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Topic: What role can battery storage systems play in the operation of electricity grids and electricity trading and give examples from existing regulation (EU level)?

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Abstract

This paper explores the pivotal role of Battery Energy Storage Systems (BESS) in enhancing the operation of electricity grids and facilitating trading within the European Union's decarbonized energy framework. It examines how EU regulations, notably the Clean Energy Package and RED III, establish legal frameworks for BESS market participation through unbundling, aggregation, and non-discriminatory access, while identifying persistent implementation gaps. Analyzing directives such as 2019/944 and 2023/2413, the study highlights challenges including inadequate market design, fragmented permitting procedures, and uneven investment opportunities across member states, exemplified by France's FCR market saturation due to its nuclear-heavy mix. The research underscores a paradox: robust legal structures coexist with systemic barriers, such as the unaddressed merit-order problem and delays in transposing RED III, as evidenced by the European Commission's infringement proceedings against 26 member states on July 25, 2025. Drawing on case studies like Bayernwerk's pragmatic distribution system operator approach, the paper argues that realizing BESS potential requires evolving from access provision to value optimization. It concludes with policy recommendations for harmonized standards, market design reforms, and enhanced implementation mechanisms to align regulatory frameworks with storage technology economics.

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List of Abbreviations

BESS	Battery Energy Storage System
CACM	Capacity Allocation and Congestion Management
DSO	Distribution System Operator
EU	European Union
€/MWh	Euro per Megawatt-hour
€/MW/year	Euro per Megawatt per Year
FCR	Frequency Containment Reserve
FRR	Frequency Restoration Reserve
GB	Great Britain
IE/NI	Ireland / Northern Ireland
RED III	Renewable Energy Directive III
TEN-E	Trans-European Networks for Energy
TSO	Transmission System Operator

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1 Introduction

Battery Energy Storage Systems (BESS) are critical for integrating renewable energy, enhancing grid stability, and enabling electricity trading in the EU's decarbonized energy system. The Clean Energy Package and RED III establish frameworks for BESS market participation, yet persistent regulatory gaps hinder practical implementation.[1] This paper examines BESS' dual role as grid operation and trading assets, analyzing how EU regulations, such as Directive 2019/944, grant market access through unbundling and aggregation while facing challenges like inadequate market design for storage valuation.[2] Understanding these gaps requires examining the evolution of regulations, exemplified by provisions like Directive 2019/944's Article 17(3)(d), which was inserted during negotiations without documented rationale.[3] The analysis proceeds in four stages: establishing BESS' regulatory framework, examining operational integration, analyzing market rules and limitations, and concluding with policy recommendations.

2 The Dual Role of Batteries

The European Union's "Clean Energy for all Europeans" package[4] establishes the foundational regulatory framework for the integration of battery storage into the energy system. The legislation is built upon three core principles that redefine the roles and rights of market participants. Firstly, it promotes prosumer empowerment, creating a legal basis for citizens and communities to actively participate in energy markets by producing, consuming, storing, and selling their own electricity.[5] Secondly, it mandates a level playing field, ensuring that new technologies like energy storage and demand response can compete on an equal

[1] Directive (EU) 2019/944 [2019] OJ L158/125; Directive (EU) 2023/2413 [2023] OJ L, 31.10.2023.

[2] Regulation (EU) 2019/943 [2019] OJ L158/54, Art. 18.

[3] Directive (EU) 2019/944 [2019] OJ L158/125, Article 17(3)(d). This provision on financial responsibility for imbalances was not included in the original Commission Proposal COM(2016) 864 final, Article 17(3) and was added during legislative negotiations without documented rationale.

[4] European Commission, 'Clean energy for all Europeans package completed' (Press Release, 22 May 2019).

