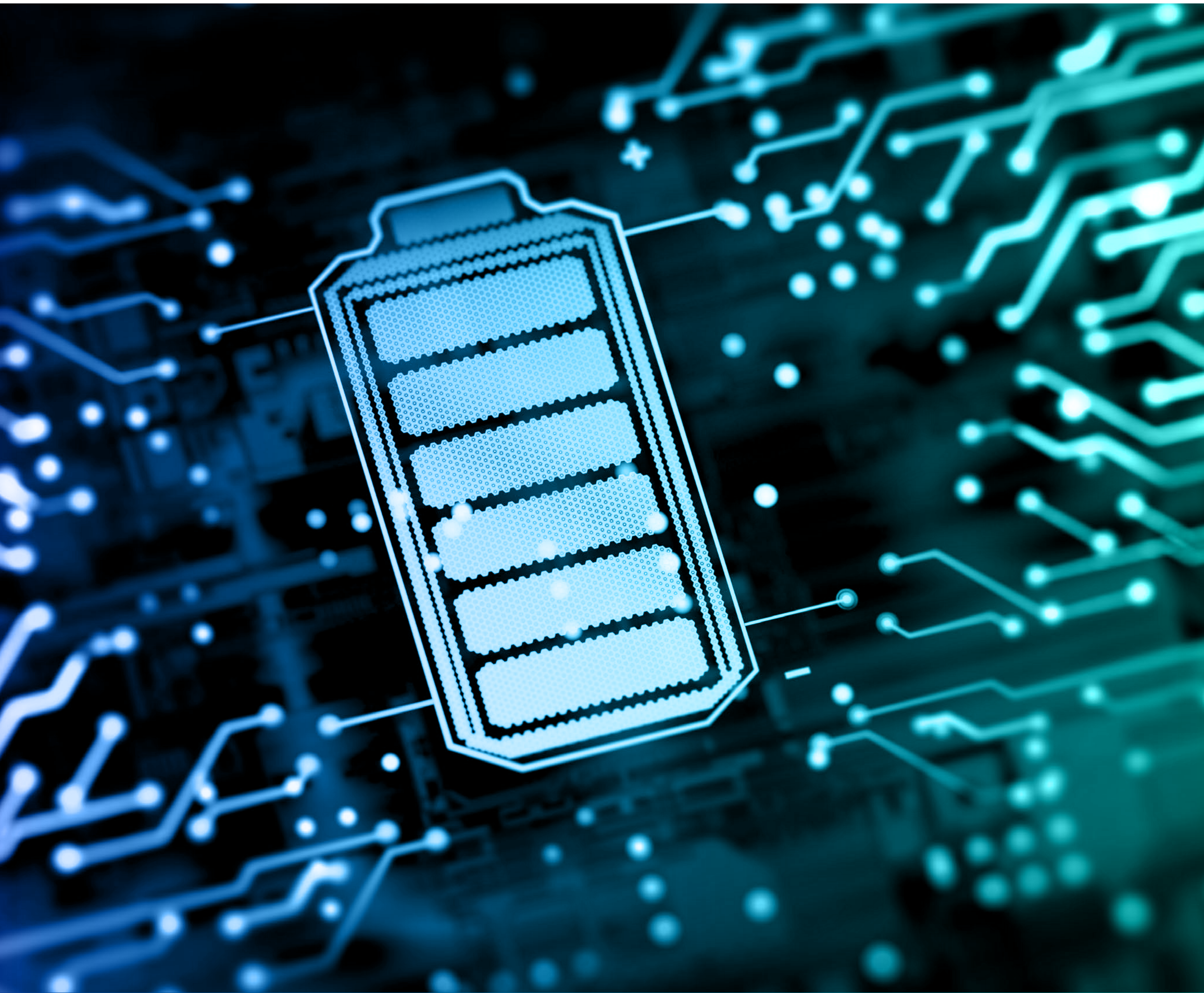
ENTSO-E Policy Paper

Market Design for Utility-Scale Energy Storage

December 2025



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Foreword

ENTSO-E, the European Network of Transmission System Operators for Electricity, is the association of the European transmission system operators (TSOs). The **40 member TSOs, representing 36 countries,** are responsible for the secure and coordinated operation of Europe's electricity system, the **largest interconnected electrical grid in the world.**

Before ENTSO-E was established in 2009, there was a long history of cooperation among European transmission operators, dating back to the creation of the electrical synchronous areas and interconnections which were established in the 1950s.

In its present form, ENTSO-E was founded to fulfil the common mission of the European TSO community: to power our society. At its core, European consumers rely upon a secure and efficient electricity system. Our electricity transmission grid, and its secure operation, is the backbone of the power system, thereby supporting the vitality of our society. ENTSO-E was created **to ensure the efficiency and security of the pan-European interconnected power system** across all time frames within the internal energy market and its extension to the interconnected countries.

ENTSO-E is working to secure a carbon-neutral future. The transition is a shared political objective through the continent and necessitates a much more electrified economy where sustainable, efficient and secure electricity becomes even more important. **Our Vision: "a power system for a carbon-neutral Europe"*** shows that this is within our reach, but additional work is necessary to make it a reality.

In its Strategic Roadmap presented in 2024, ENTSO-E has organised its activities around two interlinked pillars, reflecting this dual role:

- "Prepare for the future" to organise a power system for a carbon-neutral Europe; and
- "Manage the present" to ensure a secure and efficient power system for Europe.

ENTSO-E is ready to meet the ambitions of Net Zero, the challenges of today and those of the future for the benefit of consumers, by working together with all stakeholders and policymakers.

* https://vision.entsoe.eu/

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Introduction

Over the next 15 years, the European energy system will go through substantial changes to meet the EU greenhouse gas (GHG) emission reduction targets. Indeed, by 2030 net GHG emissions must be reduced by 55% compared to 1990 levels and at least 42.5% of the EU's gross final energy consumption must come from renewable sources – likely translating into around 70% of power generation from non-emitting sources.[1] For the 2040 horizon, in July 2025 the European Commission proposed an amendment to the European Climate Law,[2] to set a binding Union target aiming at reducing EU's net GHG by 90% compared to 1990 levels.[3]

Meeting these intermediary targets toward EU's climate neutrality will require the timely and large-scale deployment of variable renewable energy sources (vRES), such as wind and solar energy. However, high shares of weather-dependent and inverter-based generation will significantly increase the complexity of power system operations.

Key challenges will include:

Overgeneration during low-demand periods, leading to RES curtailment – depending on the circumstances, through market-based mechanisms or through out-of-market interventions for system security reasons

Periods of insufficient vRES generation relative to demand, requiring complementary resources to ensure adequacy and flexibility needs

Transmission congestion, limiting the system's ability to transfer electricity from generation sites to demand centres

Balancing reserve requirements, potentially requiring the withholding of vRES output to ensure sufficient upward or downward flexibility

Voltage stability and reactive power requirements, potentially imposing limitations on active power injections from vRES in specific grid locations

Addressing these challenges demands the large-scale deployment of clean, flexible, and system-supportive resources. Among these, utility-scale energy storage solutions play a pivotal role. They encompass a broad spectrum of technologies: (i) established ones, such as pumped hydro energy storage (PHES), currently representing a significant share of installed storage capacity;[4] (ii) rapidly expanding ones, such as lithium-ion battery energy storage systems (BESS); and (iii) emerging long-duration storage solutions, such as compressed-air and liquid-air energy storage and flow batteries.

Storage systems not only reduce curtailment by shifting renewable generation from periods of excess supply to periods of higher demand but also deliver fast-responding balancing energy and high-value ancillary services (e.g., black-start capability and, depending on the specific technology, mechanical or synthetic inertia). In addition, by relieving network congestions – regardless of whether driven by rising vRES integration, the electrification of transport, heating and cooling, or the connection of large industrial loads – utility-scale storage can help defer or reduce the need for costly grid reinforcements.

1 European Commission (2021): COM(2021) 550 final "Fit for 55": Delivering the EU's 2030 Climate Target on the way to climate neutrality; Regulation (EU) 2021/1119 and Directive (EU) 2023/2413 (RED III)

2 Regulation (EU) 2021/1119

3 European Commission (2024): COM(2024) 63 final "A climate target for 2040 and a climate architecture for delivering climate neutrality and negative emissions"

4 JRC (2023): Hydropower and pumped hydropower storage in the European Union

However, an uncoordinated market-driven ramp-up could ultimately result in inefficient siting and suboptimal operation thus increasing costs for grid users. To ensure that utility-scale storage deployment effectively contributes to the EU decarbonisation process, Europe's electricity market design must:

1. **Promote system-friendly roll-out of storage assets**
   - 1.a **Ensure the conditions for investment profitability,** to reduce the investment risks and thus improve the bankability of these projects while avoiding undue market distortions and overcompensation
   - 1.b **Provide locational signals,** to drive siting decisions where flexibility delivers the highest value for the power system
2. **Promote efficient and system-friendly dispatch,** so that existing storage assets can contribute to adequacy, RES integration, congestion management and system stability

This paper examines how the regulatory framework governing electricity markets in Europe can ensure a timely, cost-effective, and location-optimised deployment of utility-scale storage systems, while also promoting their efficient and system-friendly scheduling across Day-Ahead (DA), Intra-Day (ID) and balancing markets. To this end, lithium-ion BESS is often used as an example given its advanced technological maturity and projected growth. Nonetheless, the analysis and recommendations apply equally to all forms of utility-scale storage, including PHES, and other emerging long-duration storage solutions.

