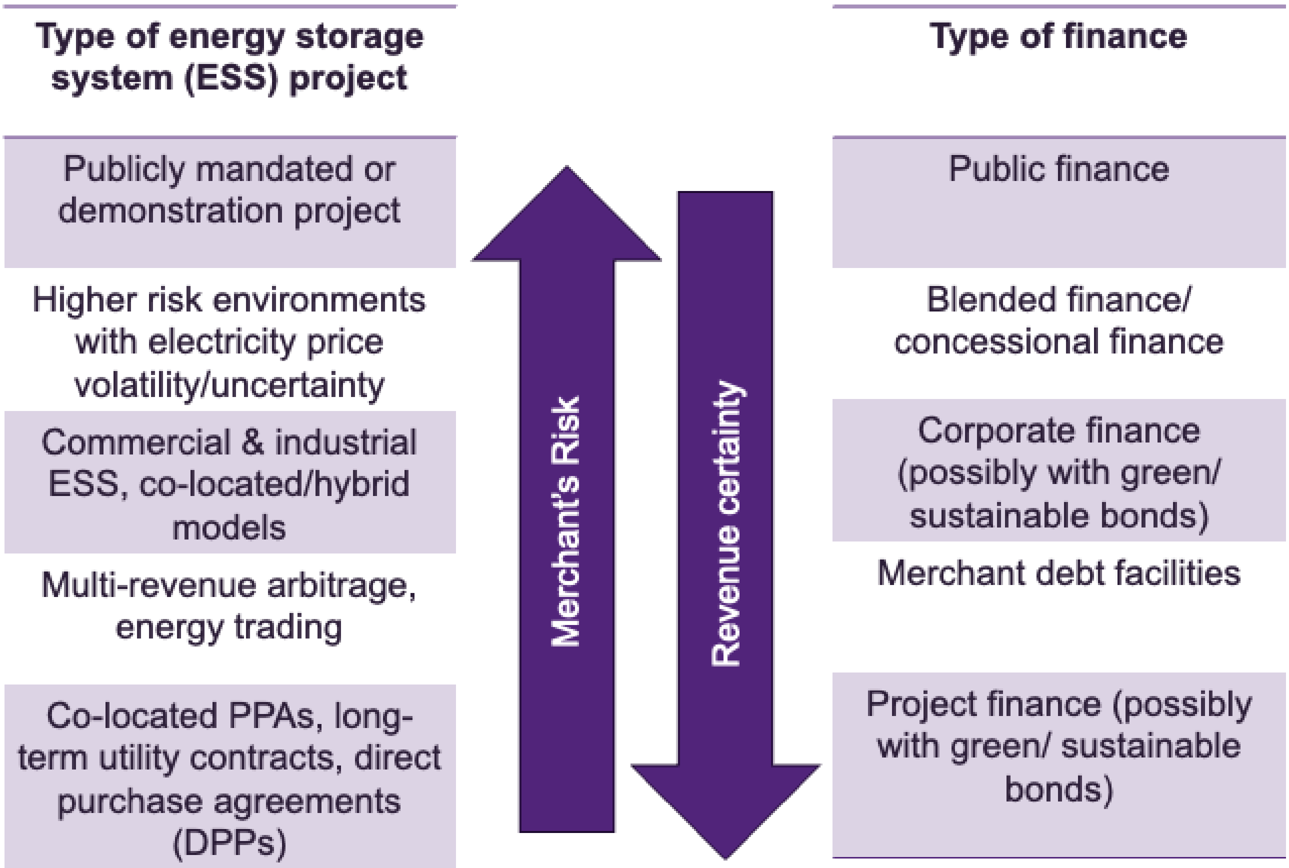
A main risk of such instruments is currency conversion particularly for USD or EUR denominated bonds (the preference for international investors). FX hedges can protect against some of the risks – yet with a cost attached to it.

Key takeaways for financing models

The suitability of an instrument depends directly on how much risk (exposure to volatile spot prices) the chosen business model carries.

Different financial models are more suitable depending on the risk profile as shown in Figure 8.

Figure 8: Matching ESS and financing models



Matching a BESS asset's risk profile with the correct financial instrument requires that such instruments are readily accessible within the host jurisdiction's capital markets. However, in developing Southeast Asian economies, the domestic commercial banking sector frequently lacks the institutional capacity, historical data, and technical framework required to underwrite merchant battery exposure or structure standard non-recourse project finance. Local senior lenders routinely view standalone battery storage as an unproven technology asset class rather than vital grid infrastructure.

To bridge this credit gap and move projects to a successful financial close, developers can target blended finance structures. This requires anchoring the capital stack with first-loss capital, concessional loans, or political risk guarantees from multilateral institutions—such as the Asian Development Bank (ADB)—alongside national policy banks. By deploying these developmental instruments to absorb early-stage operational and policy risks, international developers can de-risk the asset, creating a structured entry point for local commercial banks to participate in the credit syndicate.

The following Table 10 provides an overview of likely financing instruments applicable across various Asian economies, where it becomes clear that depending on the state of development of the financial markets (e.g., capital markets) and availability of development funding, different financing sources are more appropriate.

Table 10: BESS financing models for different Asian economies

Financial Instrument	Primary Regional Adopters	Ideal Business Model	Key Benefit	Major Hurdle
Traditional Project Finance	Australia (NEM), Japan, South Korea	Co-located PPAs, long-term utility tolls	Lowest cost of capital; high leverage potential.	Requires strict, long-term revenue certainty; inflexible.
Merchant Debt / Mini-Perms	Australia (Tier 1 IPPs like Neoen, Aquila)	Multi-revenue arbitrage stacking	Allows construction without locking into a cheap, long-term PPA.	Shorter maturities; higher interest rates; exposed to market saturation.
Concessional Debt (CEFC/ADB)	Developing Southeast Asia, Australian grid fringes	High-risk merchant or weak-grid stability assets	Provides long tenors and flexible covenants where private banks flee.	Bureaucratic structuring; requires strict alignment with public policy goals.
Green / SLB Bonds	China, South Korea, Singapore corporate markets	Corporate portfolio rollouts (FTM + BTM fleets)	Massive scale; bypasses asset-level grid interconnection delays.	Only accessible to large, investment-grade corporate balance sheets.

Box 6 provides three cases for understanding the choices for financing models

Box 6: Financing models case studies

Case 1: Fully Contracted / Utility Tolling / Co-located Solar Firming

- **Profile:** The battery has a 10-to-15-year tolling agreement or a firm PPA with a creditworthy counterparty (e.g., a state grid corporation, a strong corporate). This makes the revenue highly predictable.
- **Financial Instruments:** Traditional Project Finance Debt and Green Bonds.
- **Rationale:** Because the revenue is locked in, commercial banks can easily model the Debt Service Coverage Ratio (DSCR). Developers can maximize leverage (often up to 70-80% debt-to-equity), securing low-interest, long-tenor loans that maximize the project's internal rate of return (IRR).

Case 2: Pure Merchant Trading (Arbitrage + Stacking Ancillary Services)

- **Profile:** The asset relies entirely on capturing daily price spreads in markets like ERCOT, the Australian National Electricity Market (NEM), or liberalizing parts of Japan's wholesale market. There is no long-term contract.
- **Financial Instruments:** Merchant Debt Facilities, Concessional Debt (CEFC/ADB), and Corporate Equity.
- **Rationale:** Traditional banks will typically refuse to fund a pure merchant battery, or they will heavily "de-rate" the projected merchant revenues, requiring a high (e.g., 60-70%) equity contribution. To build these batteries, developers leverage state-

backed institutions (e.g., the CEFC in Australia), which acts as a first-mover lender to absorb risk, allowing commercial banks to confidently join the syndicate.

Case 3: Government Underwritten (e.g., Australia's Capacity Investment Scheme - CIS)

- **Profile:** The battery wins a revenue floor under a state scheme. If market prices drop below a certain threshold, the government pays the difference. If prices skyrocket, the developer shares the upside with the taxpayer.
- **Financial Instruments:** Hybrid Merchant-Infrastructure Project Debt.
- **Rationale:** The CIS framework acts as a structural gamechanger for project financing. Because the government guarantees a financial floor, commercial banks treat the "floor" portion as a contracted utility asset (allowing high leverage and low interest) while treating the upside as a merchant kicker, creating a highly efficient capital structure.

Part 2: BESS investment opportunities in Asia – a highly diverse landscape

Asian markets theoretically have large investment opportunities for ESS due to rapidly growing energy needs and a stated ambition to decarbonize energy systems. However, significant differences in ESS and BESS regulation, electricity market development, and policy ambition exist across the region Asia (including Australia).