[5] Nouicer, A. and Meeus, L., 'The EU Clean Energy Package', Florence School of Regulation, 2019, 70.

footing with traditional generation.[6] Finally, to guarantee fair competition, the principle of unbundling is applied, which structurally separates competitive market activities from regulated grid operations by prohibiting distribution network operators from owning energy storage facilities, except in limited cases.[7]

The legal foundation for the dual role of battery owners is established in the Clean Energy Package, which defines the concept of the ‘active customer’. This framework grants fundamental rights to battery owners, effectively removing key historical barriers to their market participation. Specifically, Article 15 of Directive (EU) 2019/944 ensures that national regulatory frameworks enable active customers to participate in the market and that they are entitled to a timely grid connection for their facilities.[8] It also provides protection from disproportionate licensing requirements and double charging for stored electricity that is fed back into the grid.[9] Crucially, the directive establishes the right for active customers with storage to provide multiple services simultaneously, which is the legal basis for "revenue stacking".[10]

The European Union's regulatory approach to battery integration reflects an inherent tension between promoting market innovation and maintaining system stability. Article 17(3)(d) of Directive 2019/944 exemplifies this regulatory balancing act by granting aggregation rights to battery operators while simultaneously imposing financial responsibility for system imbalances.[11] This provision demonstrates the EU's recognition that unrestricted market access without corresponding accountability could create systemic risks. Battery aggregators must assume financial liability for imbalances they cause in the electricity system, either through direct balance responsibility or delegation to qualified parties.[12] While this obligation incentivizes reliable technology

[6] Ibid., 33.
[7] Ibid., 58.
[8] Directive (EU) 2019/944, Art. 15(5)(a).
[9] Ibid., Art. 15(5)(b) and (c).
[10] Ibid., Art. 15(5)(d).
[11] Ibid., Art. 17(3)(d).
[12] Ibid.

deployment and protects grid stability, it creates a regulatory trade-off that may disproportionately impact smaller operators.

The financial responsibility requirement serves as a market discipline mechanism, preventing "race to the bottom" scenarios where unreliable battery operators could destabilize grid operations while capturing profitable market segments. However, the complexity and costs associated with balance responsibility can create barriers to entry for innovative smaller players, potentially limiting the diversity of battery service providers and concentrating market power among established utilities with existing balancing capabilities. This regulatory design reveals the fundamental challenge of integrating distributed battery resources: enabling innovation while preserving system reliability requires sophisticated risk allocation mechanisms that may inadvertently favor incumbent players over new market entrants.[13]

While EU legislation formally establishes active customer rights for battery operators, academic analysis reveals substantial implementation barriers that prevent effective exercise of these entitlements. Research by Varvesi identifies three systematic obstacles constraining prosumer battery deployment: economic barriers combining high upfront investment costs with inadequate market remuneration, administrative barriers including complex grid connection procedures and limited access to ancillary service markets, and informational barriers stemming from lack of transparent price signals and real-time grid data necessary for optimal battery operation. [14] These implementation gaps demonstrate that existing structures remain designed for large, centralized players, creating systematic disadvantages for decentralized storage systems despite formal legal recognition.[15]

Despite establishing comprehensive legal frameworks, EU regulation contains critical implementation gaps that undermine batteries' practical dual role deployment. Directive (EU) 2019/944's Article 17 "technical capabilities" clause enables regulatory arbitrage, allowing battery operators to design systems with

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[13] Ibid.

[14] Varvesi, M., 'Energy Communities of Prosumer as a Solution to Overcome Financial Barriers to Energy Poverty' in L. Ruggeri (ed.), Needs and Barriers of Prosumerism in the Energy Transition Era (Dykinson 2021) 185.

[15] Ibid., 191.

deliberately limited capabilities to avoid grid-supportive obligations while accessing profitable market segments.[16] Additionally, Article 32(2) mandates coordination between distribution system operators (DSOs) and transmission system operators (TSOs) for "optimal utilisation of resources" without specifying concrete mechanisms for enabling battery access to transmission-level markets through distribution networks, creating implementation uncertainty for multi-level service provision.[17] These regulatory gaps reveal that while EU legislation establishes the legal framework for batteries' dual role, practical integration mechanisms remain insufficiently developed.