Drawing on ENTSO-E system outlooks, national scenarios, recent EU regulatory reforms, as well as a survey conducted among ENTSO-E members, the paper covers the following topics:

- **Chapter 1** discusses the overarching principles behind a **robust and system-friendly investment framework** and outlines three alternative policy options that, depending on national specificities, can drive the deployment of new storage capacity:
  - **Policy option 1** analyses under which conditions **merchant investments** are likely to materialise, along with a focus on the current limitations of this approach.
  - **Policy option 2** assumes that **capacity markets** can facilitate investments in new capacity by providing long-term revenue certainty and discusses how their design can be adapted to boost the participation of energy storage.
  - **Policy option 3** explores the concept of **non-fossil flexibility support schemes** and shows the role they can play in supporting investment in new storage capacity.
- **Chapter 2** highlights additional market design elements that help ensure storage assets are **scheduled in a system-friendly manner**.
- **Chapter 3** reviews the **approaches taken in selected Member States** to speed up the deployment of new storage capacity.

Chapter 1 – Enabling the roll-out of utility-scale energy storage

The widespread deployment of utility-scale energy storage is increasingly recognised as a strategic necessity for achieving a secure, affordable, and decarbonised European power system.[5] Nonetheless, it is still unclear whether the EU as a whole – and its Member States individually – are moving in this direction quickly enough.

On the one hand, current storage deployment in the EU remains far below the levels needed to ensure security of supply and system flexibility in the renewables-based power system envisaged when setting the 2030 and 2050 decarbonisation objectives. According to the European Commission's Joint Research Centre, only about 73 GW of energy storage capacity is currently installed across Europe, of which PHES account for around 53 GW and li-ion BESS for around 16 GW (with UK, Germany and Italy alone accounting for more than 70 % of installed li-ion BESS).[6] By comparison, analyses by the European Association for Storage of Energy indicate that Europe will require roughly 200 GW of energy storage capacity by 2030 and at least 600 GW by 2050 to meet its progressively increasing flexibility needs.[7]

On the other hand, Europe is gaining momentum in energy storage deployment. Recent data by industry stakeholders indicate that the utility-scale energy storage segment is expanding at an unprecedented rate. For instance, SolarPower Europe projects a five-fold increase in yearly deployments of utility-scale BESS from 21.9 GWh in 2024 to 118 GWh in 2029.[8]

Overall, these figures indicate that, while market interest is rapidly growing, opportunities to improve the current investment framework remain. Given that both financial viability and alignment with system needs must be ensured for the full potential of utility-scale storage to be unlocked, two emerging considerations emerge:

- Investor perspective – new storage capacity will only be installed if private investors find the business case attractive, taking into account capital expenditure (CAPEX), operational expenditure (OPEX), cost of capital and expected revenues over the asset's lifetime.
- TSO perspective – for new storage capacity to effectively support the decarbonisation of the European power system, its deployment must be targeted to system-relevant locations – i. e., where its inherent flexibility delivers the highest value for the overall power system. Moreover, to ensure that relevant system operators can continue to operate safe and secure networks, it is essential that electricity storage modules comply with the technical requirements for grid connection as proposed by ACER to the European Commission in the Requirements for Generators (RfG) 2.0.

In what follows, we will therefore present three complementary policy and market arrangements that, depending on national and system specificities, can be applied to facilitate investments in utility-scale storage systems, while ensuring that, once realised, these assets can effectively contribute to the decarbonisation of the power sector.

5 European Commission (2023): Staff Working Document on Energy Storage

6 JRC (2025): European Energy Storage Inventory – checked on October 16th 2025

7 EASE (2022): Energy Storage Targets 2030 and 2050

8 SolarPower Europe (2025): European Market Outlook for Battery Storage 2025-2029

Policy option 1 – Improving the conditions for merchant investments

Under this first policy option, private investors deploy new storage capacity expecting that, by stacking revenues from different short- to medium-term electricity markets[9] over the asset's useful life, fixed costs will be covered, and a fair return on capital will be achieved.

Two main storage configurations have emerged so far under this policy framework: (i) stand-alone storage systems, directly connected to the transmission or distribution grid and active in multiple market timeframes; and (ii) co-located storage systems, integrated with renewable generation or demand-side assets.

Stand-alone storage systems

Stand-alone, grid-connected storage assets operate independently of other generation and demand assets and are optimised for market participation. Strategically located, they derive revenues from a combination of strategies:

- Arbitrage of price spreads across different market time units in both the DA and ID markets, realized by charging during low-price periods (typically driven by vRES oversupply) and discharging during high-price periods (when vRES output is limited and/or demand peaks) – thereby smoothing price volatility and supporting market efficiency.
- Participation in balancing and market-based congestion management processes, by providing frequency reserves, congestion relief, and other flexibility services that help maintain operational security.
- Provision of other high-value frequency and non-frequency ancillary services, such as frequency containment, reactive-power support, voltage control, or black-start capability, to the extent that these services are explicitly procured and remunerated.

Co-located storage systems with vRES or demand-side assets

Co-locating storage with weather-dependent renewable generation is becoming increasingly common across Europe. Integrating vRES and storage can benefit both the developers and the broader power system through these channels:

- Reduced vRES curtailment, by storing excess renewable output during generation peaks.
- Optimised grid connections, by managing injections and withdrawals within local constraints.
- Increased controllability and optimized dispatch, which in turn facilitates the delivery of PPAs.
- Enhanced project economics, through shared grid connection infrastructure and provision of balancing (e.g., aFRR, mFRR) or local congestion-management services.

Similarly, co-location with demand-side assets (e.g., at commercial and industrial facilities) is gaining momentum. By storing energy on-site and shifting the timing of power withdrawals, without changing overall consumption patterns, these projects can benefit both the end-user involved and the broader power system through these two channels:

- Maximising the use of limited grid capacity by flattening withdrawal profiles toward baseload levels.
- Supporting business continuity without relying on subsidies, by drawing power from the grid when prices are lower.

9 Long-term contracts allocated via a capacity market or a flexibility-support scheme are not considered here.

However, it is important to note that these benefits materialise only if co-located assets are appropriately exposed to local grid constraints (e.g., via dynamic network tariffs or operational limits). Without such exposure, co-located storage system could paradoxically exacerbate local congestions (and thus grid reinforcement needs) rather than relieve them. Ensuring alignment between storage operation and system needs is therefore essential to realise the full value of co-location.

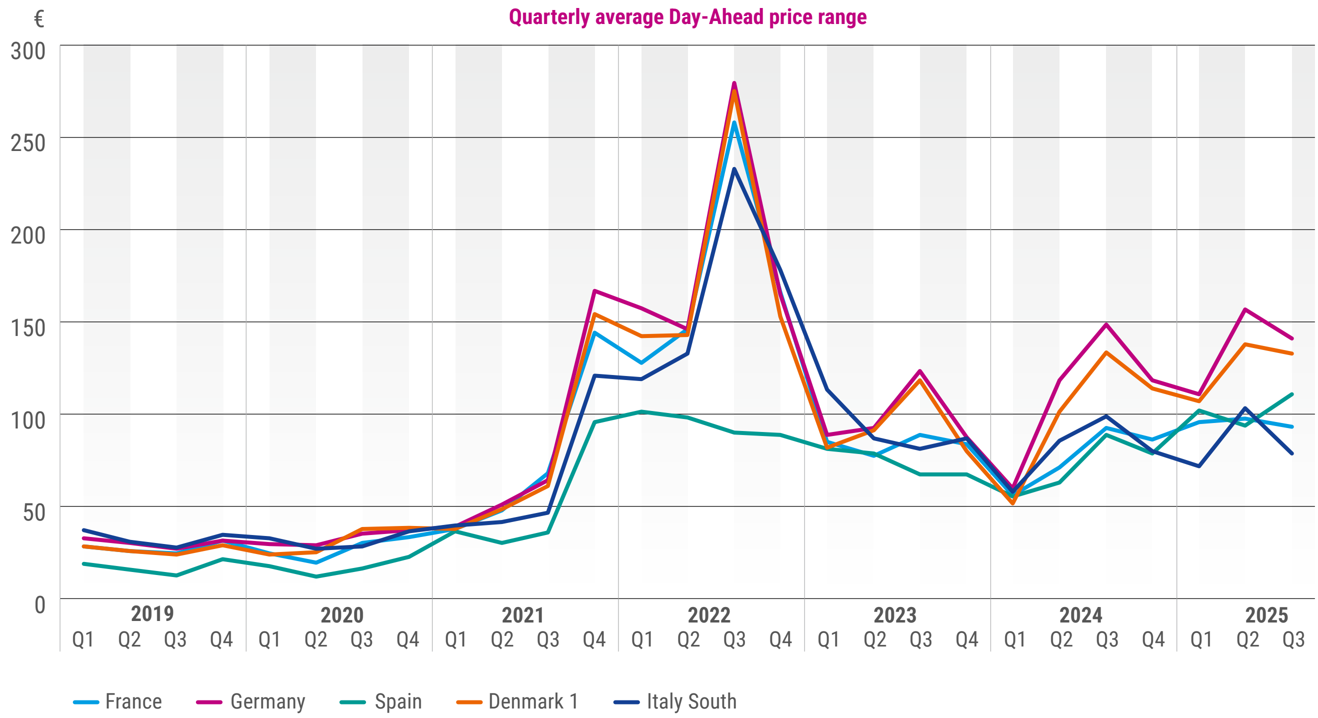


Figure 1: Quarterly average DA price range across selected bidding zones. Source: Analysis based on data from ENTSO-E Transparency Platform.

Barriers to the bankability of merchant investments

Across several Member States, the increasing share of vRES in the generation mix and the resulting increase in intraday price volatility are boosting arbitrage opportunities and, in turn, encouraging merchant investments. Figure 1 illustrates this point by presenting the quarterly average DA price range across selected bidding zones.[10]

Nonetheless, both stand-alone and co-located storage projects still face structural barriers and unfavourable investment conditions that may limit their financial viability in the absence of dedicated support measures. Most critical barriers can be found in the table below.

