POLICY BRIEF

2025/10

Battery Energy Storage System

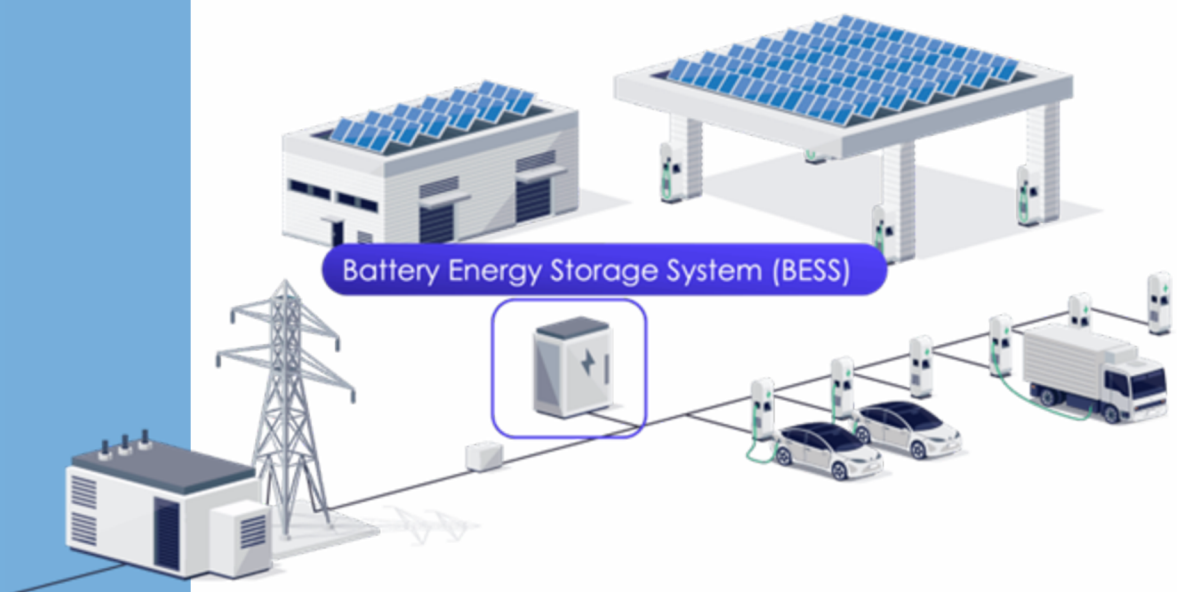
Applications and Impact on Demand Defection in the Power Sector

Introduction

The global energy landscape undergoes a transformation, defined by the dual imperatives of decarbonisation and ensuring grid reliability. Pakistan's power sector is undergoing a rapid transformation driven by the adoption of variable renewable energy (VRE), electric vehicles, and distributed generation. However, the surge in distributed generation, amplified through rooftop solar adoption, is fundamentally reshaping electricity flows, creating new technical and operational challenges for the national grid. The inherent intermittency of VRE and the rise of prosumers introduce significant complexities, including grid instability, demand defection, and the curtailment of clean energy.

A significant role of this transition is the integration of Battery Energy Storage Systems (BESS), which are emerging as critical enablers for grid flexibility, renewable energy integration, and demand-side management.

This policy brief provides the key insights from a multi-stakeholder dialogue held in September 2025 in Islamabad under the Pakistan–German Climate and Energy Partnership (PGCEP), detailing the technical imperatives, economic opportunities, and regulatory pathways for integrating BESS into Pakistan's power landscape.



Objectives

This policy brief is guided by the following core objectives:

Objective 1

To advocate for the essential role of BESS in addressing grid instability, integrating renewable energy, and preventing demand defection in Pakistan's power sector.

Objective 2

To propose specific policy and regulatory reforms that incentivise private investment in BESS and establish clear markets for its services.

Objective 3

To emphasise the importance of strategic system planning and safety standards to ensure the effective and secure integration of BESS into the national grid.

Key Messages

- With wind curtailment costs rising 39 PKR billion in FY-2024[1] annually, demand defection due to increasing rooftop solar PV uptake, and nuclear power plant contingencies threatening grid collapse, BESS has now become essential for providing fast frequency response and converting wasted energy into grid reliability.
- Falling global battery prices and improving payback periods create a strong economic case for adoption across various sectors of Pakistan especially in distribution grids.
- Without any policy reforms, the unplanned adoption of BESS could accelerate demand defection, weakening the financial sustainability of the grid.
- By establishing an ancillary services market and rationalising import duties, Pakistan can unlock 8.75 GWh BESS capacity market[2] projecting till 2030 and transforming grid challenges into private investment and energy security. Therefore, timely regulatory, fiscal reforms and industrial policy interventions can turn BESS into a driver of economic growth, energy security, and climate resilience.

Key Challenges

Demand Defection Risks:
The widespread solar rooftop and residential BESS adoption could reduce grid demand, while intensifying the financial sustainability concerns for distribution companies.

