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Redesigning Stability-Related Ancillary Services in Spain for a High-Renewables Grid (2026-2040): Market and Procurement Options for CNMC and MITECO

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Executive Summary

This project evaluates alternative market-design approaches for Spain's stability-related ancillary services in the context of a power system with a rapidly growing share of renewable generation. As synchronous generation declines, the Spanish system is losing part of the inertia, fault current and other stabilizing attributes that were historically provided implicitly by conventional plants. The relevance of these issues was reinforced after the Iberian blackout in April 2025. In this context, the project examines how Spain could redesign the procurement and remuneration of stability-related services between 2026 and 2040 in a way that maintains system security, supports efficient competition and remains credible for investors and policymakers.

The main objective of the study is to answer a practical policy question: how should Spain redesign stability-related ancillary services to ensure system security at the lowest overall system cost while preserving efficient competition in a high-renewables power system? The analysis is developed from the perspective of public decision-makers, especially MITECO and CNMC, which are responsible for shaping the regulatory and market framework governing ancillary services in Spain.

To address this question, the project applies a structured methodology combining several analytical steps. First, it reviews the Spanish market and regulatory baseline and identifies the main gaps in the current framework. Second, it assesses future stability needs and the technical and commercial readiness of potential providers such as grid-forming resources, battery storage, hybrid plants and synchronous condensers. Third, it benchmarks international experience in Great Britain, Ireland, Australia and Germany and evaluates the transferability of those models to Spain through a comparative lens. Finally, it develops three policy options for Spain, compares them through a structured qualitative assessment and tests the robustness of the recommendation through sensitivity analysis. The preferred option is then translated into an indicative implementation and economic model for 2026–2040.

The analysis finds that Spain does not lack ancillary services as such, but rather faces a growing mismatch between future system needs, current procurement arrangements and the incentives available to potential providers. The main weaknesses of the current framework lie in limited product definition, weak remuneration and investment signals, and insufficient monitoring and verification arrangements. The study also finds that the relevant technologies already exist, but that technical capability alone is not enough. Therefore, future deployment will depend on clearer revenue visibility, appropriate contract design and stronger operational rules.

Based on the comparative assessment, the project concludes that the strongest overall pathway for Spain is a hybrid model combining forward-looking system planning with targeted procurement mechanisms for stability-related capabilities. This option performs best because it balances two needs at the same time, planning-led intervention where stability needs are highly location-specific and difficult to procure efficiently through pure market mechanisms, and targeted market-based procurement for certain capabilities where competition can improve price clarity and investment signals. The recommendation is robust across the sensitivity analysis, with Option C remaining the preferred pathway in four of the five decision lenses considered.

From an economic perspective, the indicative modelling suggests that the preferred pathway is material but manageable. In the central case, Option C results in a total program cost of €1,221.0 million over 2026–2040 on an undiscounted basis, with a present value of €974.2 million and an average gross cost impact of around €0.29/MWh. The model includes ten planned synchronous-condenser-equivalent units and a competitive procurement layer reaching 10.5 GVA·s by 2040.

Overall, the project concludes that Spain should move progressively away from a framework in which stability is still partly implicit and unevenly remunerated, and towards a hybrid architecture in which critical location-specific needs are addressed through planning while services are procured explicitly through transparent mechanisms. Such a reform would be more consistent with the technical realities of a high-renewables electricity system, more supportive of flexible low-carbon investments and more robust for policymakers managing Spain's energy transition.

Keywords: grid, renewable energy, ancillary services, system stability, renewable integration.

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1. Introduction

1.1. Why stability services are a strategic issue for Spain

The Spanish electricity system is undergoing one of the fastest renewable energy transitions in Europe. Over the past decade, wind and solar capacity have expanded rapidly, transforming the generation mix and reducing reliance on conventional synchronous generation. While this transition supports decarbonization and energy independence objectives, it also introduces new operational challenges for the power system.

Traditionally, the system's stability has been a by-product not explicitly remunerated granted by synchronous conventional generation, such as nuclear, coal or combined cycles. Nonetheless, the rapid increase in wind and especially photovoltaic energies (see Figure 1) has decreased this important base of synchronous technologies, putting Spanish grid stability at risk.