10 Beyond the increase in installed vRES capacity, the dynamics observed in the day-ahead price range (and consequently its quarterly average) were also influenced by other factors. Among the most significant were fluctuations in wholesale natural gas prices and the relative shares of solar PV and wind within the national RES mix.

Category	Investment drivers	Investment barriers
Market dynamics	Growing vRES penetration increases price volatility and widens intraday spreads, enhancing arbitrage opportunities for storage. Periods of high gas prices or scarcity events may drive up wholesale electricity prices, improving profitability of storage. Increasing electrification of transport, heating, and industry creates additional flexibility needs, enhancing storage value.	Market saturation from new flexibility resources (e.g., competing utility-scale storage, EVs, heat pumps) can reduce price spreads and arbitrage value over time.[11]
Overall regulatory framework	Supportive market rules recognising the system value of storage (e.g., level playing field participation in balancing markets, introduction of scarcity pricing) enhance investment certainty.	Regulatory uncertainty (e.g., introduction of price caps or revenue clawbacks, or frequent changes in market rules) undermines revenue predictability and investor confidence. Unclear or inconsistent treatment of storage across market segments creates legal uncertainty. If applied twice, both to withdrawals and injections, network tariffs fail to reflect that storage assets act as a net system balancer.
First-mover disadvantage	Technological progress and economies of scale continue to reduce the CAPEX of BESS, while improvements in round-trip efficiency help lower its OPEX.	Uncertainty over future technology costs and performance, or supply chain constraints, may delay investment decisions.
Provision of ancillary services	Potential participation in additional ancillary services markets (e.g., inertia provision, frequency containment, or voltage support) can provide new revenue streams.	Limited or fragmented access to these markets, or restrictive prequalification rules, constrain revenue stacking.
Locational and network signals	Emerging more granular short-term price signals can guide efficient siting and enhance value capture. Targeted incentives such as connection fee discounts, co-location schemes, or flexible access rules may strengthen the business case in specific areas.	Inadequate locational signals and outdated connection rules and tariff designs may lead to suboptimal siting or prevent full value capture.

Barriers to the system-friendliness of merchant investments

The location of a new storage system not only affects the return on investment, but also its contribution to the power system. Indeed, a well-sited non-fossil flexible resource can support the integration of vRES, enhance system adequacy, alleviate grid congestion, and strengthen overall system security.

Under this first policy option, the siting decision is made by the developer to maximise expected profits from short- and medium-term markets. Potential sites would indeed be evaluated based on differences in (i) expected fixed and variable costs (where the latter are primarily reflected in the electricity price paid to charge the storage) and (ii) expected revenue opportunities. Assuming complete and perfectly functioning power markets,[12] the choice made by the developer to maximise profits would lead to the asset being sited in a system-friendly location, as revenues would be the highest, where the need to install new storage capacity is the most critical from a system perspective.

However, when markets are incomplete or, more broadly, they fail to fully account for local contingencies, siting decisions driven by profit maximization may diverge from those that would best support the overall power system. Therefore, it is important that the regulatory framework helps steer siting choices toward system-friendly locations. Under this policy option, this can be achieved by influencing the expected revenues that can be earned by siting a given asset in different alternative areas. In this regard, the mechanisms proposed in Chapter 2 to promote system-friendly scheduling could also encourage more system-friendly siting from the outset.

11 From a total welfare perspective, the reduction in arbitrage opportunities is not necessarily negative. To the extent that the financial viability of the investment is not compromised, decreased intraday price spreads are likely to increase system efficiency.

12 In this context, "complete markets" refers to a market design where every service that is needed to operate the power system is remunerated in a competitive and transparent way.

Recommendations

To address the above challenges and accelerate a cost-effective and system-aligned merchant deployment of new storage capacity, ENTSO-E recommends action across two mutually reinforcing policy pillars: (i) ensuring investments' financial viability, and (ii) steering storage siting to system-friendly locations.

1. Ensuring investments' financial viability

In this context, we underline the importance of non-discriminatory market access for all flexibility resources, including storage, and the need to remove existing distortions that impede efficient participation in wholesale and balancing markets.

Key measures

- **1.1** Ensure access to all relevant value streams (including balancing, congestion management, and ancillary services).
- **1.2** In the short term, remove double-charging of grid tariffs for storage charging and discharging, ensuring fair treatment of assets that act as net system balancers. Over time, however, the design of network tariffs for storage assets should be reassessed to ensure they remain proportionate and cost-reflective, preventing uncontrolled development of these resources or tariff-driven distortions, and avoiding unnecessary burdens on grid users.
- **1.3** If needed, promote investment de-risking frameworks at EU and national levels (e.g., through the European Investment Bank, CEF, and Innovation Fund) to facilitate project financing for capital-intensive storage solutions.

2. Steering storage siting to system-friendly locations

To improve the cost-efficiency and system value of energy storage deployment, policy frameworks should better align investment and operation with grid needs.

Key measures

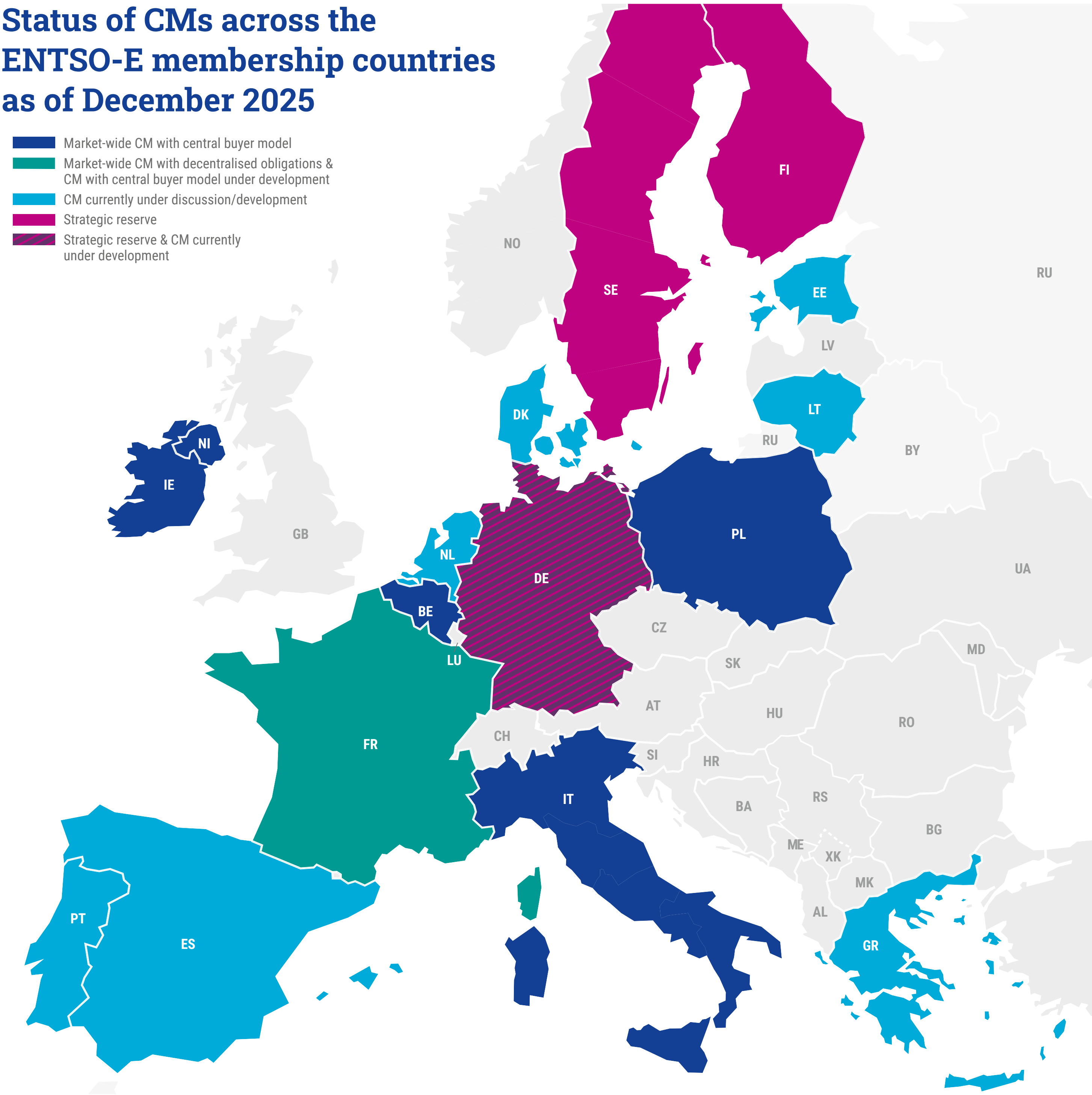
- **2.1** Ensure short-term price signals accurately reflect structural congestion patterns.
- **2.2** Engage market participants and stakeholders in the transparent regular publication of available hosting capacity at a high spatial granularity, as envisaged by the Electricity Market Design Reform to enhance grid capacity visibility.
- **2.3** Enable flexible and non-firm connection agreements to accelerate deployment without compromising operational reliability or system security.
- **2.4** Provide targeted connection incentives in high-impact areas (e.g., congested nodes or areas with high shares of vRES) while ensuring that TSOs retain operational control to effectively manage system constraints.
- **2.5** Ensure locational and time differentiated price signals that reflect network constraints, congestion risks, and the time-dependent value of flexibility.

However, this policy option may still expose investors to significant market risks. In certain Member States, the resulting revenue streams may prove insufficient - or may be considered too uncertain - to support widespread deployment without additional risk mitigation measures or complementary instruments, such as long-term contracts granted through capacity mechanisms or non-fossil flexibility support schemes. For this reason, we introduce Policy option 2 and Policy option 3.