In the hitherto most comprehensive survey of Asian markets[14], the following analyses provides investors with an overview of BESS opportunities in different Asian markets. The analysis – based on a regional survey, interviews and desk research from February 2026 to July 2026, evaluates FTM ESS opportunities, behind-the meter ESS opportunities, and policy-driven ambitions across 14 major Asian markets. It also evaluates specific business cases in Indonesia and Pakistan to highlight how investors must properly comprehend different markets if they want to be successful.

Front-of-the-meter BESS opportunities in Asia

Front-of-the-meter (FTM) ESS business opportunities (such as utility-scale BESS operated e.g., for hybrid or stand-alone batteries) are driven by two main factors:

- **Policy settings supporting BESS business models**: Asian economies have varying support for different BESS business models such as arbitrage, ancillary services or revenue stacking, some with explicit support, some with explicit bans, some with a lack of regulation
- **Electricity arbitrage**: price differentials in a wholesale electricity market allows for tariff differentials between buying and selling price, supporting the economics of an arbitrage business models

Policy setting for energy storage in Asia

Asian countries have varying policy settings that impact which business models have regulatory support or restrictions.

Table 11 shows for different Asian countries, whether major revenue models and revenue stacking of different models is supported. Of particular interest are energy storage without generation, hybrid to generate and store electricity in one facility, virtual power plants to combine BTM storage systems to sell to the grid, capacity payments, ancillary services, reserve services.

Australia and Viet Nam, for example, enable and support all business models, while Malaysia, Pakistan, South Korea, Taiwan, Thailand have significant limitations in supporting business models.

The survey of expert, however, also suggest that countries like Lao PDR and to a lesser extent Vietnam and Pakistan do not directly restrict business models through regulation but rather lack policies that make the various business models feasible (e.g., pricing for ancillary services, reserve services etc.).

Table 11: Policy support and restrictions for ESS business models in Asia

Country/ Economy	Storage/ energy trading without generation*	Hybrid**	Virtual Power Plants***	Capacity payment#	Ancillary services##	Reserve services###	Revenue stacking####
Australia	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bangladesh	Yes	Yes	X	Yes	Yes	Yes	Yes
China	Yes	Yes	Yes	Yes	Yes	Yes	Yes
India	Yes	X	Yes	X	Yes	Yes	Yes
Indonesia	Yes	Yes	X	Yes	Yes	Yes	Yes
Lao PDR	Yes	Yes	Yes	Yes	X	X	Yes
Malaysia	X	Yes	X	X	Yes	X	X
Pakistan	(X)	Yes	(X)	X	X	X	Yes
Philippines	Yes	Yes	Yes	Yes	Yes	Yes	X
South Korea	X	Yes	X	X	X	X	X
Taiwan	Yes	Yes	X	X	X	Yes	X
Thailand	X	Yes	X	X	X	X	X
Viet Nam	Yes	Yes	Yes	Yes	Yes	Yes	Yes

* buy low, sell high - including peak shaving
** combination of generation and storage in one facility for more continuous energy deployment
*** digital combination of multiple batteries into one "virtual" large battery to be dispatched, including residential batteries
# battery exists to maintain capacity and is only discharged to provide sufficient system capacity
e.g., frequency containment, voltage control
e.g., blackstart and outages
e.g., bundling of various of the above business models

Yes – business model allowed or not prohibited
(X) – business model not supported but not prohibited
X – business model not supported

Interestingly, several Asian countries (e.g., Malaysia, Philippines, South Korea, Taiwan and Thailan) currently do not support revenue stacking. This significantly limits revenue streams of BESS for investors. Box 7 highlights how a limitation on revenue stacking undermines battery storage investment.

Box 7: The financial cost of revenue stacking limitations in Asia

The restriction on revenue stacking across half of the surveyed Asia-Pacific economies (such as the Philippines, Taiwan, and Malaysia) represents a severe drag on project economics. In mature markets like Australia, where stacking is permitted, an asset can capture a base margin from wholesale day-ahead arbitrage and lift its total gross margin by layer-fusing real-time balancing mechanisms and ancillary frequency control.

When regulators force a strict separation between energy trading and grid-support services, the financial impact is twofold:

- **Asset Underutilization and Extended Paybacks:** A battery sized and optimized for a single revenue stream operates with significant idle capacity. For instance, an arbitrage-only battery sits unutilized during flat pricing windows when it could otherwise provide valuable local frequency containment. Without the ability to monetize these secondary windows, the asset's asset turnover ratio drops, extending typical project payback periods from an optimal 5–7 years to over 11 years, making it unbankable for non-concessional commercial equity.
- **Inability to Absorb Volatility Squeezes:** Single-revenue assets are entirely exposed to market saturation. As demonstrated by the rapid decline of standalone ancillary revenues in early-mover markets, a battery relying solely on grid-stability payments faces a revenue cliff once total regional BESS capacity expands. Stacking acts as a portfolio hedge; prohibiting it means investors bear the unmitigated downside of localized policy or price shocks in that single chosen stream.

In economies maintaining these prohibitions, project viability hinges on limited revenue models, many of which are not available in these markets (see below), including high, fixed Time-of-Use (ToU) industrial tariff spreads or mandatory integration mandates for renewable generators (e.g., in the Philippines).

To strengthen revenue streams (particularly in economies without revenue stacking), some governments provide subsidies for BESS installations as shown in Table 12: Few economies, including Australia, India, and South Korea offer subsidies for residential, industrial and utility scale solar, while only Australia, India, South Korea and Thailand offer some subsidy for utility scale solar.

Table 12: Subsidies for energy storage across Asian countries (X means subsidy or government support available)

Country/ Economy	Subsidies residential	Subsidy industrial	Subsidy utility
Australia	X	X	X
Bangladesh			
China			
India	X	X	X
Indonesia			
Lao PDR			
Malaysia		X	
Pakistan			
Philippines			
South Korea	X	X	X
Taiwan		X	
Thailand		X	X

Viet Nam

Overall, business opportunities for FTM BESS in Asia are limited to few more developed economies (e.g., Australia, China, South Korea). Other Asian economies countries would need to provide concessional finance (e.g., blended finance, guarantees) or public finance to attract investors and accelerate BESS development under current regulatory regimes.

Electricity arbitrage

Electricity arbitrage depends on the ability to buy electricity at low and sell at higher prices. This depends on market design where electricity can be traded between producers and consumers (BESS – as a third asset class – is both a provider and consumer) at volatile market prices driven by supply and demand or, alternatively, based on contracted values where contracts can have different time durations.

As can be seen in Table 13, most economies across Asia Pacific either have long-term contracts (e.g., Bangladesh, Indonesia, Lao PDR) or hybrid markets with some elements of energy markets and long-term contracts (e.g., China, Pakistan, India). Only few have fully open markets that allow for short-term energy trading based on supply and demand (e.g., Philippines, Singapore, South Korea). This overall limits possibilities for BESS investors to benefit from arbitrage.

Furthermore, as can also be seen in Table 13, the daily price spread in economies with some elements of a wholesale electricity market are also diverging – with high spreads in economies like Australia, Philippines, to a lesser extent China, India, and Pakistan, while South Korea's market has very low spreads.

Box 8 highlights how Pakistan's electricity price has been evolving in a wholesale electricity market that has been emerging in 2026.

Table 13: Energy market designs across Asia and opportunities for BESS arbitrage

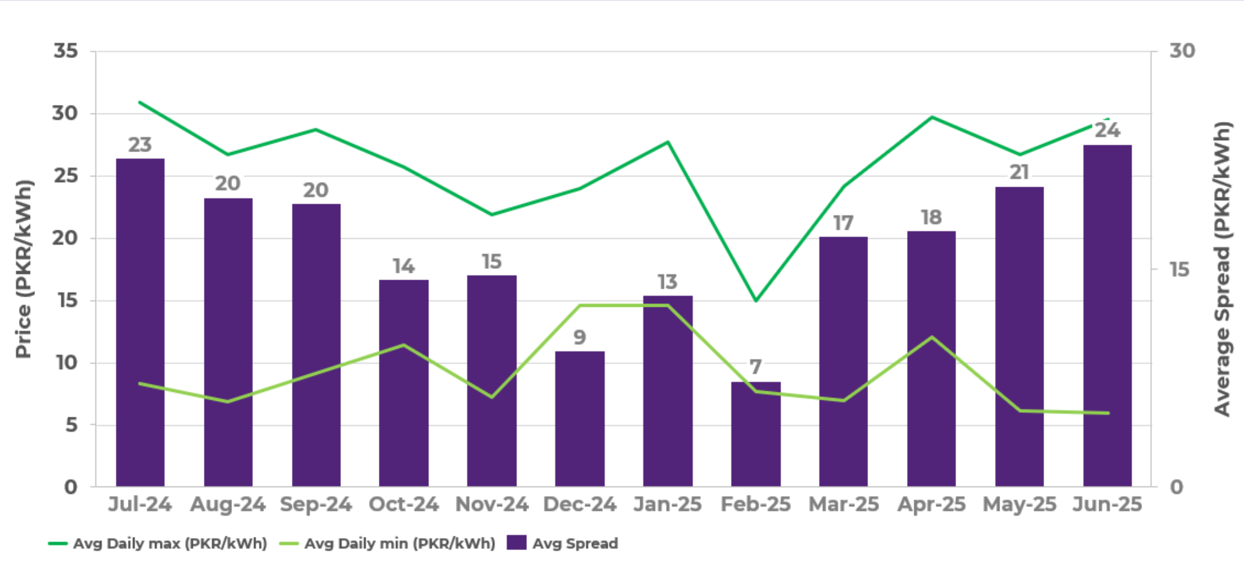
Country/ Economy	Energy market	Daily spread (in summer) (USD/MWh)	Opportunity for arbitrage
Australia	market	200	High
Bangladesh	long-term contracts		Low
China	hybrid - mid-to long term with growing real time trading	110	High
India	hybrid - mid-to long term with growing real time trading	100	High
Indonesia	long-term contracts		Low
Lao PDR	long-term contracts		Low
Malaysia	regulated prices		Low