Despite implementation barriers and regulatory gaps, the EU is developing innovative approaches to realize batteries' dual role potential through new institutional frameworks and technology mandates. Energy communities represent a promising regulatory innovation that enables collective battery ownership and operation, with both renewable energy communities and citizen energy communities explicitly authorized to own and operate energy storage facilities.[18] This collective approach addresses individual prosumer barriers by enabling shared investment costs, professional management, and aggregated market participation that can achieve scale economies unavailable to individual battery owners. Complementing stationary storage developments, Directive (EU) 2023/2413's Article 20a(4) mandates bi-directional charging capabilities for new recharging points, including those with restricted access, transforming millions of mobile batteries into potential grid resources.[19] This regulatory requirement fundamentally scales distributed storage beyond traditional stationary deployments, creating potential for vehicle-to-grid services that leverage existing transport investments for grid support functions. These emerging solutions demonstrate the EU's recognition that realizing batteries' dual role requires regulatory innovation beyond traditional market access rights, encompassing new institutional models and technology integration strategies.

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[16] Directive (EU) 2019/944, Art. 17(2).

[17] Ibid., Art. 32(2).

[18] Caramizaru, A. and Uihlein, A., 'Energy Communities: An Overview of Energy and Social Innovation' (Joint Research Centre, 2020) 11.

[19] Directive (EU) 2023/2413, Art. 20a(4).

3 Grid Operation and System Services

The integration of battery storage into grid operations requires a multi-layered regulatory approach that progresses from fundamental market principles to specific operational requirements. This analysis examines three critical stages: the foundational market opening through unbundling and non-discriminatory access rules, the operational mandates that transform BESS from optional add-ons to integral system components, and the practical implementation gaps that reveal ongoing regulatory challenges.

3.1 Framework for BESS System Services

The European Union establishes the foundational prerequisites for BESS grid service markets through two complementary regulatory mechanisms that prevent market distortion and ensure equal access. The unbundling principle, codified in Articles 36 and 54 of Directive 2019/944, prohibits distribution and transmission system operators from owning storage facilities except in limited cases requiring regulatory derogation.[20] This structural separation prevents network operators from favoring their own assets over third-party storage providers, creating competitive neutrality essential for market-based grid services.

Complementing this ownership restriction, Article 18 of Regulation 2019/943 establishes comprehensive non-discrimination principles for network access charges. The regulation explicitly mandates that "network charges shall not discriminate either positively or negatively against energy storage or aggregation and shall not create disincentives for self-generation, self-consumption or for participation in demand response."[21] This non-discrimination principle ensures that BESS operators face identical grid access conditions regardless of technology, size, or ownership structure, establishing the regulatory foundation upon which competitive markets for system services can develop.

Building upon this foundational framework, the EU transforms BESS from optional market participants into integral system components through binding operational requirements within the Network Codes. The Electricity Balancing Guideline creates a binding obligation for transmission system operators to

[20] Directive (EU) 2019/944, Arts. 36, 54.
[21] Regulation (EU) 2019/943, Art. 18(1).

systematically consider market-based bids from storage resources and mandates that standard products "facilitate the participation of... owners of energy storage units as balancing service providers."[22] Additionally, TSOs must perform cost optimization analysis that explicitly includes "non-contracted balancing energy bids which are expected to be available... within the European platforms," forcing systematic consideration of market-based BESS services.[23] This mandate ensures that TSOs must actively integrate BESS into daily operations rather than treating storage as discretionary resources.

Furthermore, the System Operation Guideline enables sophisticated revenue models by allowing Frequency Containment Reserve (FCR) providing units to transition seamlessly between services. For GB and IE/NI synchronous areas, the regulation explicitly states that "a FCR providing unit or FCR providing group... shall activate its FCR until it activates its FRR."[24] This regulatory provision directly enables sequential and complementary service provision, supporting multi-service business models where BESS can provide both frequency containment and frequency restoration reserves while maintaining system reliability standards.