Policy option 2 – Adapting Capacity Mechanisms to increase storage participation

Capacity Mechanisms (CMs) are designed to ensure security of supply by remunerating capacity availability during periods of system stress – i.e., when available resources may be insufficient to cover demand and maintain required reserve margins. CMs are typically introduced to complement energy-only markets by addressing the so-called "missing money problem", whereby energy-market revenues alone are too uncertain, volatile, or low to justify investment in new capacity or even the continued operation of existing assets.

Status of CMs across the ENTSO-E membership countries as of December 2025



Source: Based on ENTSO-E's "The role of Capacity Mechanisms to enable a secure and competitive energy transition" (Figure 2, page 19) and recent developments

Figure 2: Status of CMs across the ENTSO-E membership countries as of December 2025

By 2023, eight Member States had implemented a CM.[13] Since then, the number of countries that have implemented, are in the process of implementing, or are considering the implementation of a CM has continued to grow, as shown in Figure 2 above based on ENTSO-E's policy paper on this topic (published in April 2025)[14] and the latest national developments. Reflecting this trend, the recent amendment to the EU Electricity Regulation[15] recognises that CMs may become a structural feature of European electricity markets, particularly where energy-only markets fail to provide sufficient long-term investment signals.

In this context, and to further support decarbonisation, the Electricity Regulation places particular emphasis on the need to incentivise the use of non-fossil flexible resources, including energy storage, in delivering adequacy. Article 19g(1) explicitly states that Member States applying CMs "*shall consider to make the necessary adaptations […] to promote the participation of non-fossil flexibility such as demand side response and energy storage*."

Storage assets already participate in several existing CMs. However, given their specific technical capabilities, the legacy design of many mechanisms may not fully recognise or remunerate the value that storage systems provide to both adequacy and operational flexibility. By delivering non-fossil, dispatchable capacity and balancing support during periods of system stress, energy storage can serve as a key enabler of resource adequacy in power systems with high shares of vRES, reducing the need for peaking fossil units. Beyond this adequacy role, storage can shift renewable output across time, respond rapidly to balancing requirements. These characteristics make utility-scale energy storage a critical contributor to both system adequacy and operational flexibility, and position it as the most versatile non-fossil flexibility resource to complement variable renewable generation and support the secure operation of decarbonised power systems.

Different approaches exist to value adequacy and flexibility, possibly even in combination. While CMs primarily target adequacy objectives and flexibility needs may be addressed through dedicated markets or support schemes, storage should be able to participate fully and competitively in CMs (where it contributes to adequacy). Although CMs are generally technology-neutral in principle, their detailed design often still reflects the operational characteristics of conventional thermal generation, which remains the predominant provider of capacity. As a result, energy-constrained but highly flexible technologies such as BESS may face participation barriers or may see their contribution undervalued.

Therefore, without prejudice to a Member State's choice of adequacy or flexibility procurement instruments, CM design should allow storage to compete on a genuinely level playing field. While this principle is already embedded in most CM frameworks, further targeted design adaptations can help ensure that storage's contribution to adequacy is properly recognised and incentivised.

The following design adaptations should therefore be considered to enhance storage participation in CMs:

Topic	Storage characteristics	Possible design adaptations
Lead times	Lead times vary significantly across different storage technologies. BESS projects can typically be delivered within 1–3 years, while PHES projects often require 6–10 years due to complex permitting and construction processes. Predictable auction schedules and adequate lead times are therefore essential to ensure alignment with project development cycles.	Introduce intermediate auctions (e.g., Y-2) to facilitate BESS participation and/or allow for longer lead times to accommodate other storage technologies such as PHES.
Derating factors	Storage adequacy contribution depends on duration, round-trip efficiency and operational patterns.	Differentiate derating factors at least by duration of the storage asset.
Performance requirements	Li-ion BESS delivers energy over limited durations (commonly 2–4 hours, though longer-duration batteries up to 6–8 hours are increasingly emerging), but with very high response speed and ramping capabilities.	Require storage assets to be able to run for consecutive hours corresponding to duration used to calculate their derating factor.
Degradation	Li-ion BESS experience 1–2% annual energy capacity degradation, depending on cycling intensity.	Include degradation-adjusted capacity commitments or allow periodic re-certification for li-ion BESS.
Hybrid assets (e.g., co-located vRES + BESS)	If appropriately exposed to local grid constraints, hybrid projects can optimize the utilisation of the existing network, while improving the adequacy contribution of vRES.	Develop clear methodologies for calculating the de-rating factor to be applied to these resources.

13 ACER (2024): Security of EU electricity supply -2024 Monitoring Report

14 ENTSO-E (2025): The role of Capacity Mechanisms to enable a secure and competitive energy transition

15 Regulation (EU) 2024/1747

Recommendations

The recommendations below aim to (i) enhance investment certainty and bankability for storage projects; (ii) ensure derating methodologies accurately reflect storage's contribution to system adequacy; and (iii) align performance obligations with actual system requirements during scarcity events.

1. Adaptations to the overall auction design

To ensure that CMs effectively support the deployment of non-fossil flexibility such as storage, several adjustments to the structure and parameters of the auction design may be required.

Key measures

- **1.1** Introduce intermediate auction timelines (e.g., Y-2) to align procurement with typical li-ion BESS development, permitting and grid-connection lead times.[16] This approach helps reduce delivery risks and supports realistic project scheduling.
- **1.2** Apply progressively stricter emission limits or reserve a share of the procured capacity for non-fossil technologies.
- **1.3** Incorporate locational signals within auction clearing to steer storage investment towards areas where it alleviates network constraints and delivers the highest marginal adequacy value.
- **1.4** Member States may seek to address scarcity events that are short, dynamic, and require fast response (rather than prolonged injections) through a joint procurement of adequacy and flexibility. Such procurement may include auction premiums that reward rapid delivery during scarcity periods rather than long continuous output.

2. Adaptations to derating methodologies and contractual obligations

Refinements to derating approaches and contract structures are needed to ensure storage assets are valued accurately, subject to proportionate obligations, and able to participate on a level playing field while maintaining system reliability.

Key measures

- **2.1** Differentiate derating factors by storage duration and require assets to run for the number of consecutive hours corresponding to the duration used to calculate their derating factor.
- **2.2** Develop transparent methodologies for determining derating factors for hybrid assets (e.g., solar PV + Li-ion BESS), ensuring their combined adequacy contribution is appropriately recognised.
- **2.3** Enable access to multi-year capacity contracts for storage assets when investment levels exceed predefined CAPEX thresholds.
- **2.4** Allow degradation-adjusted contracting so that Li-ion BESS can account for predictable capacity decline over multi-year periods without incurring penalties, thus avoiding inflated bids due to unnecessary risk premiums.

16 See the Belgian example of CRM design adaptation in Chapter 3.

Policy option 3 – Designing effective non-fossil Flexibility Support Schemes

The 2024 reform of the EU electricity market design introduced non-fossil Flexibility Support Schemes (NFFSS) as a new policy tool to facilitate the decarbonisation of the power sector. NFFSSs are specifically designed to support the deployment and operation of non-fossil flexible resources such as storage and demand-side response, particularly when merchant investments alone are insufficient to meet national flexibility needs.

In the short to medium term, utility-scale storage is expected to play a central role in NFFSS due to:

- The current low participation rate of demand side response in CMs
- The limited technological maturity of other non-fossil flexible resources (e. g., CCUS-equipped gas-fired plants or large-scale deployment of green hydrogen)

Notably, NFFSSs can offer a valuable opportunity to support the deployment of capital-intensive technologies for long-duration energy storage (such as PHES) which may struggle to secure long-term contracts in a technology-neutral CM.

The theoretical framework

While CMs and FSSs share some similarities in their design – both select counterparties by means of competitive processes, award long-term contracts, and enforce performance obligations – they serve distinct policy objectives. When well designed, NFFSSs can play a key role in the decarbonisation process, by providing predictable revenues to storage developers and directing flexibility siting to where it is most valuable for the power system.

Mechanism	Primary objective	Focus
CMs	Safeguard system adequacy in an increasingly decarbonised power system	Availability of firm capacity during scarcity events
NFFSSs	Strengthen system flexibility to ensure reliable operation of power systems with a high penetration of variable RES	Time-shifting of vRES generation, ramping capabilities, congestion management

To achieve the above, a robust NFFSS should therefore be designed in line with the following principles:

- Ensure the timely deployment of non-fossil flexible resources to meet identified system needs.
- Incorporate locational signals into the tender procedure, so to prioritise investment in high-value locations, such as congested or renewable-rich areas.
- Enable higher renewable integration by reducing both curtailment levels, and redispatch and balancing costs.
- Preserve efficient short-term price formation, ensuring that being awarded a long-term NFFSS contract does not affect bidding strategies in spot markets.
- If in a given Member State short-term prices are expected to lead to inefficient scheduling, consider adding time-varying constraints or reward and penalties, to induce a system-friendly operational behaviour.
- Require participation in balancing and redispatch markets.
- Ensure availability of contracted resources during scarcity periods, thanks to transparent performance and penalty frameworks.

While the optimal design depends on national objectives and system conditions, different design models have been implemented or are being considered across Europe:

- Auction-determined annual fixed payments in exchange for installation of new capacity and compliance with other contractual obligations such as:
  - Availability requirements on both wholesale and balancing markets, to prevent strategic capacity withholding.
  - Dynamic restrictions on scheduling rights, aimed at aligning market behaviour with local grid contingencies.
  - Pay-back and claw-back clauses, to prevent excessive remuneration.