Pakistan	hybrid - mid-to long term with bilateral competitive market emerging	70	Medium
Philippines	market	170	High
Singapore	market	70	High
South Korea	market	10	Low-medium
Taiwan	long-term contracts		Low
Thailand	long-term contracts		Low
Viet Nam	hybrid - mid-to long-term contracts with growing share and new regulations accelerating real time trading	minimal	Low-medium

Box 8: Arbitrage opportunities in Pakistan

Pakistan is planning to commence trading electricity on wholesale markets. While the market is expected to become operational later in 2026, variations in the system marginal price provide an indication of the potential price spreads that could support energy-storage arbitrage once market trading begins.

Monthly daily spreads show how the strength of this arbitrage window varies across the year. Spreads are generally wider in the warmer months, averaging around Rs 21/kWh from May to September, and narrower in winter, averaging around Rs 10/kWh from December to February. This suggests that storage would likely find stronger charge-and-discharge differentials in the warmer half of the year.



Monthly Average Spread available for Arbitrage

Behind-the-meter energy storage opportunities in Asia

The feasibility of BTM ESS (e.g., at homes, at industrial sites) is impacted by four factors:

- **High tariffs** for residential and/or industrial consumers lead to a search for alternative and cheaper "at home" electricity sources and energy storage solutions
- **Peak demand charges** where residential or industrial users pay significant extra cost for peak demand for power or voltage in a specific period.[iii]
- **High tariff spreads** particularly for ToU tariffs, can provide incentives for household and industry to install BTM energy storage to reduce peak loads during peak tariff times. This requires net metering and **net billing**[iv] for electricity generating units that swap extra capacity at peak production times for drawing capacity at low production times to utilize a price differential between selling price (i.e., selling excess electricity at lower cost) and buying price (i.e., buying electricity at a higher price).

High tariffs and peak demand charges as a driver for behind-the meter ESS

Economies with high electricity tariffs can be expected to have a high potential for BTM energy storage installations. Table 14 shows the average[v] residential and commercial tariffs as well as the peak demand charges for industrial uses across various Asian economies.

Higher tariffs marked in darker green shading signal stronger opportunities for cost saving through BESS, available in economies like Australia, Pakistan, Philippines, Singapore for residential tariffs. For industrial tariffs, Australia, Singapore, Philippines and Taiwan have high tariffs, offering potential cost saving through combined BTM generation and storage. No country but Australia has a peak demand charge for residential users.

Table 14: Average tariff levels for residential and industrial users, and high-demand charges (color code: dark green more suitable for behind-the-meter (BTM) energy storage)

Country/ Economy	Residential tariff (average)	Industrial tariff (average)	Peak demand charges for industry (USD/KW or *USD/KW month)	Peak demand charges explanation	Behind-the meter energy storage opportunity

[iii] An example is Australia, where both residential and industrial consumers are charged daily for their peak load. As an Australian residential consumer, for example, the highest load during peak times (about 4-9 pm) will be multiplied with a factor of e.g., 0.20 AU$/kW. If the highest use during that time is 8 kW, the user will pay 1.60 AU$ for that day, if the peak would be 4kW, the user would pay 0.8AU$ for that day.

[iv] For behind-the-meter ESS that utilize ToU tariffs to charge from or discharge to the grid, net metering and net billing are essential. This is not strictly necessary for self-consumption batteries that do not sell back to the grid and do not rely on ToU tariffs.

[v] The average is calculated between the highest bracket and lowest bracket for either ToU or fixed tariffs.

Australia	0.1895	0.18665	18.67	Max KW per day in peak tariff window	High
Bangladesh	0.08185	0.10275	1		Low
China	0.115	0.1276	5	Mandatory monthly capacity fee for transformer capacity exceeding 315 kVA	Medium
India	0.1065	0.12235	3.5	High voltage entities pay fixed capacity overhead charge calculated using a 15-minute max demand tracker	Medium
Indonesia	0.09115	0.0729	1		Low
Lao PDR	0.08	0.07015			Low
Malaysia	0.09535	0.0711	8	Peak 30-minute demand between 8 am and 10 pm	Low
Pakistan	0.225	0.10455	5.39	Peak capacity during grid stress window	High
Philippines	0.2383	0.2427	5		High
Singapore	0.2212	0.17775			High
South Korea	0.1	0.1095	*3.1		Low
Taiwan	0.1	0.1614	0.25	Spike over registered capacity hit with 100-200% extra tariffs	High
Thailand	0.145	0.10855	*5	Single highest 15-minute load spike/month	Medium
Viet Nam	0.08355	0.10785		Maximum capacity threshold	Low

Tariff spreads driving behind-the meter BESS for load shifting

For an arbitrage model to work BTM, differences between buying and selling price of electricity throughout the day must be significant, which is typically only possible in countries with Time of Use (ToU) tariff structures (for either or both residential and industrial consumers).

Most surveyed countries (except for Philippines, Lao PDR and Singapore) have ToU tariffs as an option for industrial tariffs. This **provides some opportunities for either FTM (as well as BTM) usage of ESS** to buy at lower prices and sell at higher prices.

Table 15 summarizes the findings of the different countries and to what extend arbitrage ESS business models are feasible.

Table 15: Select Asian countries' residential and industrial tariff systems

Country/ Economy	Provider	Residential Standard Tariff	Residential ToU option	Industrial Standard Tariff	Industrial ToU option	Cost avoidance ESS business model theoretical feasibility
Australia	NEM, DISCOs	ToU	Yes	ToU	Yes	Yes
Bangladesh	BPDB/DESCO Network	Fixed	Yes	Fixed	Yes	Limited
China	State Grid (and other SOEs)	ToU	Yes	ToU	Yes	Yes
India	State DISCOs	Fixed	Yes	Fixed	Yes	Limited
Indonesia	PLN	Fixed	No	Fixed	Yes	Industrial
Lao PDR	EDL	Fixed	No	Fixed	No	No
Malaysia	TNB	Fixed	Yes	Fixed	Yes	Limited
Pakistan	NEPRA, DISCOs	Fixed	Yes	Fixed	Yes	Limited
Philippines	Meralco Grid	Fixed	Yes	Fixed	Yes	Limited
Singapore	SP Group / Open Electricity Market	Fixed	Yes	Fixed	Yes	Limited
South Korea	KEPCO	Fixed	No	ToU	Yes	Industrial
Taiwan	Taipower	Fixed	Yes	Fixed	Yes	Limited
Thailand	Metropolitan Electricity Authority/ Provincial Electricity Authority	Fixed	Yes	Fixed	Yes	Limited
Viet Nam	EVN	Fixed	No	Fixed	Yes	Industrial

Table 16 shows the tariff spreads for residential and commercial ToU tariffs across select Asian economies. Australia and Taiwan have significant spreads between different times of up to USD 0.30 per kWh, making arbitrage models feasible. Meanwhile Indonesia, Philippines, Malaysia, Lao, Thailand as well as Vietnam have no or low feasibility for arbitrage due to low or no price spread between different times of the day.