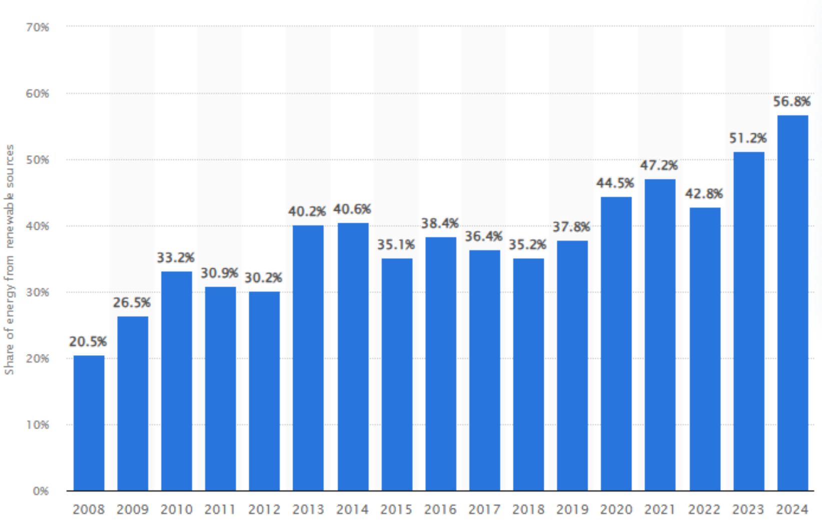

Figure 1. Share of energy from renewable sources in Spain (2008-2024) [1].

According to *Red Eléctrica de España* (REE), in 2025 the Iberian Peninsula had 56.6% of renewable generation on average [2]. Furthermore, there were time-slots with more than 80% renewable penetration [3]. This supports the achievement of European and Spanish energy-policy objectives, such as the *Plan Nacional Integrado de Energía y Clima* (PNIEC), which plans to have mainly renewable energies on the energy mix by 2030, pursuing clean-energy use and energy independence [4]. However, it also creates many risks, as the loss of the synchronous technologies that give stability mentioned earlier. The April 2025 Iberian blackout [5] highlighted all these stability problems in the system, reinforcing the urgency of revisiting stability procurement mechanisms.

Moreover, the 20th of March 2026 ENTSO-E published their final report on the mentioned incident [6]. This report highlighted that the event was not solely driven by reduced system inertia, but rather by a combination of voltage control issues, insufficient reactive power management, and dynamic interactions within a high share of inverter-based generation. It pointed to limitations in existing operational practices, monitoring capabilities and technical requirements, which were not fully adapted to the needs of a high-renewables system. Overall, the findings reinforce the need to reconsider how stability is defined, procured and ensured in the Spanish electricity system.

In this scenario, new technologies are emerging that can help keep grid stability without the need for strong synchronous capacity.

1.1.1. Challenge in the market

This technological shift creates a structural market design challenge. While solutions are commercially available, current market frameworks in Spain do not explicitly define or remunerate the stabilizing attributes they provide. Therefore, developers rationally deploy lower-cost configurations that meet existing compliance requirements but may not optimally support long-term system stability.

This misalignment between system needs and investment incentives constitutes a coordination problem. If Spain aims to maintain security of supply at the lowest total system cost, it must determine whether and how to procure stability services through dedicated mechanisms in a way that encourages efficient deployment of capabilities that stabilize the grid.

1.2.Scope, assumptions, and constraints

- **Scope**

This study evaluates alternative market design approaches for stability-related ancillary services in the Spanish electricity system over the period 2026–2040. The analysis focuses on how these services are remunerated in several countries and their applicability to Spain. Finally, a simplified cost analysis for the recommended approach is conducted, in order to see the potential economic impact of the approach.

- **Assumptions**

The analysis assumes that advanced inverter-based resources, including grid-forming technologies and battery storage, will be technically available and commercially deployable during the timeframe considered.

- **Limitations**

The study relies on publicly available data, regulatory documents and international experience to assess policy and market design options. Many assumptions are made considering Great Britain's and Australia's data and extrapolated to the Spanish electricity market. The geographical scope of the analysis is limited to the Spanish peninsular electricity system.

1.3. Decision questions

The main objective of this project is to address the following strategic question: how should Spain redesign stability-related ancillary services to ensure system security at the lowest overall system cost while preserving efficient competition in a high-renewables power system?

This question is analysed from the perspective of public decision-makers, particularly the *Ministerio para la Transición Ecológica y el Reto Demográfico* (MITECO) and the *Comisión Nacional de los Mercados y la Competencia* (CNMC), which are responsible for shaping the regulatory and market framework governing ancillary services in the Spanish electricity system.

1.4. Methodology

This project applies a structured methodology to evaluate alternative market design options for Spain's stability-related ancillary services. It begins with a PESTEL analysis to frame the external context, followed by a baseline review of the current Spanish ancillary services framework. On this basis, a gap analysis is carried out to identify misalignments between the current design and the needs of a high-renewables system.

The study then assesses future stability requirements from a functional perspective and evaluates the technical and commercial readiness of potential providers such as storage, hybrid plants and grid-forming technologies. International benchmarking, particularly from Great Britain, Ireland, Australia and Germany, is used to extract relevant lessons and assess their transferability to Spain through a comparative lens based on the CAGE framework. Finally, the project develops and compares several market design options through a comparative assessment and translates the preferred option into an implementation roadmap for 2026–2040, analysing the potential costs of the chosen option.