- Cap-and-Floor models, where the successful bidder is subject to both an upper and a lower revenue threshold – one set administratively, the other determined through a competitive auction. During the delivery period, if actual (or benchmark) revenues:
  - Fall below the lower threshold, the counterparty is entitled to receive the difference as compensation;
  - Exceed the upper threshold, the counterparty must return (all or part of) the excess.

  Also in this case, specific contractual obligations could be included to prevent strategic withholding of capacity and to induce system-friendly operation of procured resources.

As for Contracts for Difference (CfDs), the assessment is more nuanced. In line with the views expressed in a previous ENTSO-E's position paper,[17] standard CfDs are not well-suited for flexible resources, as they largely eliminate exposure to price fluctuations in spot markets. In principle, innovative CfD designs could be developed to better reflect the operation characteristics of storage systems – for instance, a CfD where the reference price is based on the daily min-max spread observed in the DA market. However, the effectiveness of such innovative designs should be further investigated to ensure they do not introduce undue distortions in the functioning of wholesale markets.

In any case, given the novelty of the topic, this paper does not endorse any specific design. Each approach presents distinct trade-offs between investment certainty, market efficiency, and public cost exposure. Therefore, the optimal solution should be identified at the national level, as it depends on national flexibility needs, system conditions, and the expected interaction with other elements of the national market design, such the CM and RES-support mechanisms (if present).

Ensure effective coordination between CMs and NFFSSs

As envisaged by both the amended Electricity Regulation and by the recently adopted Clean Industrial Deal State Aid Framework (i.e., the so-called and hereinafter CISAF),[18] Member States can decide to implement both a technology-neutral CM and a targeted NFFSS, reflecting two distinct yet complementary objectives: adequacy and flexibility. After all, this duality mirrors the coexistence of RES support mechanisms (e.g., two-way CfDs) and CMs observed in many national markets, and it is not per se problematic.

A joint procurement of both adequacy and flexibility may be optimal from a cost-minimisation perspective. However, in some Member States, adequacy and flexibility needs may arise in different regions of the country. In such cases, it may be operationally challenging for a single auction to convey conflicting locational signals. A sequential procurement approach – where flexibility is procured first via the NFFSS – could therefore be preferrable. Indeed, to the extent that flexible resources can also contribute to system adequacy, contracted flexibility via the NFFSS would then reduce the capacity to be secured under the CM.

However, when a NFFSS is implemented alongside a CM, the following principles should be observed:

- To avoid double remuneration for the same investment:
  - Whenever the NFFSS awards an auction-determined annual fixed payment, the same asset – more precisely, the same share of a given asset – should not be allowed to participate in both support mechanisms simultaneously.
  - Whenever the NFFSS is designed as a Cap-and-Floor mechanism, payments obtained from being awarded a CM contract should be accounted for when assessing actual revenues.
- To prevent excessive procurement of firm capacity, volumes to be secured through the CM should be reduced to account for the derated capacity of flexible resources already contracted under the NFFSS.

17 ENTSO-E (2024): Sustainable Contracts for Difference (CfDs) Design

18 Communication from the Commission, Framework for State Aid measures to support the Clean Industrial Deal (Clean Industrial Deal State Aid Framework), OJ C, C/2025/3602, 4.7.2025

Defining the perimeter of eligible storage technologies

A wide range of energy storage technologies are available today – with many more likely to be developed in the future. However, these technologies vary greatly in terms of technical and commercial maturity.

Among all the energy storage technologies currently available on the market, only PHES and li-ion BESS seem to have already reached full technical and commercial maturity. Therefore, defining the perimeter of eligible storage technologies in a NFFSS becomes a very sensitive political decision.

Indeed, a Member State implementing a NFFSS should strike an appropriate balance between the following (potentially conflicting) policy objectives:

- Safeguarding security of supply
- Ensuring an efficient use of public funds
- Promoting innovation
- Avoiding new dependencies on resources predominantly located outside Europe

To operationalise this balance, the following key measures are proposed:

- NFFSSs should primarily target utility-scale technologies with high Technology Readiness Levels (i.e., TRL ≥ 8) capable of providing reliable flexibility services. NRAs or TSOs should assess eligibility using transparent criteria reflecting both technical maturity and supply-chain robustness.
- Facilitate innovation through dedicated pilot schemes (or dedicated quotas within the main NFFSS) to support the market entry of emerging storage technologies with lower TRL. These pilots should test the performance and scalability of new technologies without compromising overall system security.
- Mitigate concentration and supply-chain risk where reliance on a single technology type poses material or geopolitical dependencies. Consider technology-specific quotas or predefined non-price/diversification criteria to maintain a resilient and sustainable storage technology mix over time.

Recommendations

To unlock the full potential of utility-scale energy storage, NFFSSs should be designed to provide stable investment conditions, system-relevant locational signals, and clear coordination with existing market and adequacy mechanisms. The following recommendations outline key design principles to ensure that NFFSSs effectively mobilise needed investments for utility-scale storage solutions while maintaining efficient market operation.

1. General design principles

- **1.1** The amended Electricity Regulation introduced NFFSSs, acknowledging that adequacy and flexibility needs are conceptually different.
- **1.2** NFFSSs should ensure the timely deployment of non-fossil flexible resources to meet identified system needs.
- **1.3** NFFSSs should steer investments to high-value locations by applying sufficiently granular locational signals in the tender procedure.
- **1.4** Flexible resources procured through an NFFSS should face significant incentives to operate in a system-friendly manner.

2. Ensure effective coordination with CMs

- **2.1** Member States that have a CM in place may choose between joint procurement of adequacy and flexibility, or sequential procurement through the coexistence of a CM and an NFFSS. In this latter case, flexibility should be procured first.
- **2.2** Whenever a Member State implements both a CM and an NFFSS: (i) the coexistence of the two support mechanisms should not result in the overcompensation of a given asset; (ii) to avoid over-procurement, capacity procured through the NFFSS should be accounted for when defining adequacy needs to be met through the CM.

3. Definition of eligible technologies

- **3.1** Eligible technologies should be chosen to strike a balance among conflicting political objectives: ensuring security of supply, minimise procurement costs, promote of innovation, avoid new form of dependency on non-EU technologies.
- **3.2** NFFSSs should primarily target mature technologies with a well-established supply-chain.
- **3.3** Innovative technologies may be supported via dedicated pilot projects or quotas within the main NFFSS auction.

Chapter 2 – From investment to operation: enabling the efficient use of storage

The previous chapter outlined three complementary policy options to stimulate timely investment in storage capacity at system-critical locations: promoting merchant investments, adapting the design of CMs and/or introducing dedicated NFFSSs. This chapter shifts the focus from investment to operation, posing a key follow-up question: *"can the existing spot market structure ensure the efficient scheduling of non-fossil flexible resources, such as storage systems?"*

While in theory, well-functioning short-term markets should lead to an efficient scheduling of available resources, in practice, several structural and regulatory barriers may prevent storage assets from operating in a way that maximises social welfare – even when they were sited at system-friendly locations.

For instance, in a recent study focusing on the British power system in mid-2024,[19] the authors found persistent misalignments between wholesale market signals and physical system conditions, leading to inefficient scheduling of flexible assets and increased system costs. In particular, the analysis showed that, due to the current nationwide wholesale market configuration:

- While batteries located in the South of GB were acting as a beneficial source of non-fossil flexibility, injections by batteries located in the North (i.e., close to wind generation) were frequently worsening intrazonal congestions and had to be constrained off on the balancing market.
- The costly redispatch actions implemented by the NESO could have been avoided if the battery's participation in the wholesale market had been consistent with grid constraints.
- While batteries have the potential to reduce the need for costly grid reinforcements, under a poorly designed wholesale market, the deployment of additional storage capacity may paradoxically justify more grid upgrades by exacerbating intrazonal congestion.[20]

Whilst similar trends are likely emerging across the EU, all the above underscore the need to better align wholesale market outcomes with the operational constraints of the power system, so to ensure that storage can contribute effectively to congestion management, system adequacy, and decarbonisation objectives. To this end, the following measures will be discussed:

Measure	Description
Enable flexible connection agreements	Facilitate faster and more dynamic integration of storage assets by allowing conditional access under predefined operational constraints, particularly in congested zones or areas awaiting reinforcement.
Make use of dynamic grid tariffs	Introduce pricing mechanisms for transmission and distribution services where the tariff rates vary by location and/or time (e.g., based on forecasted demand levels and vRES injections or expected congestion).
Introduce dedicated market rules for flexible assets	Introduce market rules that limit the participation of flexible assets in wholesale or balancing markets when their actions are likely to jeopardise the secure operation of the power market.
Bidding zone reconfigurations	Enhance the granularity of wholesale market prices, so to more accurately reflect structural congestions and localized system conditions.

19 Mann J., Perkins J. and Schittekatte T., The Curious Case of Batteries Flip-Flopping: How the Current GB Wholesale Market Design Fails to Make Best Use of Flexible Assets, December 2024

20 The authors suggested three potential solutions: (i) do nothing and accept increasing redispatch costs; (ii) implement new market rules to restrict the operational behavior of flexible assets in wholesale markets; (iii) introduce a zonal wholesale market design (the preferred option by the authors). It is worth mentioning that, against the views expressed by Ofgem in the framework of the Review of the Electricity Market Arrangements (REMA), the UK Government rejected in July 2025 the proposal to modify the current national wholesale market design, while proposing a set of measures to enhance the locational signals in their system, such as "planning reform, seabed leasing (the process by which new offshore projects are brought forward and sequenced), network build (the Centralised Strategic Network Plan (CSNP)), reforms to the connections regime, and reforms to network charging)".