Financial Loss from Curtailment:
Pakistan has already faced massive wind and solar curtailments. The cost of wind curtailment, termed as Non-Project Missed Volume (NPMV) has jumped up from 4 billion PKR a few years ago to 39 billion PKR during FY-2024[1], highlighting a critical need for energy storage systems.

High Upfront Costs and Taxation:
The research study on Battery storage and the future of Pakistan's electricity grid[2] indicates that the heavy taxation including custom duties and surcharges, adds up to 50% to the cost of BESS in Pakistan. As a result, lithium-ion battery pack prices range from $160 to $300 per kWh, compared to a global average price closer to $115 per kWh.

> ***Pakistan can unlock 8.75 GWh BESS capacity market projecting till 2030.***

[1] State of Industry Report, NEPRA (2024).
[2] Institute for Energy Economics and Financial Analysis (IEEFA) Report on "Battery storage and the future of Pakistan's electricity grid", June 2025.

System Inertia and Contingency Risks:
A case study on system inertia and contingency analysis[3] has revealed the grid tripping reasons of K2 and K3 nuclear power plants, having installed capacity of 1,100 MW. This is mainly during winter season, when off-peak demand drops around 8,400 MW, causing frequency to crash at 49.04 Hz. However, with the continuous increment in VRE penetration and no BESS adaptation, this could drop to a dangerous level at 48.73 Hz.

Regulatory and Planning Gaps:
A consistent theme is the lack of a specific regulatory category for BESS, which can act as both generation and load. The current grid code and Integrated Generation Capacity Expansion Plan (IGCEP) have mentioned BESS requirements significantly, but still lack detailed provisions for performance standards, interconnection, and market participation.

Opportunities

System Reliability:
BESS provides fast frequency response (within milliseconds), ramping support, black start capability, and virtual inertia while enhancing resilience against contingencies such as tripping of K2 and K3 nuclear power plants.

Mitigating Demand Defection and Supporting the Grid:
For behind-the-meter, BESS can effectively manage the grid demand and can be aggregated into Virtual Power Plants to provide ancillary services to the grid, turning potential demand defection into a grid supporting asset. In Pakistan, several industrial consumers (e.g., Sapphire, Liberty, Kohinoor) are already deploying BESS in Virtual Synchronous Generator mode to counter grid instability.

Optimising Grid Planning through Forecasted BESS Deployment:
The development of accurate load demand forecasting systems with the integration of projected BESS deployment can present a significant opportunity to optimise generation planning. By enabling better visibility of distributed storage potential, the power system can reduce reliance on large-scale generation and instead utilise small-scale, distributed batteries to meet localised demand, particularly in areas with high daytime reverse power flows.

Massive Market Growth[2]:
Pakistan has imported 1.2 GWh of BESS capacity in 2024 alone, with over 400 MWh being imported monthly in early 2025. With precedent annual growth, the national BESS capacity could reach 8.75 GWh till 2030, significantly impacting peak demand management.

> *BESS is a very reliable option, even for ancillary services. But a proper study is essential. I would also urge donors to increase their support for all stakeholders, especially at the utility level, because this is the way forward.*
> — Imtiaz Hussain Baloch, Director General Licensing, National Electric Power Regulatory Authority (NEPRA)

[3] Findings of the Independent System Market Operator (ISMO) R&D Department.

Lessons Learned

International BESS Adaption Cases[4]:
Globally, BESS deployment offers a clear roadmap for Pakistan. In pioneering markets like Germany, BESS integration followed a phased approach, initially targeting BESS as Frequency Containment Reserve (FCR) where they now provide 95% of the service due to fast response and declining costs. As prices are falling and renewables penetration increased, their role expanded to highly profitable energy arbitrage, capitalising on large intraday price spreads. This evolution was enabled by evolving regulatory frameworks, including the grid codes. By the end of 2024, the leading markets demonstrated massive scale, in which China exceeds 30 GW and USA with 15 GW leading BESS installed capacity, driven by national policy and revenue streams from grid services into critical grid-forming BESS solutions.

Private Investment Drives Growth:
In Europe, BESS are predominantly privately owned and operated. Clear price signals from transparent ancillary service providers and wholesale markets players are key drivers to incentivise BESS investments through proper incentive mechanisms.

Technology Trends:
Lithium-ion technology dominates the global BESS market with approximately 95% share[4], driven by significant cost reductions, proven reliability, and high availability rates. The sector continues to evolve with several key advancements including rapid adoption of grid-forming inverters for enhanced stability, modular containerised systems (typically 2-5 MWh per unit) for scalability and provide flexibility for hybrid PV/BESS solutions.

Consequently, rigorous safety standards, advanced cell-level monitoring, and flood-resistant site planning have become critical components for effective risk mitigation.

Critical Role of Forecasting and Visibility:
Effective integration of BESS requires bottom-up, feeder-level load forecasting that accounts for distributed solar and storage. Without this load demand visibility, distribution companies cannot plan effectively, leading to over-procurement of centralised capacity.