2. Spanish Market and Regulatory Baseline

2.1. Current procurement of ancillary/stability-related services

In this section the current Spanish framework for ancillary and stability-related services is reviewed. It examines the institutional structure, the main existing service arrangements, and the extent to which system stability is still delivered through a combination of explicit services and implicit support from synchronous generation. This provides the basis for the gap analysis developed in section 2.2.

2.1.1. External context for reform: a PESTEL view

From a **political** perspective, electricity system reform in Spain is increasingly linked to broader concerns about energy security and strategic autonomy. Recent geopolitical developments and volatility in international energy markets have reinforced the importance of reducing dependence on imported fossil fuels and strengthening the resilience of national energy systems. Within the European Union, this objective has translated into a stronger policy emphasis on renewable energy deployment, electrification and the expansion of domestic low-carbon energy sources, including nuclear energy. In Spain, social rejection to nuclear energy challenges such approach, leaving renewables as unique clear alternative.

Looking into **economy**, the main challenge is to ensure that stability services are delivered at the lowest overall system cost while keeping clear investment signals for existing and emerging providers. As the generation mix evolves, the historical model under which part of system stability was provided implicitly by conventional synchronous generation becomes less robust, increasing the need for more clearly defined procurement and remuneration arrangements regarding stability services. This raises questions not only about operational efficiency, but also about cost allocation, investment bankability and long-term market design.

Socially, system stability is ultimately linked to the quality, reliability and continuity of electricity supply, which makes it a matter of public interest rather than a purely technical operational concern. In practice, ancillary services exist precisely to ensure the quality, reliability and security conditions of the electricity supply [7]. As a result, the adequacy of these services has implications not only for system operators and market participants, but also for consumers and the wider economy.

The **technological** dimension is particularly important in the Spanish case. According to REE, renewable sources accounted for 56.6% of electricity generation in Spain in 2025, while renewable installed capacity represented 68.9% of total installed capacity [2]. This shift increases the need for new sources of system support. Technologies capable of providing inertia-like response, voltage support and other stability-related capabilities are already technically feasible. Moreover, artificial intelligence may also support future system operation through forecasting and monitoring tools, but its detailed implementation is outside the scope of this project.

From an **environmental** point of view, the continued expansion of renewables is not optional but central to Spain's long-term energy and climate strategy.

Finally, the **legal** or regulatory dimension is critical because any redesign of stability-related services must remain consistent with the broader European electricity market framework. Regulation (EU) 2019/943 states that "transmission system operators shall select capacity providers by means of a transparent, non-discriminatory and competitive process", establishing the principle that system services should be competitively procured whenever possible [8].

2.1.2. Current institutional and regulatory architecture in Spain

The design and operation of ancillary and stability-related services in Spain depend on a layered institutional structure in which policymaking, regulatory supervision and real-time system operation are distributed across different actors.

At the strategic level, MITECO defines the overall direction of Spanish energy policy and establishes the legislative framework governing the electricity sector [9]. At the regulatory level, CNMC supervises electricity markets and is responsible for approving key methodologies related to regulated activities, access tariffs and system services [10]. At the operational level, REE acts as transmission system operator and transmission grid manager, ensuring secure system operation and managing the adjustment mechanisms needed to maintain system balance and network security [11].

The legal foundation of the Spanish electricity system is established in Law 24/2013 on the Electricity Sector [12], which defines the general framework for system operation and assigns responsibility for maintaining the technical security of the electricity system to the transmission system operator.

In addition to the national framework, the Spanish system is increasingly influenced by European electricity market regulation. Balancing services have progressively been aligned with EU rules through the implementation of the Electricity Balancing Guideline and the integration of the Spanish system into European balancing platforms such as PICASSO and MARI [13]. As a result, ancillary service design in Spain is shaped not only by domestic institutions but also by the broader process of European market integration.

2.1.3. Existing ancillary services and procurement mechanisms

Within the current institutional framework, the Spanish electricity system relies on a combination of balancing services, non-frequency services and operational processes used by the transmission system operator to maintain secure system operation [14]. In practice, the mechanisms used by REE include both market-based ancillary services and operational redispatch processes required to ensure network feasibility.

The main services currently implemented in the Spanish peninsular system include secondary control (aFRR), tertiary control (mFRR), replacement reserves (RR), voltage control, black start, and a specific balancing mechanism for active demand response (SRAD) [14].

Table 1 summarises the main services and operational mechanisms currently used in Spain and the way they are procured.

Table 1. Main ancillary services in the Spanish electricity system. Author's elaboration based on [14].