Before detailing the measures mentioned above, it is important to reiterate that, for system operators to continue to operate safe and secure networks, it is essential that electricity storage modules comply with the technical requirements for grid connection as proposed by ACER to the European Commission in the RfG 2.0.[21] As stated in "*Whereas (s1)*", the technical requirements for electricity storage modules shall be the same as those for power generation modules unless explicitly specified otherwise in the Regulation. Furthermore, Article 6 (6) establishes that electricity storage modules shall meet the relevant requirements both when injecting and when withdrawing active power from the network.

Flexible connection agreements

Flexible connection agreements are among the most promising instruments to accelerate the grid integration of new resources while dynamically managing congestion. Well-designed agreements enable storage assets to connect to the grid even in the absence of available firm connection capacity, by requiring asset owners to accept predefined operational limits and curtailment conditions. This way, the deployment of new resources does not compromise system operations.

Based on the recent amendment of the Electricity Directive,[22] flexible connection agreements can be either temporary or permanent solutions:

- Temporary flexible connections can serve as bridging solutions for projects awaiting firm grid access and should not delay planned grid reinforcement works in the area concerned.
- Permanent flexible connection agreements may be considered a structural solution for congestion management. However, as prescribed by Article 6a(1)(c) of the amended Electricity Directive, they may only apply in "*[…] areas where the regulatory authority or another competent authority where a Member State has so provided, deems network development not to be the most efficient solution […]*".

Pros	› Accelerating deployment of new storage capacity, by reducing waiting times for grid connection › Increasing siting efficiency, by enabling storage to locate closer to renewable generation or demand centres, even in areas awaiting grid reinforcements › Enhancing system operation by allowing the TSO or the DSO to manage congestions dynamically › Reducing system costs, by lowering reliance on costly market-based redispatch
Cons	› Potentially difficult implementation › Greater uncertainty about market revenues that can be captured › Insufficient compensation linked to the imposed limitations › In some Member States, upgrades to the TSO or DSO IT infrastructure, to enforce (and benefit from) the agreements

Overall, given the urgency to connect increasing volumes of vRES and storage to meet the EU emission reduction targets – while also avoiding a surge in redispatch costs – flexible connection agreements are expected to play a significant role in the coming years.

However, to maximise their effectiveness and ensure they are acceptable to market participants, regulators and TSOs should ensure a transparent and non-discriminatory application of flexible connection agreements by: (i) clearly stating the objectives of the measure; (ii) establishing standardised curtailment criteria, communication protocols, and compensation mechanisms; and (iii) providing a clear timeline for granting a firm connection (in the case of temporary flexible connection agreements).

21 ACER (2025): NC RfG DC Recommendation: Annex 1a – Amended RfG Regulation TC compared to the current Regulation

22 Directive (EU) 2024/1711

Dynamic grid tariffs

Dynamic tariffs could play a meaningful role in enabling the efficient operation of energy storage by ensuring that network charges better reflect the true impact of storage on local grid conditions. Under traditional tariff structures – typically static, averaged, and largely volumetric – storage faces limited incentives to operate in ways that alleviate local constraints. Uniform tariffs can inadvertently encourage charging during periods of local high demand or discharging during periods of local high renewable output, thus contributing to redispatch needs and increasing total system costs. Dynamic grid tariffs aim to correct these inefficiencies by introducing sharper cost-reflective signals.

Dynamic grid tariffs constitute a valuable complementary tool to energy market signals, as they provide forward-looking incentives for system-efficient charging and discharging behaviour. Consistent with ENTSO-E's principles on cost-reflective tariff design, dynamic tariffs can help better align market-driven operations with expected network conditions, thereby reducing congestion-related costs and improving the utilisation of existing grid infrastructure.

In practice, however, experience to date shows that dynamic network tariff structures remain challenging to implement. For example, under the French TURPE 7 framework, storage users already face specific time-of-use signals combined with locational signals. While the regulator explored the introduction of truly dynamic ("mobile peak") tariff components, these were not retained for the 2025–2029 regulatory period due to their operational and modelling complexity, particularly in regions with high and difficult-to-predict injection peaks (e.g., high wind penetration areas).[23] This illustrates that while dynamic tariffs are conceptually attractive, their design requires careful consideration to avoid unintended or counterproductive signals.

Moreover, where implemented, the effectiveness of dynamic tariffs to reflect changing system needs is limited in time, as it would be impractical to apply dynamic signals for grid user beyond the day-ahead timeframe. In intraday and balancing timeframes storage operators' dispatch decisions are driven by market prices rather than network charges. As such, TSOs cannot rely on dynamic tariffs as a tool to manage congestions and operational issues close to real time. Consequently, even under well-designed tariff structures, suboptimal charging or injections worsening congestion cannot be fully avoided at shorter timeframes.

For this reason, while some regulators (e.g., CRE in France) are exploring whether more dynamic structures could become feasible as forecasting tools and operational practices evolve, dynamic tariffs should not be seen as a silver bullet but rather as part of a broader toolkit to manage local constraints. They should be complemented by operational measures (such as flexible connection agreements, dedicated market rules for flexible assets and, whenever appropriate, more granular price signals in wholesale markets), to ensure that flexible resources contribute effectively to system needs across all market timeframes.

Dedicated market rules for flexible assets

To address non-structural congestion, some Member States may opt for the introduction of dedicated market rules for flexible assets, aimed at promoting system-friendly behaviours in both wholesale and balancing markets.

For example, such rules could limit their admissible actions on the market when their activation is likely to exacerbate an expected congestion.[24] In addition, storage assets like BESS could be incentivised to make any remaining flexibility, not already committed in earlier market stages, available on short notice for redispatch processes, thereby enabling more effective curative redispatch.

Importantly, the public acceptance of these rules may increase if these restrictions were to be linked to the remuneration provided through an NFFSS. In all cases, these rules must be transparent, non-discriminatory, and consistently applied across different flexible technologies to prevent market distortions and ensure a level playing field.

On a different note, the ability of BESS to change output within milliseconds causes frequency disturbances in some Capacity Calculation Regions (CCRs), by generating the so-called "sawtooth" frequency pattern around Imbalance Settlement Periods (ISPs) boundaries. To prevent any further exacerbation of this issue, it is recommended to introduce ramping constraints (e.g., a 10 min ramp, ±5minutes around ISP switching) via grid connection codes and/or Terms and Conditions for Balancing Responsible Parties.

23 In its decision on TURPE 7, the French NRA (CRE) concluded that a mobile-peak signal would be too complex to implement given the difficulty of predicting injection peaks in certain areas, while a fixed-peak alternative could send counterproductive incentives. CRE therefore postponed the introduction of such a dynamic component and requested RTE to prepare a mobile-peak design for the TURPE 8 period (post-2029).

24 Mann J., Perkins J. and Schittekatte T., The Curious Case of Batteries Flip-Flopping: How the Current GB Wholesale Market Design Fails to Make Best Use of Flexible Assets, December 2024, p.10

Bidding zone reconfiguration

Where enduring structural congestion are observed, a reassessment of the existing bidding zone configuration may be warranted. Since it constitutes a structural and long-term measure, this policy option should not be considered as a remedy for short-term redispatch inefficiencies. In fact, a bidding zone review should only be pursued when repeated redispatch actions reveal enduring bottlenecks that cannot be efficiently resolved through lower-impact operational or market-based solutions.

In any case, a review of bidding zone configurations must be conducted in full compliance with the provisions set out in the Electricity Regulation and the Capacity Allocation and Congestion Management Regulation.[25] The process should ensure transparency, coordination among relevant stakeholders, and alignment with the broader objective of market integration.

Recommendations

Achieving efficient operation of storage requires dynamic, proportionate, and transparent arrangements – enabling flexibility where and when it brings the greatest system value, while maintaining coherence with Europe's broader market design and congestion management framework.

1. Short-term solutions

Key measures

- **1.2** Enable temporary flexible connection agreements to accelerate deployment of new storage capacity without worsening intrazonal congestions.
- **1.2** Investigate locational-specific and time-varying operation signals (e.g., dynamic grid tariffs, or dedicated market rules for flexible assets) to address short-term price signals that do not reflect actual grid conditions at a local level.

2. Long-term solutions

Key measures

- **2.1** Whenever analyses show clear advantages, reflect structural congestions in the wholesale market structure in line with the current regulatory framework – i.e., the Electricity Regulation and the Capacity Allocation and Congestion Management Regulation.
- **2.2** For non-structural congestion patterns, support the continuous implementation of locational-specific and time-varying operational signals (e.g., dynamic grid tariffs, or dedicated market rules for flexible assets).
- **2.3** Subject to a cost-benefit analysis by the National Regulatory Authority showing that, at given locations, grid reinforcements are not an efficient solution, enable permanent flexible connection agreements.

25 Commission Regulation (EU) 2015/1222.

Chapter 3 – Relevant national experiences

While the previous chapters focused on various policy options and regulatory developments to stimulate deployment and ensure efficient operation of utility-scale storage solutions, this chapter illustrates how several Member States are already putting these principles into practice. It combines survey-based evidence from a subset of ENTSO-E members, and three in-depth national case studies (Belgium, Italy, Germany).

As not all TSOs have contributed data, the findings reflect the systems represented in the survey and should not be interpreted as representative of all European transmission systems. Nonetheless the responses, together with selected case studies, illustrate the diversity of approaches emerging across Europe and highlight the evolving role of storage within electricity market design and system operation.

On connection requests

The survey responses confirmed that grid connection requests for battery storage have increased very rapidly, although the pace and scale differ significantly between Member States. In smaller systems, reported open grid connection requests remain in the tens of megawatts (e.g., around 30 MW in Luxembourg as of September 2025) whereas other TSOs report multiple GW of requests as seen in Czechia, Denmark, Greece, the Netherlands, and Spain.