> *Pakistan's energy systems faces growing challenges, especially with the increasing share of solar power and grid reliability issues. BESS can play a decisive role in addressing these - providing grid stability, reducing losses and enabling the effective integration of renewable energy. The German Development Cooperation remains committed to supporting Pakistan in building a flexible, reliable and low carbon power system - where BESS is a key enabler of energy security and sustainability.*
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> —Jens Brinkmann, Head of Project, GIZ Pakistan

[4] Based on Presentation by Tobias Dertmann in the Event "Battery Energy Storage Systems: Applications and Impact on Demand Defection in the Power Sector of Pakistan", 9th September 2025.

Policy Recommendations

Develop a BESS-Specific Regulatory Framework:

Create a distinct category for storage within the grid code, licensing procurements, interconnection requirements, technical standards (e.g. ramp rates, depth of discharge, protection schemes, island mode operations etc.), defining its rights and responsibilities as both a generator and a load, learning from the global regulatory precedents. BESS shall be defined in all the regulatory documents as a device providing multiple services. Furthermore, payment procedures against offered services should be clearly defined to cultivate investor confidence.

Establish Ancillary Services Markets:

Expedite the implementation of a market for ancillary services such as frequency regulation, voltage support, and ramping rates. This will create a clear revenue stream for private BESS investors, avoiding the need for the government to act as the sole procurer, just like in case of Europe including Germany. Currently, NEPRA lacks dedicated Ancillary Services Regulations, which are essential drives for such market participation. As CTBCM wholesale market nears its commercial operations, a consistent regulatory framework is required to govern capacity auctions and procurement mechanisms, allowing BESS to competitively participate in capacity and ancillary service tenders under CTBCM. This will accelerate BESS adoption and send strong investment signals to the vendors.

Nodal Level BESS Deployment:

Determine the optimal locations at nodal level for BESS deployment while avoiding risky investments by expanding the role of network planning tools like PSS/E, PSCAD and DIgSILENT. Under the grid code planning documents, the system planners shall identify, on annual basis, the nodes where such services are required. This will provide visibility to BESS investors for ideal placement within the power network. This could be carried out as a part of IGCEP and TSEP development.

Fiscal Reforms:

Rationalise duties and surcharges on batteries and introduce concessional financing, Viability Gap Funding (VGF), and green credit instruments to reduce upfront cost barriers and encourage the market entry of investors. A working group comprising the Ministry of Energy, State Bank of Pakistan (SBP), Planning Ministry, Federal Board of Revenue, Customs, and battery manufacturers/importers should determine optimal duty structures aligned with Pakistan's energy needs. A low-interest loan mechanism such SBP's Renewable Energy Financing Scheme may also be introduced for BESS, with similar example from India that is providing VGF covering up to 30% of BESS CAPEX[5] to accelerate its capacity growth.

[5] Institute for Energy Economics and Financial Analysis (IEEFA) Report on "The Standalone Energy Storage Market in India", April 2025.

Enforce Quality and Safety Standards: Mandate technical standards to ensure safety, reliability and interoperability such as ICE 62933 and IEEE 1547 for voltage and frequency regulation, protection schemes and communication interfaces. It is further suggested that an association of battery manufacturers should be established and tasked to develop local BESS quality standards. An SRO shall be passed mandating the clearance of only certified, tested BESS products in Pakistan.

Promote Indigenous R&D and Manufacturing: Explore the potential pathways and develop an industrial policy to utilie local salt reserves for sodium-ion battery production reducing import dependency, localise supply chains for BESS components, and creating a new export industry. Moreover, strengthening the academia-industry linkages through the R&D centre currently under development by Power Planning & Monitoring Company (PPMC).

Enhance System Planning: To optimise system planning and avoid over-procurement, mandate the IGCEP and DISCOs to incorporate bottom-up Distributed Energy Resources (DER) forecasts, conduct mandatory Hosting Capacity Analyses, and the deployment of DER Management System (DERMS) platform for efficient integration of DER resources.

De-risking BESS via Pilot Concepts: Demonstrate utility-scale BESS pilot use cases/models capitalising on blended finance schemes, i.e., public-private partnerships, showcasing operation, financial viability, risk aversion for early investments to increase investor confidence.

Foster Local Capacities: Introduce training curricula/modules on BESS O&M for the organisational capacity building of system, market, and network operators in partnership with universities and vocational institutions.

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GIZ Country Office, Level 2, Serena Business Complex, Khayaban-e-Suhrawardy, Sector G-5/1, Islamabad, Pakistan
Phone +92 51 111 489 725
www.giz.de

Programme Pakistan-German Climate and Energy Partnership

Responsible Kim Brinkmann, PGCEP Advisor

Design Muhammad Qasim Ali, Communication Advisor

Text Jens Brinkmann, Head of Project

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Knowledge partner

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