Table 16: Time of Use (ToU) tariff spread across Asian economies for residential and commercial tariffs

Country/ Economy	Residential ToU tariff spread	Industrial ToU tariff	Cost avoidance

	(USD/kWh) except India	spread (USD/kWh)	model feasibility
Australia	0.281	0.1867	High
Bangladesh	0.0618	0.0379	Medium
China	0.17	0.2	High
India	40%	0.0549	Medium
Indonesia	0	0.0268	No
Lao PDR	0	0.0185	No
Malaysia	0.009	0.034	No
Pakistan	0.0265	0.0557	Low
Philippines	0.035	0.005	No
Singapore	0.2	0.1185	Medium
South Korea	0	0.101	For industrial
Taiwan	0.186	0.2018	High
Thailand	0.0413	0.0103	Low
Viet Nam	0	0.1171	Medium

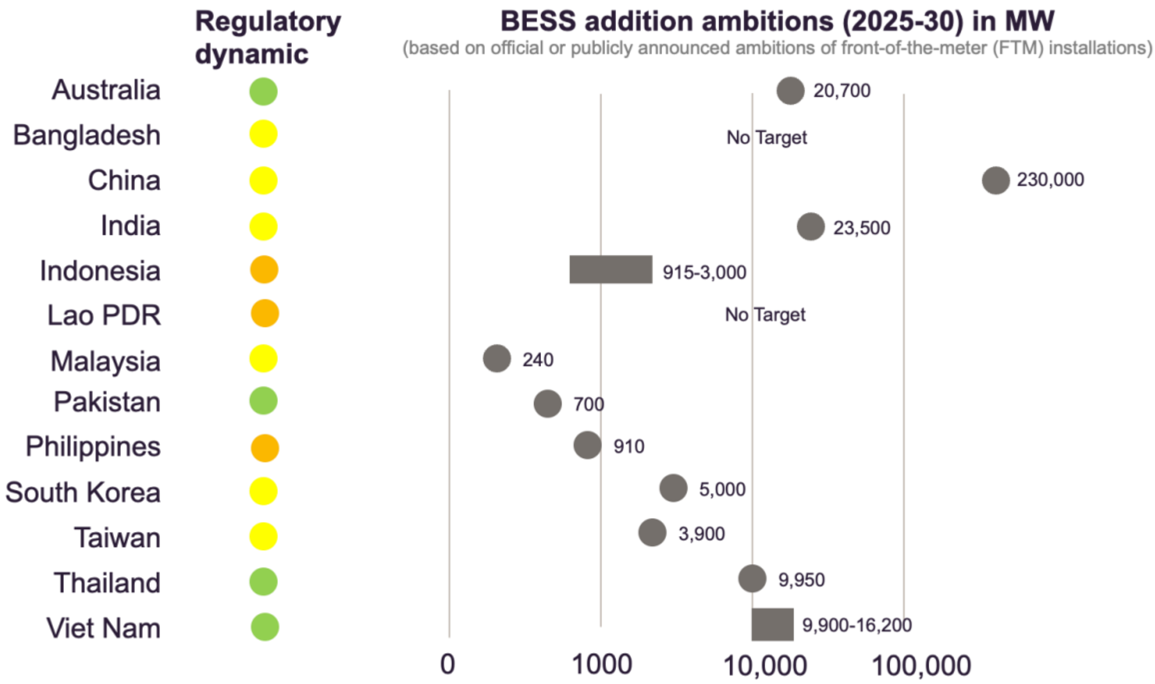
Policy ambitions driving future ESS opportunities in Asia

Looking at future policy ambitions of Asian economies to support ESS and BESS in particular, the survey suggests varying levels of ambitions regarding both stated installation goals and business model support policies.

Some notable examples of new ambitions include South Korea, where it is expected that the government will expand ESS Central Contract Market and use Jeju as an arbitrage pilot to other regions. In Viet Nam, ancillary pricing is expected to be provided soon while BESS might participate in the wholesale electricity market. In Taiwan, changes to allow revenue stacking across multiple grid programs are anticipated while cash subsidies are being phase down. In the Philippines, new variable renewable energy facilities of 10 MW or more must integrate storage equal to at least 20% of their capacity since 2026[15].

The following provides a sentiment tracker of expected policy changes with dark green shading signaling stronger policy ambitions. It shows that many Asian economies like Thailand, Viet Nam and Australia have significant ambitions to improve investor landscapes for BESS, while few countries, e.g., Lao PDR and Indonesia still have significant room to strengthen their ambitions.

Figure 9: Policy ambitions across Asian economies for BESS[vi]



Summary of BESS investment opportunities in Asia

As the above analysis highlights, Asian economies including Australia have varying degrees of business opportunities for BESS in 2026 both for FTM and BTM BESS.

Figure 10 provides the overall summary. As can be seen, overall, Australia remains the most competitive market for BESS investment due to its strong regulatory dynamic, in-front-of meter and BTM business opportunities. Bangladesh also has some positive dynamic particularly for FTM, which would be strengthened if arbitrage opportunities could be improved. China and India both provide significant opportunities for FTM (utility) BESS. Near future opportunities are particularly to be expected in Pakistan and Vietnam, and potentially Thailand and Philippines.

[vi] Regulatory dynamic based on evaluation of answers from interviews and survey,

Figure 10: Summary of Asian BESS investment opportunities

BESS investment case studies in Asia

The following chapter summarizes the results from an extensive simulation of BESS opportunities in Pakistan and Indonesia (both simulation studies are published separately to this guidance). Pakistan and Indonesia were chosen due to their different electricity market systems with Pakistan having experienced a rapid growth of rooftop solar since 2024, having a more open market with varying IPPs and even distribution companies as well as having relatively high electricity prices. Meanwhile, Indonesia is a highly concentrated electricity markets dominated by the state-owned PLN with low electricity prices, yet many microgrids due to its geography with many islands.

Pakistan Bhikki Power Plant – from gas to hybrid

Executive business overview

- The **Bhikki Power Plant** is a 1,180 MW RLNG based combined cycle power plant
- Pakistan's duck curve is increasingly pushing thermal plants including Bhikki into deep part-load operation and steep daily ramps, increasing PLAC exposure for consumers.

- Bhikki illustrates this stress clearly: in FY2025, the plant operated below 80% of dependable capacity for 4,638 hours and below 50% for 1,771 hours, including sharp swings and daytime shutdowns.
- A 200 MW / 800 MWh BESS can cover around 49.6% of Bhikki's dispatch-smoothing requirement, reducing deep cycling and supporting more stable plant operation.
- Applying this coverage to Bhikki's annual PLAC exposure gives an indicative avoided PLAC value of around PKR 5.85 billion (USD 21.1 million) per year.
- The business case is attractive under base assumptions, with USD 100 million CAPEX, year 1 net cash flow of USD 18.8 million, 16% IRR, USD 39.7 million NPV, and a simple payback of around 6 years.

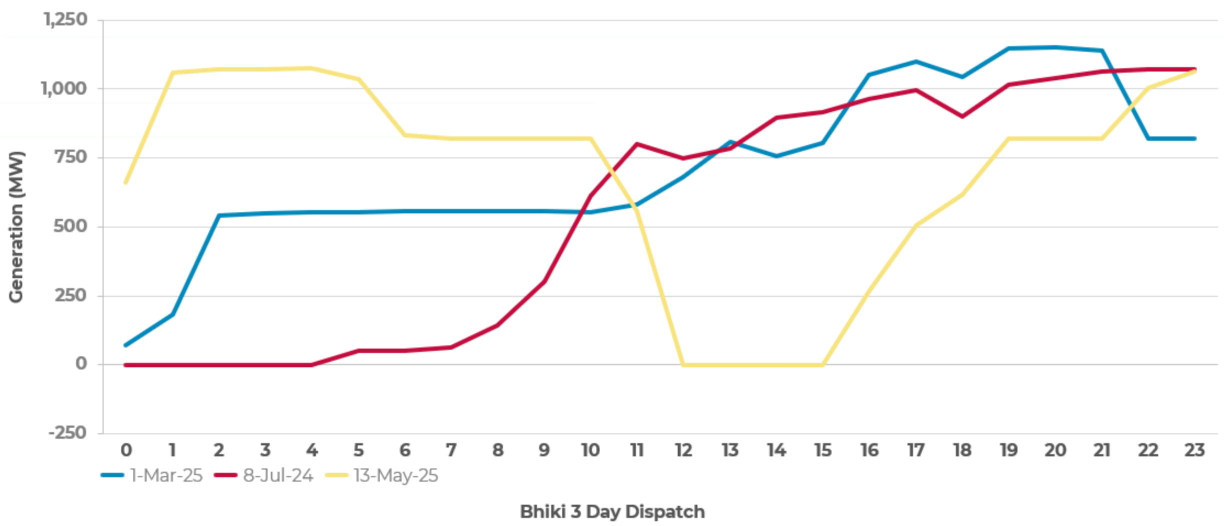
Introduction

The Bhikki power plant is located near Sheikhupura, in the Punjab province of Pakistan (see Figure 11). The plant is owned and operated by Quaid-e-Azam Thermal Power Limited (QATPL), a company wholly owned by the government of Punjab. The plant commenced commercial operations on May 20, 2018.