However, several TSOs emphasise that a sizeable share of these requests is still at an early or non-binding stage, often reflecting speculative or "option value" applications submitted before firm investment decisions are taken. The situation is more pronounced in Germany and Italy, where TSOs report exceptionally large numbers of requests. German TSOs collectively record around 230 GW of BESS connection applications, while Terna reports around 300 GW of storage connection requests in Italy.

Taken together, these figures suggest a strong and growing developer interest in utility-scale BESS, but they also highlight the need for efficient connection procedures, transparent prioritisation rules, and credible market and tariff frameworks to ensure that only system-relevant projects proceed to realisation.

On flexible connection agreements

The survey also explored the use of flexible connection agreements for storage, and here again practices are highly heterogeneous. Some TSOs, including those in Belgium, Denmark, Spain, the Netherlands and Switzerland, already apply flexible connection arrangements in a systematic way. These allow storage units to connect under specified curtailment or operational constraints, thereby facilitating faster integration while maintaining system security. Other TSOs do not yet make use of such agreements, although several indicate that appropriate frameworks are being developed, planned or considered, including in Luxembourg, Finland, Germany, Greece and Italy. In a few systems, flexible approaches are not formalised but are acknowledged implicitly, such as in Serbia, where applicants are warned during the connection process that future operational limitations may arise.

Even where flexible agreements do exist, many TSOs apply the same rules to storage as to other asset types, while some have pilots or early-stage schemes that have not yet been widely deployed, as in Czechia and Luxembourg.

Taken together, the responses suggest that although flexible connection agreements could play a key role in managing increasing volumes of BESS and enabling more system-oriented behaviour at the grid edge, they remain an under-used or still-evolving tool in many European systems.

On grid tariffs

Another area where national practices diverge considerably concerns the application of grid tariffs to storage. Responses from TSOs show that some TSOs apply standard tariff rules to battery units, as is currently the case in Austria, Finland and Luxembourg. In contrast, other systems grant partial or full exemptions from consumption and/or generation grid tariffs. Examples include Spain, Italy, Germany and Serbia. A further group of TSOs reports tariff regimes that vary over time or depending on location or operational behaviour, such as in the Netherlands and Switzerland, or notes that ongoing reviews may lead to future adjustments.

Across all these responses, tariff frameworks in many countries have not yet fully caught up with the rapid expansion of storage systems, particularly given their dual role as both consumers and generators. The resulting heterogeneity raises questions about efficiency, investment predictability and cross-border consistency.

On the provision of real-time State of Charge information

An operational aspect examined in the survey, reveals a similarly uneven landscape. Some TSOs, such as those in Spain, Italy and Czechia, already receive real-time State of Charge (SoC) data from storage assets, particularly where these assets participate in balancing markets or provide grid-support services. Others, including TSOs in Finland, Germany, Austria, Denmark and the Netherlands, do not receive such information, either because storage is predominantly connected at the distribution level (and storage deployment may be too recent for TSO – DSO operation protocols to be already in place) or because existing market rules have not yet been updated.

The absence of a consistent approach across countries highlights an emerging structural challenge: as BESS volumes increase and their contribution to system services expands, real-time visibility of storage behaviour will become increasingly important for maintaining secure system operation, particularly in balancing and congestion management.

Case studies from selected countries

Against this backdrop of diverse national practices and rapidly evolving regulatory, operational and market conditions, several Member States have already begun to design and implement targeted frameworks to address the emerging challenges identified in the survey. These initiatives offer valuable practical insights into how storage can be effectively integrated into adequacy mechanisms, renewable integration strategies and grid operation. The following section therefore presents three case studies that illustrate concrete national approaches: the amendments to the Belgian CRM aimed at facilitating storage participation; Italy's dedicated procurement mechanism for new utility-scale storage capacity (MACSE); and Germany's Grid Booster projects, which represent one of the most advanced examples of system-integrated storage for curative congestion management. Together, these examples provide a tangible illustration of how Member States are operationalising principles discussed in earlier chapters and point to potential design pathways for future European policy development.

CASE STUDY 1: Amendments to the Belgian capacity remuneration mechanism to facilitate participation of storage

Belgium provides a clear example of how a capacity mechanism can be progressively adapted to better accommodate storage technologies while remaining technology neutral and compliant with EU State Aid Guidelines.

The original Belgian capacity remuneration mechanism (CRM), approved by the European Commission in 2021, relied on two auction timings:

- A Y-4 auction, intended to support new large-scale generation with long construction times, and
- a Y-1 auction, better suited for shorter-lead-time resources, such as demand response.

However, these timelines proved misaligned with the investment cycle of utility-scale batteries as Y-4 is too early to provide bankable revenue signals, while Y-1 is too late to secure financing and reaching final investment decisions.

To address this misalignment, Belgian policymakers identified multiple options to facilitate the participation of storage in the mechanism, which were again submitted to and approved by the European Commission in 2024.[26] The amended auction design introduced a new Y-2 auction which:

- Aligns more closely with battery lead-timelines;
- Remains fully technology neutral, as all capacity types can participate; and
- Preserves the integrity of the original CRM design.

Introducing a new auction raised concerns about the allocation of demand over the different auctions (i.e., Y-4, Y-2 and Y-1), as other units (that are not batteries) might feel disadvantaged because *ceteris paribus* there is less capacity available for them in the Y-4 or Y-1 auction. The solution has been the introduction of a so-called dynamic capacity reservation. Whereby, if it is observed that technologies expected to participate more in the Y-2 or Y-1 auction do in fact participate in the Y-4 auction, less capacity is reserved for the subsequent Y-2 and Y-1 auction. Thus, ensuring a level playing field between technologies, while still providing an optimally timed auction to batteries.

Additionally, the Belgian CRM is designed as a reliability option. This means that whenever the market price exceeds a pre-defined price threshold, any profits above those are considered as windfall profits and need to be paid back. This serves a twofold purpose:

- Contracted capacities are doubly incentivised to be running during periods with high prices, and
- The total costs of the mechanism are reduced.

For conventional power units, this is appropriate, as higher prices typically correspond to higher margins. However, for storage technologies, this so-called payback obligation posed a problem. This created situations where high prices triggered payback obligations, while spreads (and thus actual storage revenues) remained low. To avoid penalising storage units unfairly, the amended CRM exempts storage from payback obligations, thereby restoring an appropriate risk-reward balance and facilitating their effective participation.

Lastly, the Belgian CRM incorporates several smaller design elements to better capture the operational characteristics of storage units, which include but are not limited to:

- A degradation factor for battery units, to account for declining performance over time.
- Explicit treatment of technological constraints, notably the duration for which storage is expected to be "available".
- Flexible selection of these aforementioned availability hours ahead of the auction, to allow market participants to choose the number of consecutive hours their asset can reliably operate.

26 EC State Aid decision SA114003

CASE STUDY 2:
Procurement of new utility-scale storage capacity in Italy (MACSE)

Italy represents one of the first EU Member States to introduce a dedicated competitive mechanism for the procurement of new utility-scale energy storage capacity, the so called MACSE (*Mercato per l'Approvvigionamento di Capacità di Stoccaggio Elettrico*).

Based on Terna's estimates, large volumes of utility-scale storage capacity will be required alongside new vRES to meet the emission reduction targets set in the Fit-for-55 package. A tailored support mechanism was therefore deemed fundamental to:

- Coordinate investments in vRES, storage capacity and grid infrastructure in both space and time; and
- Lower investment risk – and consequently, financing costs – by offering long-term contracts with a central counterparty.

The MACSE was developed by Terna based on Legislative Decree 210/2021 and NRA's Resolution 247/2023, and was approved by the European Commission as compatible with State aid rules in December 2023.[27]

The MACSE will coexist with the Italian market-wide CM. One of the reasons behind this design choice is that, in the Italian context, the load is mainly located in the North of the country, while utility-scale vRES will be mainly deployed in the South. In a country featuring 7 bidding zones, the adequacy-related locational signals (i.e., firm capacity is best located close to the load) are expected be different from locational signals for vRES integration (i.e., storage is best located close to v-RES farms to avoid unnecessary curtailment).

To avoid any risk of over-procurement, the adequacy contribution of "MACSE storage systems" will be accounted for when assessing the need of a new CM auction. Furthermore, to avoid any risk of double remuneration, a given storage capacity will not be allowed to participate in both mechanisms.

How is new storage capacity procured?

Before each tender, both Terna and the NRA must carry out certain preliminary activities. While Terna is responsible for (i) identifying the set of eligible storage technologies, (ii) quantifying the volumes to be procured and (iii) defining technology-specific parameters (e.g., lead time, delivery period, target duration and round-trip efficiency), the NRA is responsible for setting the reservation price of the auction.

Locational signals are given to potential bidders by applying the following methodology. First, Terna defines a national need for a given target year. Then, for each of the 7 bidding zones (or for an aggregate of those), a minimum (required) and a maximum (admissible) level of storage capacity is defined. Bids are selected so to maximise social welfare nationally, provided that the procured capacity in each bidding zone is between the respective min-max values.

Successful bidders will then be remunerated (based on the pay-as-bid criterion) starting from the end of the lead time and for the whole delivery period. At the same time, they will be required to realise contracted capacity on schedule and then make it available for the whole delivery period.

How is new storage capacity scheduled on energy markets?

The mechanism also introduces so-called time-shifting contracts to schedule contracted storage capacity on both DA and ID markets.

- Time-shifting contracts will be auctioned on a platform managed by Italian NEMO based on the overall level of storage capacity procured in a bidding zone through the mechanism.
- These contracts will be differentiated based on: (i) performance and location of the capacity they are associated to; and (ii) the duration of the contract itself (i.e., multi-yearly, yearly, monthly, weekly, or daily).
- Holders of these contracts will be entitled to schedule on both DA and ID markets a "virtual" storage system, endowed with a fraction of the overall MACSE storage capacity available in that bidding zone.
- The time-shifting contract associated with a given "virtual" storage system determines its power/energy limitations.
- For each market time unit and bidding zone, Terna will aggregate the schedules of "virtual" storage systems and will allocate the resulting overall schedule among the physical assets located in the same bidding zone.