Despite establishing comprehensive regulatory frameworks, practical implementation reveals significant gaps that constrain BESS deployment. The EU's primary infrastructure policy, the Trans-European Networks for Energy (TEN-E) Regulation, recognizes energy storage as eligible for support but requires transmission-level connections (110 kV or more), effectively excluding most commercial BESS projects operating at distribution level.[25] Responding to administrative barriers, RED III introduced streamlined six-month permitting procedures for co-located storage below 150 kW in renewable acceleration areas, though this solution remains geographically limited due to its restriction to these designated areas.[26] Furthermore, EU frameworks demonstrate systematic bias toward physical co-location over Virtual Power Plants, despite evidence that

[22] Commission Regulation (EU) 2017/2195, Art. 25(6).
[23] Ibid. Art. 32(1)(c).
[24] Commission Regulation (EU) 2017/1485, Art. 156(7) and (8).
[25] Regulation (EU) No 347/2013, Annex II(1)(c).
[26] Directive (EU) 2023/2413, Art. 16a(2).

virtual aggregation can provide superior system efficiency. [27] These implementation barriers illustrate that while the EU has established the legal architecture for BESS integration, translating regulatory intent into market reality requires addressing persistent structural obstacles.

3.2 DSO Implementation: The Bayernwerk Case Study

The EU mandates that distribution system operators procure flexibility services through "transparent, non-discriminatory, and market-based" procedures, explicitly including energy storage among eligible resources.[28] However, these general requirements leave implementation details unspecified, creating regulatory gaps that market actors address pragmatically. Bayernwerk Netz exemplifies this "regulation by contract" approach, using location-specific operational windows rather than standardized time slots for grid-supportive storage services, balancing arbitrage opportunities with local network requirements through contractual arrangements. [29] To ensure fair treatment, Regulation 2019/943 establishes that BESS receive financial compensation for non-market redispatch equal to the higher of operating costs or foregone day-ahead revenues, protecting storage operators from revenue loss due to grid service obligations. [30] This implementation model demonstrates how local solutions can bridge the gap between high-level EU mandates and practical grid operation requirements.

4 Electricity Trading and Arbitrage

While grid operation services focus on physical system stability and reliability, the commercial viability of battery storage ultimately depends on participation in competitive electricity markets. This transition from operational integration

[27] Apostolopoulou, D. & Poudineh, R., "Coupling storage and renewables: in the physical or virtual world?", Oxford Energy Forum, Issue 140, 2024, pp. 15-20, 19.

[28] Directive (EU) 2019/944, Art. 31(7).

[29] Bayernwerk Netz et al. (2024), Positionspapier zu netzorientierten Fahrweisen von Speichern, 2024, 3–4.

[30] Regulation (EU) 2019/943, Art. 13(7).

to market participation reveals a distinct set of regulatory challenges where formal market access rights encounter practical implementation barriers.

4.1 Internal Market Rules for BESS Trading

The EU establishes comprehensive market access rights for battery storage through the aggregation framework and capacity allocation mechanisms. Article 17 of Directive (EU) 2019/944 ensures that aggregated storage resources can participate in all electricity markets while requiring them to assume financial responsibility for system imbalances they cause, either directly as balance responsible parties or through delegation to qualified entities.[31] This framework is reinforced by non-discriminatory obligations requiring transmission and distribution system operators to treat battery storage fairly when procuring ancillary services, preventing preferential treatment of conventional technologies. [32] Additionally, the Capacity Allocation and Congestion Management Regulation facilitates cross-border trading opportunities for storage resources, enabling arbitrage across different EU market zones where price spreads justify transaction costs and efficiency losses.[33]

While the EU framework grants formal market access, it does not address a fundamental flaw in the market's design for valuing energy-limited resources. The traditional merit-order model, based on the short-run marginal cost of generation, is ill-suited for batteries. The marginal cost of dispatching a battery is not its near-zero operational cost, but rather the opportunity cost of not being able to sell that same energy at a potentially higher price in the future.[34] The current market structure does not systematically provide the price signals needed to optimize the dispatch of storage based on this opportunity cost. Consequently, while the EU provides the legal framework for market participation, it has not yet solved the underlying design problem of how to correctly value and incentivise the unique capabilities of battery storage in the market. Moreover, the complexity of determining accurate opportunity costs creates additional

[31] Directive (EU) 2019/944, Art. 17.

[32] Nouicer, A. & Meeus, L., 'The EU Clean Energy Package', Florence School of Regulation, 2019, 83.

[33] Commission Regulation (EU) 2015/1222 [CACM], Whereas (4); see also Articles 1 and 3.