Figure 11: Location of Bhikki power plant Pakistan

Bhikki provides a solid example of how the duck curve is reshaping thermal dispatch in Pakistan. The 1,180 MW RLNG-fired combined-cycle power plant was designed to operate as a high-efficiency baseload or intermediate-load facility. However, in 2025 dispatch data reveals a markedly different operational reality. On several days, the variation was higher than commercially feasible due to the decline in demand based on significant solar PV production. This led to a difference between peak and low demand of approximately 1,080 MW on 1 March, a complete shutdown during solar-rich hours on 13 May, and a near zero-to-full ramp on 8 July (see Figure 12).

Figure 12: Bhikki, 3 Day Dispatch



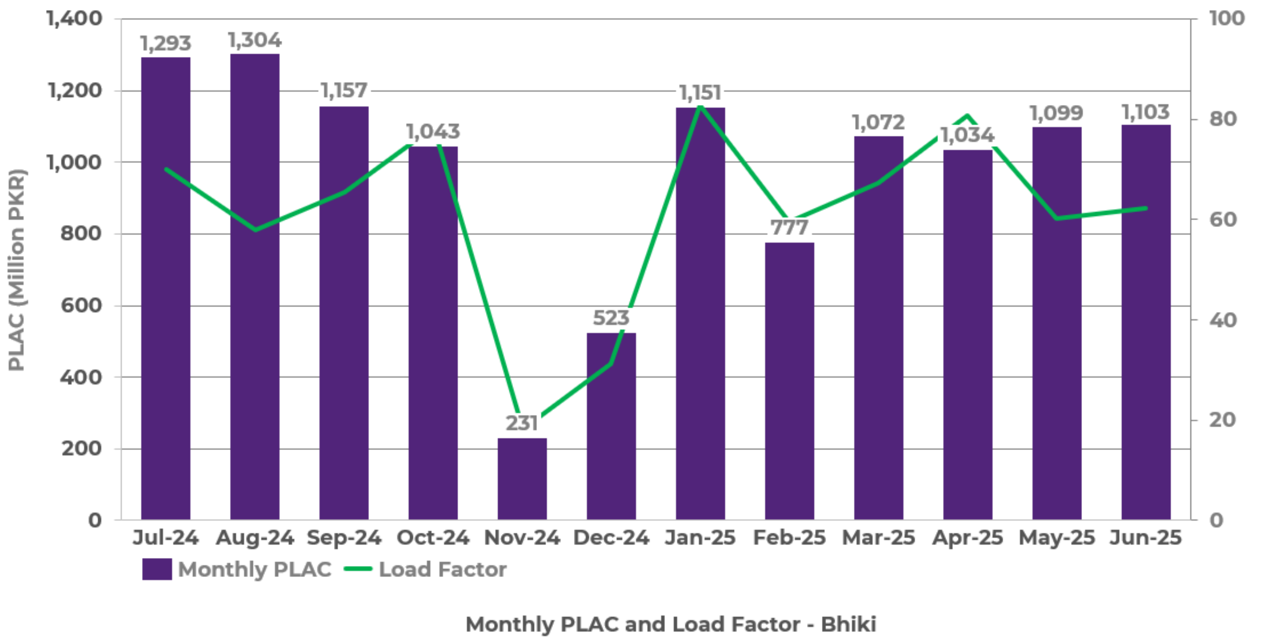
These operating patterns demonstrate that Bhikki is increasingly being used as a flexibility resource rather than a conventional baseload or intermediate-load plant. In 2025, the plant frequently operated below efficient loading levels, including extended periods below 80% and 50% of dependable capacity (see Table 17).

Table 17: Operational Characteristics of Bhikki

Benchmark	Hours below threshold	Share of year
Offline / zero generation	1,337 hrs	15.2%
80% of dependable capacity	4,638 hrs	52.9%
50% of dependable capacity	1,771 hrs	20.2%

The financial consequences of this operating pattern are reflected in recurring partial load adjustment charges (PLAC) (see Figure 13).

Figure 13: Monthly partial load adjustment charges (PLAC) and load factor - Bhikki



BESS-Based Flexibility Solution

A battery co-located with Bhikki, or located near the relevant load centre, can reduce the short-duration variability currently being imposed on the thermal plant. Rather than requiring Bhikki to follow sharp intra-day ramps, the battery can absorb part of the downward dispatch movement by charging and support upward movement by discharging. This allows the plant to operate on a smoother profile, reducing abrupt cycling, deep part-load operation, and the operating conditions that contribute to PLAC exposure.

The BESS case is therefore modelled as a dispatch-smoothing intervention.
The objective is to reduce sharp ramps and avoid deep operating dips where feasible.

We assumed 125 MW/hour ramp-smoothing constraint and a 50% minimum operating threshold of 565 MW, while keeping zero-generation/offline hours separate. A 200 MW / 800 MWh BESS is then simulated chronologically across the full 8,760-hour FY2025 dispatch profile (see Table 18). The battery charges when smoothing require Bhikki to generate above actual dispatch and discharges when smoothing require support above the revised plant output (see Figure 14)

Figure 14: Bhikki Dispatch Smoothing with BESS - 1 March 2025

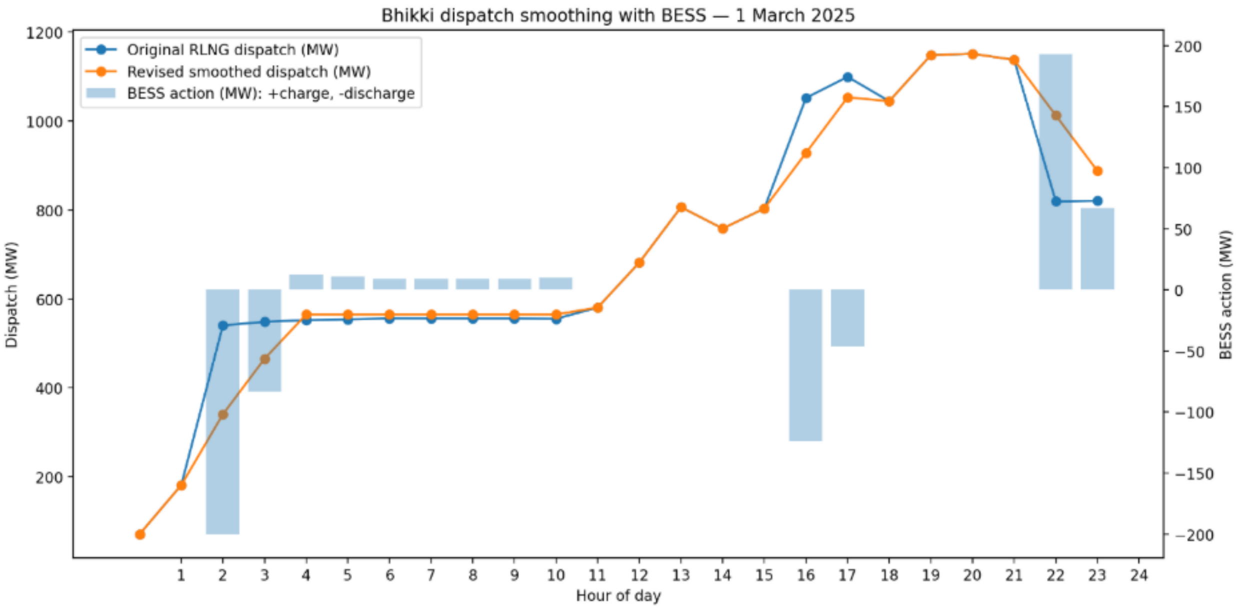


Table 18: Key Assumptions for Bhikki

Parameter	Value
Dependable capacity	1,130 MW
Minimum operating threshold	565 MW
Ramp-smoothing limit	125 MW/hour
BESS power rating	200 MW
BESS energy capacity	800 MWh
Required smoothing adjustment	166,820 MWh
BESS-covered adjustment	82,690 MWh
Smoothing coverage	49.6%

On this basis, the 200 MW / 800 MWh BESS is estimated to cover approximately 49.6% of the relevant dispatch-smoothing requirement. This coverage factor is used as a practical proxy for the portion of PLAC exposure linked to operational flexibility stress that could be reduced through storage. Applying this to Bhikki's annual PLAC exposure gives an indicative avoided PLAC value of approximately PKR 5.84 billion per year. Actual PLAC recovery will depend on dispatch instructions, contractual treatment, heat-rate curves, start-stop costs, market settlement rules, and the operational availability of the BESS.