Revenues generated through the sale of time-shifting contracts to market participants will contribute to lowering the net cost of the mechanism borne by end-users.

27 State Aid SA.104106 (2023/N) – Italy Support for the development of a centralised electricity storage system in Italy

How do contracted storage systems participate in the Italian market for balancing and redispatch?

Storage systems built under the MACSE must participate in Italy's balancing and redispatch markets via a Balancing Service Provider (BSP) identified by the asset owner, while the above-mentioned time-shifting contracts do not play any role in this time frame.

While the BSP can freely operate in these markets, the asset owner who initially signed the MACSE contract will face the following obligations:

- Pay-back obligation on bids for upward activations – the asset owner must pay back the difference (if positive) between a reference and a strike price:
  - The reference price is defined as a function of both upward bids submitted by the BSP and prices prevailing in the market for upward activations.
  - The upward strike price is equal to the standard hourly variable cost of an OCGT, determined applying the same methodology already in use for the Italian CM.
- Pay-back obligation on bids for downward activations – the asset owner must pay back the difference (if negative) between a reference and a strike price:
  - The reference price is defined as a function of both downward bids submitted by the BSP and prices prevailing in the market for downward activations
  - The downward strike price is 0 €/MWh.
- Claw-back clause – the asset owner must pay back to Terna 80 % of the revenues (if positive) obtained by the asset from participating the market for redispatch and balancing.

The proceeds obtained from the pay-back obligation and the claw-back mechanism will be allocated to reducing the net cost of the mechanism borne by end-users.

Evidence from the first tender procedure

The first tender took place in September 2025. In that occasion, around 10 GWh of new BESS was procured at a country-wide average price below 13 k€/MWh-year, with delivery starting in 2028 for a 15-year period. Capacity was awarded in several areas: Centre-South, Sardinia, Sicily, South + Calabria.

Area	Assigned volumes [MWh]	Average price [€/MWh-year]
Centre-South	2,000	14,566
Sardinia	500	15,029
Sicily	500	15,846
South + Calabria	6,968	12,137

This experience makes Italy a front-runner in dedicated storage procurement, providing useful lessons on how long-term contracts, locational targeting and integration into energy and balancing markets can be combined in a coherent framework.

CASE STUDY 3: Grid booster projects in Germany

Germany provides some of the most advanced examples of system-integrated storage used directly for grid operation. The "Grid Booster" projects initiated by TenneT and Amprion show how large-scale battery storage can serve as a *virtual transmission line*, increasing the utilisation of existing assets and avoiding costly preventive redispatch actions.

In 2022, Germany's redispatch costs exceeded € 4.2 billion, driven by increasing congestion between renewable-rich northern regions and industrial demand centres in the south.[28] Grid boosters are designed to address this challenge by shifting from preventive to curative congestion management, enabling the grid to operate closer to its physical limits while maintaining security.

The TenneT Grid Booster is a *curative congestion management solution* approved by the Bundesnetzagentur as part of the Grid Development Plan 2030 (2019).

Two 100 MW / 100 MWh battery systems are installed at geographically distinct substations – Audorf (Schleswig-Holstein) and Ottenhofen (Bavaria). The batteries are connected through the transmission grid and operate as follows.

When a transmission line between the two substations experiences an outage, the northern storage unit (Audorf) absorbs excess power, while the southern unit (Ottenhofen) injects energy into the grid.

28 Bundesnetzagentur (BNetzA) Monitoring Report 2023. Total redispatch costs in Germany amounted to € 4.2 billion in 2022, compared to € 2.3 billion in 2021.

This “balanced activation” acts as an automated redispatch, mitigating overloads on parallel lines and preserving system stability without operator intervention.

By enabling curative instead of preventive congestion management, the grid booster increases the loading limit of existing transmission corridors and reduces reliance on redispatch. Beyond congestion management, the system can also provide voltage control, virtual inertia, and black-start capability – demonstrating the multifunctional value of utility-scale storage in system operation. Commissioning of both units is expected in 2027.

The Amprion Grid Booster project, approved under the Grid Development Plan 2037/2045, applies the same concept in a decentralised and modular configuration. It will deploy 250 MW / 250 MWh of battery capacity distributed across five locations in Bayerisch-Schwaben: Vöhringen, Gundremmingen, Woringen, Leupolz, and Meitingen. Each site integrates several battery modules with control and switching technology connected through existing substations.

Each module comprises several battery units with integrated switchgear and control systems, connected via existing transformer stations. Batteries can deliver power within milliseconds to alleviate line congestion and reduce redispatch costs.

Amprion’s tender offers two variants:

- Full-year availability (8,760 hours) for exclusive TSO use.
- Seasonal operation, excluding April - August.

When not required for TSO operation, facilities may temporarily participate in the market under § 11a (2) of the German Energy Industry Act, ensuring optimal asset utilisation. The decentralised design enhances availability, lowers connection costs, and minimises environmental impact. The project is expected to enter operation by December 2026. By enabling fast-acting, automated curative response, the system allows for higher transmission line utilisation and reduced reliance on fossil redispatch resources. Although the region has a significant need for reactive power, Amprion is legally prohibited from jointly tendering reactive power services within the same procurement, reflecting ongoing regulatory boundaries between system operation and market-based flexibility.

Emerging lessons from national experiences

Across the survey results and case studies, several common lessons emerge:

1. **Investment interest is growing, but further efforts are needed to ensure timely and effective management of connection requests**
   Very large pipelines of storage projects are visible in some systems, particularly Germany and Italy. This underscores both the perceived opportunity and the need for robust, predictable frameworks to filter and guide investments.

2. **Flexible connection and system-integration tools are still evolving**
   Many TSOs are only beginning to investigate flexible connection agreements and system-focused storage models, suggesting significant scope for further innovation and knowledge sharing.

3. **When it comes to designing capacity mechanisms, details matter**
   The Belgian example shows how adjustments to the overall CM design can significantly facilitate storage participation, without compromising the principle of technology-neutrality.

4. **Locational and functional targeting are increasingly important**
   Italy’s MACSE demonstrates how storage procurement can be designed to support vRES integration where it is most needed, while Germany’s Grid Boosters may constitute an alternative solution to address congestions.

These experiences provide concrete building blocks for the design of future European and national frameworks for utility-scale storage and inform the policy recommendations developed in the previous chapters.

Conclusions

Storage assets will be an essential element of the generation mix in any decarbonised power system. To this end, the European regulatory framework for storage should be guided by the following principles:

1. Deployment stage

- Establish conditions that allow private investors in these capital-intensive technologies to achieve a fair and predictable return, as a prerequisite for deployment.
- Guide siting decisions by private developers to locations where storage delivers the highest value for the system.

2. Operation stage

- Ensure that the inherent flexibility of these resources can enhance system security, reliability and reduce overall costs.

Increasing short-term price variability is improving the conditions for merchant investments in flexible resources such as storage systems. In some Member States, this trend may be sufficient to trigger large-scale and timely deployment of storage. In such cases, the key regulatory challenge in the deployment stage is to guide investment to system-friendly locations.

In other Member States, merchant initiatives alone may be ineffective at delivering storage capacity at the required scale and in the most beneficial locations. In such cases, complementary long-term contracting instruments should be considered the most appropriate solution.

Firstly, CMs can enable a system-friendly roll-out of adequacy-contributing storage systems, provided their design (e.g., auction timing, derating methodologies, performance requirements) is adapted to reflect the characteristics of these energy-constrained technologies and locational signals are integrated into auction clearing mechanisms.

Secondly, NFFSSs could be introduced to efficiently procure the required level of flexible resources. A well-designed NFFSS should steer investments to system-relevant nodes and ensure a system-friendly operation of contracted resources. When a CM is also in place, measures must be in place to prevent double remuneration of the same asset and avoid capacity over-procurement at the national level.

Irrespective of the chosen approach to ensure the timely roll-out of storage at system-friendly locations, the regulatory framework must ensure that these flexible resources contribute effectively to the operation of the power system. If wholesale price signals alone cannot ensure system-friendly scheduling (e.g., when network constraints are not adequately reflected in short-term markets), additional operational measures should be considered, including flexible connection agreements, dedicated market rules for flexible assets or dynamic grid tariffs. Where structural congestion persists, market design measures should be complemented by structural solutions, including grid reinforcement or bidding-zone review, in line with the existing regulatory framework.

List of Acronyms/ Abbreviations

aFRR	Automatic Frequency Restoration Reserve
BESS	Battery Energy Storage System
BSP	Balancing Service Provider
CAPEX	Capital Expenditure
CCUS	Carbon Capture, Utilisation and Storage
CfD	Contract for Difference
CISAF	Clean Industrial Deal State Aid Framework (referred to as "CISAF" in the paper)
CM	Capacity Mechanism
DA	Day-Ahead (market)
GHG	Greenhouse Gas
ID	Intraday (market)
ISP	Imbalance Settlement Period
MACSE	Mercato per l'Approvvigionamento di Capacità di Stoccaggio Elettrico (Italian market for procurement of storage capacity)
mFRR	Manual Frequency Restoration Reserve
NFFSS	Non-Fossil Flexibility Support Scheme
OCGT	Open-Cycle Gas Turbine
OPEX	Operational Expenditure
PHES	Pumped Hydro Energy Storage
PPA	Power Purchase Agreement
PV	Solar Photovoltaic
vRES	Variable Renewable Energy Sources

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