[34] Mays, J., "Market reform considerations for bulk energy storage", Oxford Energy Forum, Issue 140, 2024, pp. 27-29, 28.

challenges,[35] as distinguishing between legitimate arbitrage strategies and potential market manipulation remains unresolved in current regulatory frameworks and requires further regulatory clarification through specific market mechanisms for valuing storage resources.

4.2 Market Practice: BESS Arbitrage and Revenue Stacking

The commercial viability of battery storage depends on successfully combining multiple revenue streams with fundamentally different compensation structures. Energy markets provide payments per megawatt-hour (€/MWh) for actual electricity delivery through day-ahead, intraday, and balancing mechanisms, while capacity markets offer annual payments per megawatt (€/MW/year) purely for availability during critical periods.[36] Ancillary services create additional complexity, combining reserve capacity payments with potential activation fees when services are actually called upon. This "revenue stacking" requires sophisticated operational strategies since some services are mutually exclusive during activation periods, while others can be provided simultaneously, creating a complex optimization challenge for storage operators seeking to maximize returns across multiple market segments.[37]

Despite regulatory market access, BESS face significant practical barriers that undermine business case viability. In many EU countries, the persistent issue of unfair grid charges, such as excessive network tariffs imposed on BESS providing flexibility services, creates a financial disadvantage compared to gas power plants, which are often exempt from such tariffs in imbalance markets.[38] This unequal treatment reduces arbitrage margins and limits the economic attractiveness of battery storage investments. Furthermore, real-world market evidence demonstrates saturation risks even in theoretically accessible markets. Analysis of European FCR markets reveals that France experienced greater market saturation than Germany despite having lower installed battery capacity, reflecting how national energy system characteristics - specifically France's nuclear-heavy generation mix reducing the need for flexibility services - create

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[35] Ibid.

[36] Al-Saadi et al., "Stacking Battery Energy Storage Revenues in Future Distribution Networks" (2022), 35033.

[37] Ibid., 35034.

[38] SolarPower Europe, 'European Market Outlook for Battery Storage 2025-2029' (2024), 17.

uneven BESS investment opportunities across member states despite uniform EU market access regulations.[39]

5 Conclusion

This analysis reveals a fundamental paradox in EU battery storage regulation: comprehensive legal frameworks that guarantee market access while failing to address core market design inadequacies that constrain BESS economic viability. The regulatory architecture successfully establishes non-discriminatory participation rights through unbundling principles, operational integration mandates via network codes, and revenue stacking capabilities, yet systematic barriers persist in translating these rights into sustainable business models.

Three critical regulatory gaps emerge from this examination. First, the merit order problem demonstrates how traditional market clearing mechanisms inadequately value energy-limited resources, creating systematic mispricing that undermines storage economics despite formal market access. Second, implementation barriers including fragmented permitting procedures and inconsistent national approaches reveal the disconnect between EU-level policy integration and member state execution. Third, market saturation evidence from FCR markets illustrates how uniform regulatory frameworks interact unpredictably with diverse national energy system characteristics, creating uneven investment incentives across the Union.

The disconnect between regulatory intent and practical implementation is further exemplified by recent enforcement challenges. On July 25, 2025, the European Commission initiated infringement proceedings against 26 Member States, including Germany, for failing to meet the May 21, 2025 deadline for transposing RED III.[40] Such delays compound the regulatory design limitations identified throughout this analysis, potentially inhibiting the practical realization of storage system potential.

Future regulatory development should prioritize market design reform addressing opportunity cost valuation mechanisms, harmonized implementation standards preventing member state fragmentation, and dynamic market entry management preventing premature saturation. Enhanced regulatory transparency requiring systematic documentation tracing regulations from initial impact assessments to underlying theoretical frameworks could further improve policy implementation and stakeholder compliance. The EU has established the legal foundation for battery storage integration; realizing this potential requires

[39] Danthine, A. and Zerain, A., 'What are the economic risks associated with investing in energy storage' (2024) Oxford Energy Forum, Issue 140, pp. 6-10, 8.

[40] Harmsen, S., 'EU-Kommission mahnt Deutschland', Energie & Management (26 July 2025).

evolving from access provision to value optimization frameworks that align regulatory architecture with storage technology economics.