The financial model evaluates PLAC avoidance as the primary value stream. The model is built on the following inputs (see Table 19):

Table 19: Key Assumption of BESS's in Bhikki

Parameter	Value
Power rating	200 MW
Energy capacity	800 MWh (4-hour)
Round-trip efficiency	90%
Cycles per year	300
Installed Cost (CAPEX)	USD 125/kWh
Project Life	20 years
Discount Rate	10%
Annual PLAC Exposure	PKR 11,788 million / USD 42.1 million
PLAC Coverage	49.6%

These operational features allow for the battery to provide a 16% IRR, and a simple payback after 5.57 years, and similarly a discounted payback after 8.86 years. Table 20 shows the summary of the investment.

Table 20: Summary of the Results for Bhikki

Total CAPEX	USD 100 million
Year 1 net cash flow	USD 18.8 million
IRR	16%
NPV @ 10%	USD 39.7 million
Simple payback	5.57 years
Discounted payback	8.86 years

Indonesia - co-locating BESS with diesel generators (e.g., microgrids on islands)

Indonesia's electricity system, which is dominated by the state-owned power company PLN acting as main generator, transmission and distribution company, operates multiple large and small grids. Due to the current market structure with no wholesale market, low and constant prices (without ToU), and long-term planning based on various policy documents with little market design, the main grid is currently growing BESS only due to policy goals. However, with many micro-grids serving various small island communities dependent on diesel generators, we identified opportunities in co-locating BESS with diesel generation to lower fuel cost and thus provide a return on investment for BESS installations. Yet, as the analysis shows, different diesel-hybrid systems have different investment returns.

Executive business overview

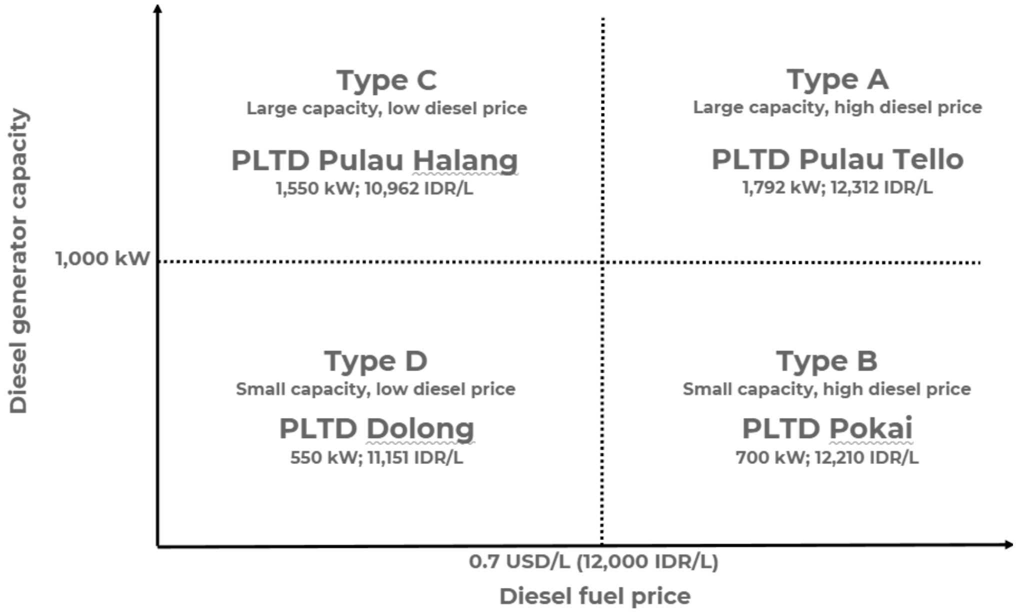
- Co-located BESS with diesel-hybrid systems has an estimated national market pipeline of 0.5 GWh to 2.0 GWh, representing a BESS market value of USD 100 million to USD 200 million.
- Project location assessment is divided into four distinct archetypes (Types A, B, C, and D) based on localized diesel generation capacity and localized fuel prices.
- Type A (large capacity, high fuel price; Tello): the strongest archetype on both axes. Optimal solar share rises from ~40% to 70-80% as battery costs fall, LCOE drops up to 40% to $0.20-0.25/kWh, IRR 12-18%, and BESS capacity scales close to fourfold. Strategy: anchor asset for large-ticket capital, staged to scale up as battery prices fall.
- Type B (small capacity, high fuel price; Pokai): same fuel-price economics as type A, similar LCOE gain and IRR, but a small ticket per site. Strategy: margin play built on volume, replicating one standardised configuration across many high-fuel-cost sites.
- Type C (large capacity, low fuel price; Pulau Halang): scale without margin. Cheap diesel caps solar at ~20% and LCOE gains at ~25%, with no return under conservative capital costs. Strategy: secure the pipeline now, defer construction until battery costs fall or tariff support closes the gap.
- Type D (small capacity, low fuel price; Dolong): weakest fundamentals, diesel still ~80% of the mix, yet the site clears the hurdle on solar resource alone. Strategy: selective entry screened site-by-site on irradiation and delivered capital cost, with the lowest capital at risk.
- Near-term investment feasibility for this entire diesel-hybrid segment is high due to clear operational value from diesel fuel savings and a viable existing procurement mechanism.

Introduction

Co-located BESS with diesel hybrid system has presented a lucrative market segment for BESS development in Indonesia. Historically, diesel generators have been the default power source for remote Indonesian regions unreachable by PLN, where low localised demand fails to justify expensive grid expansion. Energy security and rising diesel prices have started to drive the shift towards solar PV + BESS as diesel replacement.

To further evaluate the viability of this business model, the potential diesel replacement sites are categorized into four distinct quadrants based on two primary variables: diesel generation capacity and localized diesel fuel price. A representative site from each archetype is modelled using HOMER Pro to determine key technical and financial metrics, including the LCOE, IRR, and the total investment potential in BESS. The matrix framework and the specific representative sites chosen for each archetype are detailed in Figure 15. Diesel power plants with large capacity (> 1 MW) and high fuel price (> 0.7 USD/L) fall into type A plants, which is the most favorable category in terms of investment return and scale of project. Type B represents diesel power plants with small capacity and high fuel price, while type C represents the opposite (large diesel capacity, low fuel price). Type D represents diesel power plants with low fuel price and small capacity, which is generally less favorable compared to other categories.

Figure 15. Diesel replacement site archetyping and representative sites



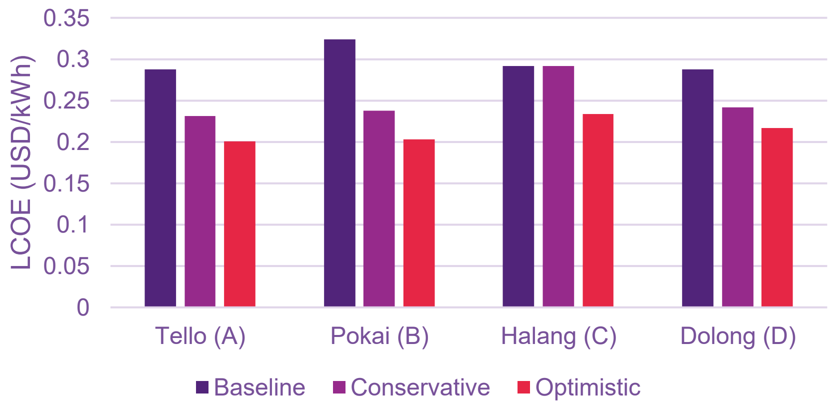
The optimisation shifts reveal different behaviours based on localised fuel prices and diesel generator capacity:

- Types A and B - Tello and Pokai: For both Tello and Pokai, high localised fuel prices create an aggressive economic incentive to displace diesel. Under conservative technology costs, the optimal mix hovers around 40% solar PV contribution, running primarily as a daytime fuel saver. However, when storage costs fall by 37.5% in the optimistic scenario, the economic threshold crosses into deep load-shifting. The optimal solar contribution surges to 70% - 80%, meaning the hybrid system runs almost entirely on clean energy, keeping the diesel generator on standby purely for low-solar contingencies or night peaks.
- Type C and D - Pulau Halang and Dolong: Even in the optimistic scenario, solar PV penetration only increases to only around 20%, leaving diesel as the dominant power source (80%). Because of low fuel costs, the financial penalty of burning diesel is low. Consequently, it remains uneconomical to build an oversized solar and battery network to chase deep nighttime load-shifting.

Business model considerations

The optimisation LCOE results demonstrate that across all four archetypes, hybridizing existing diesel assets with an optimised solar PV + BESS configuration is highly competitive. Crucially, this economic viability holds true even under conservative cost assumptions (higher CAPEX), as shown in Figure 16.

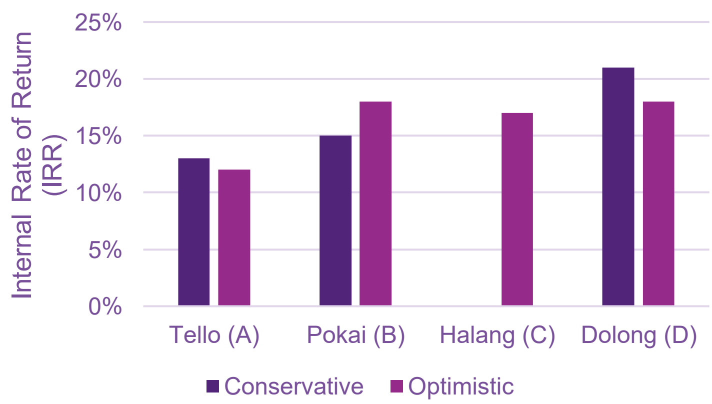
Figure 16. LCOE comparison in representative sites



Type A & B exhibits the most dramatic decrease in LCOE. The baseline LCOE for 100% diesel generation at these sites is exceptionally high (approaching \$0.60/kWh) due to the high fuel costs. Introducing a hybridised PV + BESS in the electricity mix slashes the LCOE by up to 40%, dropping it to roughly \$0.20-0.25/kWh. Meanwhile, types C and D also experience LCOE drop of up to 25% despite the diesel fuel cost are comparably lower than type A or B.

Project IRRs for type A & B sample sites ranges from 12% to 18% (Figure 17), comfortably exceeding typical hurdle rates for renewable energy projects in Indonesia. However, project return is also influenced by specific solar resources in each site, capital cost (including logistics), and diesel fuel cost. For instance, Pulau Halang site (type C) does not provide project return under conservative capital cost assumptions due to already low diesel fuel cost, but Dolong site (type D) still provide return due to favorable solar resource.

Figure 17. IRR comparison in representative sites



However, project IRR does not reveal the whole picture on the investment opportunity. As shown in Figure 18, type A and B projects present bigger investable BESS sizes due to favorable site capacity and resources paired with steady fuel savings. Consequently, the 37.5% drop in battery unit costs in the optimistic scenario translates directly into a lower total project CAPEX (**Error! Reference source not found.**).

*Figure 18. 4-hour BESS **capacity comparison** in representative sites*

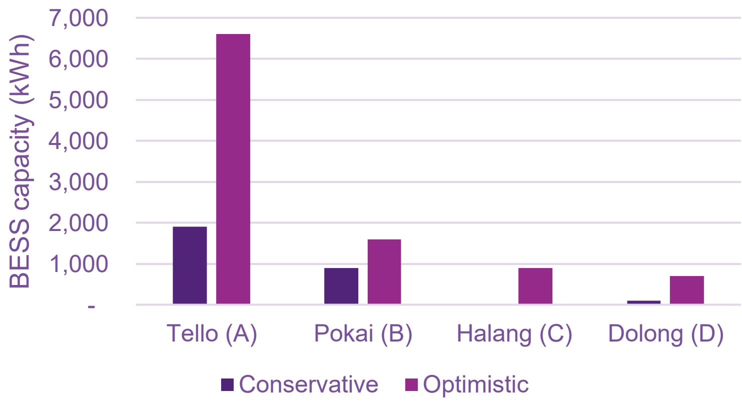
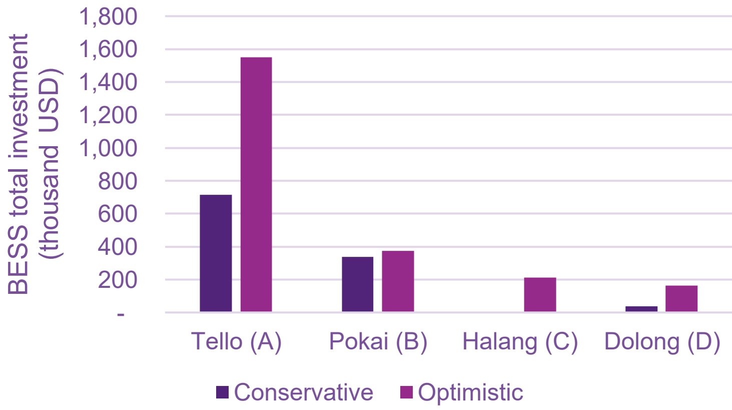


*Figure 19. BESS **total investment comparison** in representative sites*



As shown in Figure 18, the optimal BESS capacity for type A scales nearly four times due to cheaper battery costs, transforming the asset from a modest peak-shaving system into a heavy baseload displacement microgrid. Even at a lower unit cost, buying more battery capacity causes the total absolute dollar investment to skyrocket (Figure 19).

While this heavy capital injection slightly lowers the IRR due to the larger denominator in the financial equation, the high optimal BESS capacity maximizes the project's NPV, absolute fuel displacement, and long-term carbon reductions. This represents an exponential opportunity for capital deployment if investors can secure lower-priced BESS equipment.

In summary, Table 21 provides the investment guidelines for the BESS in the diesel-hybrid system.

Table 21. Investment guideline for co-located BESS in diesel-hybrid system

Project archetype	Investment Strategy	Ideal Investor Profile	Strategic Rationale
Type A (Scale Anchor)	Large-ticket, staged deployment	International IPPs, infrastructure conglomerates, and utility-scale funds.	High fuel price and large capacity combine to give both the steepest LCOE reduction of the four archetypes (up to 40%, from roughly \$0.60/kWh under 100% diesel to \$0.20-0.25/kWh hybridised) and the largest absolute BESS ticket. Optimal battery capacity scales close to fourfold

			under optimistic costs, placing the IRR at the lower end of the 12-18% band.
Type B (Margin Play)	Standardised, replicable roll-out	Mid-market Independent Power Producers (IPPs) and regional developers.	Shares the fuel-price economics of type A, with a comparable LCOE reduction and an IRR within the same 12-18% band, but a smaller capacity caps the ticket per site. Value is built by aggregating many similar high-fuel-cost sites under one standardised configuration.
Type C (Contingent Pipeline)	Option-building, deferred build	Patient infrastructure capital and incumbents with existing diesel assets.	Large capacity provides scale, but low fuel prices cap the optimal solar share at roughly 20% even under optimistic costs and limit the LCOE gain to about 25%. Best treated as a pipeline position to secure now and construct once battery costs fall further or a contractual or tariff mechanism closes the remaining gap.
Type D (Selective Entry)	Small-ticket, resource-screened entry	Local developers, agile private equity, and impact or blended-finance funds.	The weakest fundamentals on the matrix, with diesel still supplying around 80% of the mix even under optimistic costs and an LCOE reduction of up to 25%. Returns are driven by site-specific conditions rather than fuel savings. Requires site-by-site screening on irradiation and delivered capital cost.

Summary

The shift toward intermittent renewable energy across Asia positions Energy Storage Systems (ESS) as vital infrastructure for grid stability and peak load management as well as a driver enabling further expansion of the electricity system's green transition.

Driven by a 30% to 35% decline in the levelized cost of electricity (LCOE) for renewable energy stacks between 2020 and 2025, investment interest is accelerating globally, led by China and complemented by targeted regional initiatives like Australia's home battery scheme. Meanwhile, many other Asian economies are currently aiming to strengthen ESS and particularly BESS deployment.

For investors, the Asian landscape provides mixed opportunities for FTM and BTM ESS investment. Few Asian countries are accelerating their efforts to attract BESS investment, such as India, Pakistan, Vietnam with stronger regulatory design and energy market liberalization. Other economies, meanwhile, are acting slower, including Indonesia. This does not mean that these countries have no BESS investment opportunities, as our investment case from Indonesia above shows. Rather it means that investors need to clearly evaluate business opportunities and understand local market conditions and policy dynamics.

Accordingly, Asian BESS investors require a highly localized approach to navigating three core variables:

- **Business model sophistication:** While simple energy arbitrage ("buying low and selling high") is possible in some countries, improving asset returns depends on a developer's ability to identify localized revenue streams: Australia, for example, offers front-of-the-meter opportunities for large-scale and small-scale projects, while Indonesia offers mostly off-grid projects. Many countries offer significant behind-the meter opportunities, particularly those with high electricity tariffs or stacked tariffs.
- **Technology choices, sizing, and siting:** Technology is developing rapidly with falling cost and changing competitive landscapes. Early movers might benefit from better access to good asset sites either close to generation (rural co-location) to maximize access to grid, or in load centers unlocking higher-value local grid-support contracts. Investors need to understand the impact of siting on technical sizing: short-duration, high-power profiles are optimal for sub-second grid stabilization (e.g., for substations), whereas long-duration configurations are required to survive multi-hour wholesale arbitrage windows.
- **Financing Profiles:** Early movers might benefit from financial or regulatory support, including concessional financing from development finance institutions (like ADB, Islamic Development Bank), but must address less experienced markets. Various Asian economies are likely to strengthen policy support through better payment schemes and potentially subsidies (like Australia) with the goal to lower overall electricity cost for the economy.

Ultimately, successful BESS execution in Asia requires investors to also address emerging markets with some opacity around regulation and more volatile revenue streams. As in all new sectors, early investors can earn extra returns in the short-term and long-term through stronger connections and local experiences, while they must manage risks of rapidly changing markets.

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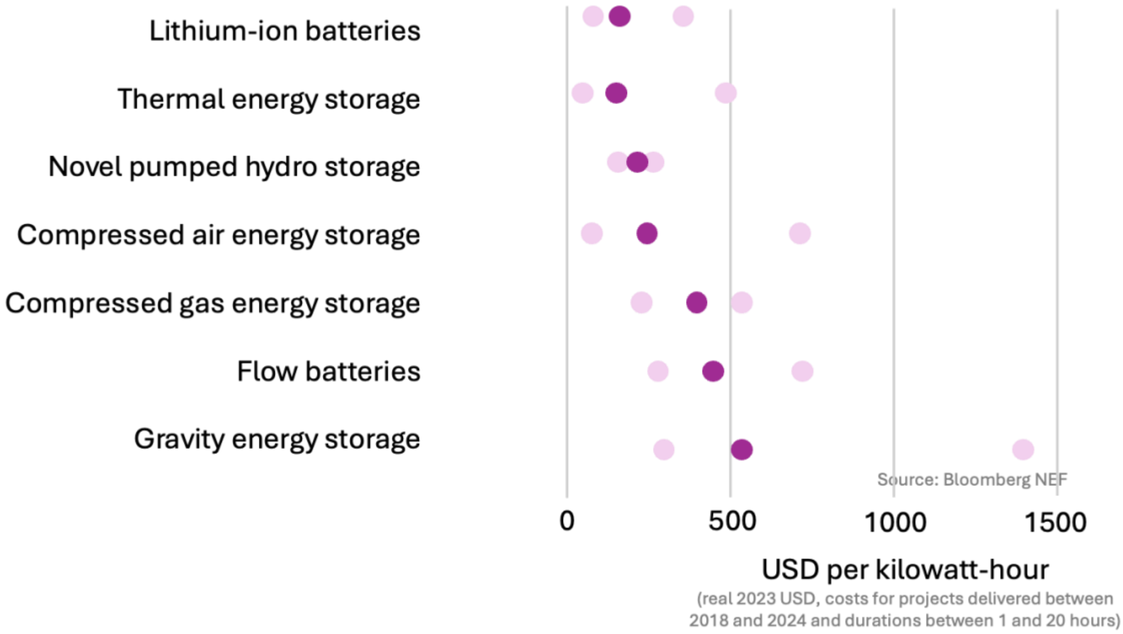
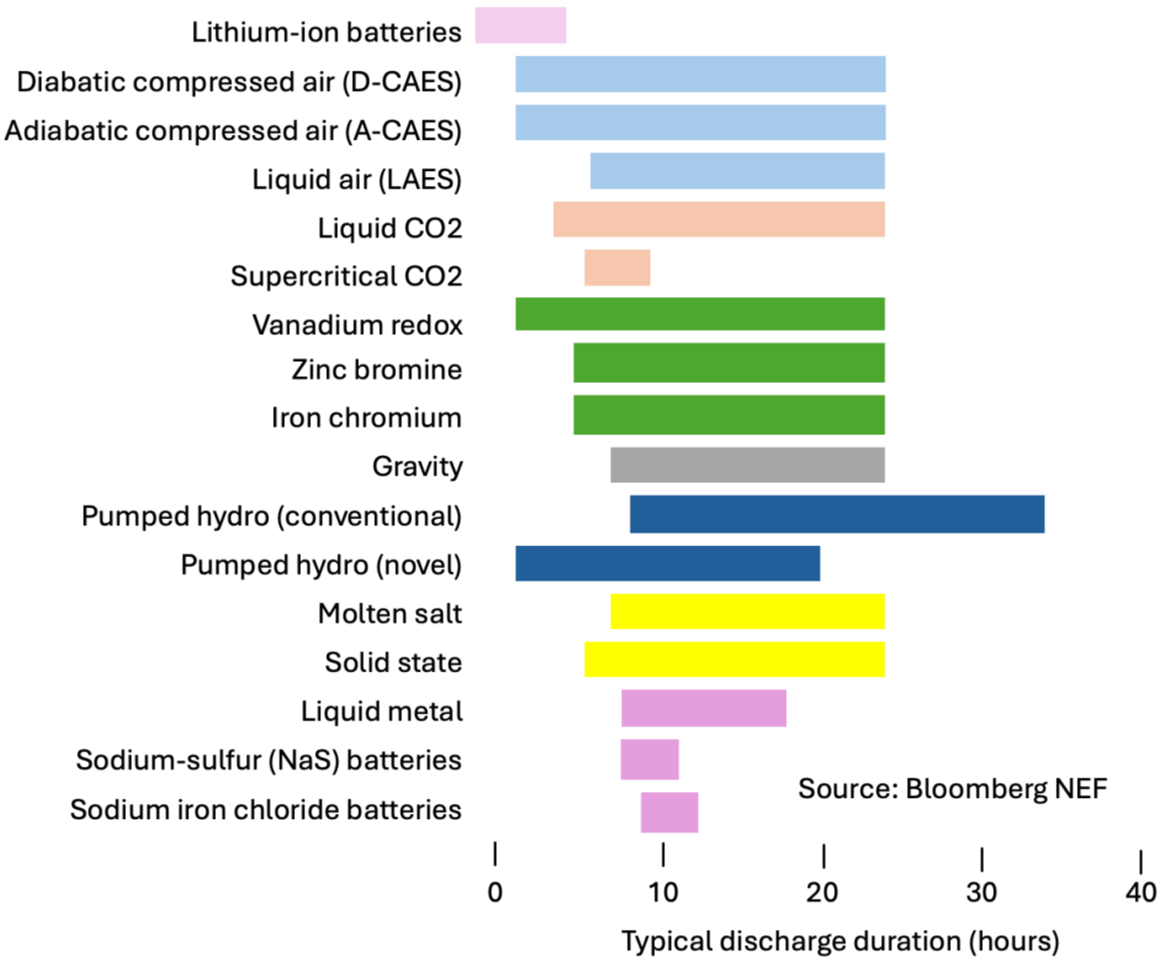
Appendix

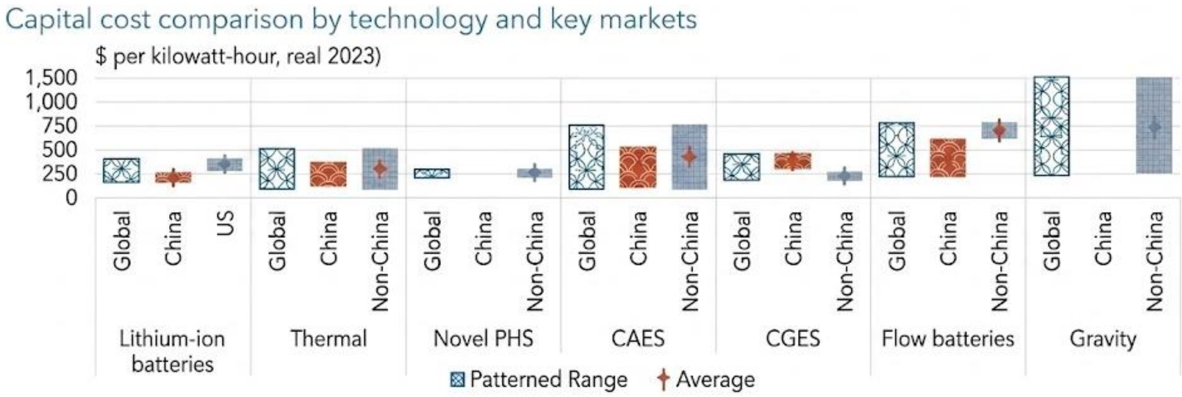
Appendix 1: Technology cost for energy storage systems[10]



Appendix 2: ESS discharge times[10]



Appendix 3: Fully installed Energy Storage Systemsaverage capex and ranges by technology, 2018-2024[16]



Note: CAES = compressed air energy storage. CGES = compressed gas energy storage. PHS = pumped hydro storage. Costs are for projects delivered between 2018 and 2024 and durations between one and 20 hours. *For novel pumped hydro, storage costs are for projects delivered between 2018 and 2030. Lithium-ion battery costs correspond to a four-hour duration system in 2023 and global ranges represent ranges of China and US.

The University of Queensland, Business School

St Lucia, QLD 4067, Australia

https://business.uq.edu.au