Service	Category	Purpose	Procurement mechanism
Technical constraints	System operation	Resolve network feasibility and security constraints	Redispatch by system operator
aFRR	Balancing	Automatic correction of frequency and schedule deviations	Capacity and energy market
mFRR	Balancing	Restore secondary reserves and resolve imbalances	Mandatory capacity offers
RR	Balancing	Support balancing energy platforms	Market-based procurement
Voltage control	Non-frequency	Maintain voltage levels and reactive power balance	Regulated service
Black start	Restoration	Restore system after blackout	Contracted service
SRAD	Balancing	Provide upward reserve from demand	Auction-based mechanism

Overall, the current framework combines different types of service arrangements. Some mechanisms are market-based, others are regulated, and some are implemented directly through operating procedures managed by the system operator. The framework works, but it has not been designed as a coherent stability-services architecture.

However, other important stability attributes, including inertia, short-circuit strength and fast reactive current support, have historically been available as a product of synchronous generation rather than through explicitly bought attributes. As synchronous generation declines, these capabilities may need to be explicitly defined and procured in the future.

2.2. Main gaps in the current framework: gap analysis

The review of the current institutional and operational framework suggests that the Spanish system works reasonably well today, but it is not yet fully adapted to a power system with a growing share of inverter-based resources. Spain already has balancing and non-frequency services in place, but the current architecture has developed gradually over time rather than through a broader redesign aimed at future stability needs.

The main issue is therefore not the lack of ancillary services as such, but the growing gap between what the system will need in the coming years, what is currently procured, and what providers are incentivised to invest in and deliver.

This gap analysis identifies three main areas of concern: product definition, remuneration and investment signals, and monitoring and verification. Together, they help explain why a framework that still works today still has many gaps that affect stability.

2.2.1. Product definition gaps

The first gap concerns the definition of stability service products. Although the Spanish framework already includes explicit balancing and non-frequency services, not all relevant stability attributes have been translated into clearly defined service products. European regulation recognises capabilities such as inertia, fast reactive current support, short-circuit strength, black-start capability and island operation capability as relevant non-frequency ancillary services [8]. In practice, however, the Spanish framework has mainly developed voltage control and black start, while the other stability attributes remain only partially reflected in the service design [15]. As a result, some of the capabilities that are likely to become more important in the future are still not fully specified as products that can be clearly procured and valued.

2.2.2. Remuneration and investment gaps

The second gap concerns investment incentives. In the current framework, many revenues linked to system services remain short-term and operational, often depending on participation in adjacent markets rather than on a stable contractual recognition of the underlying capability. This may be manageable for conventional assets, but it is more difficult for newer technologies such as battery storage, hybrid plants or grid-forming solutions, whose business case often depends on clearer and more durable revenue streams. As noted by the National Renewable Energy Laboratory, “the same storage project can often provide multiple services to the grid. This multi-use approach to asset utilization is known as *value stacking*” [16]. However, when market frameworks do not clearly reward these different value streams, investment incentives for new flexibility and stability providers remain weaker than they could be.

2.2.3. Monitoring and verification gaps

The third gap concerns monitoring and performance verification. As long as a significant share of stability comes from synchronous generation, system operation can rely to some extent on technical characteristics that are simply present in the system. That becomes more difficult once the service's demand requires the use of storage and inverter-based technologies. In those cases, it is more important to define clearly what is being delivered, how it is measured, and how compliance is verified. Without clear monitoring and compliance mechanisms, new services may be hard to implement in practice even when product definitions exist.

2.2.4. Summary

The three gaps analysed in sections 2.2.1-2.2.3 suggest that the main issue is not that the Spanish system is unable to work today, but that the current design is not yet fully ready for the next stage of the transition. Spain already has a functioning ancillary service architecture, and recent reforms point in the right direction. However, the framework still fails to be a model in which stability services are clearly defined, consistently procured and supported by credible incentives for new providers.

Table 2 summarises the gaps identified in the current framework. This diagnosis provides the bridge to section 3, which examines in more detail the stability needs of a high-renewables system.

Table 2. Summary of identified gaps.

Gap	Description	Implication
Product definition	Some stability attributes not defined as services	Hard to procure capabilities
Investment signals	Revenue uncertainty	Weak incentives
Monitoring	Limited verification frameworks	Difficult implementation

3. Future Stability Requirements and Market Readiness

As mentioned in the previous sections, the transition to high-renewable systems requires the electrical markets and operators to adapt. But what are the technological and commercial realities in Spain today?

3.1. What modern assets can realistically provide

These are the different technologies currently available, that can cope with the adaptation to this new system.

3.1.1. Grid-forming technology (GFM)

Most inverter-based renewable resources currently deployed in Spain operate using grid-following controls. These systems synchronize with the voltage and frequency waveform already present in the grid and inject current accordingly. In practice, they rely on the presence of a strong and stable electrical reference provided by synchronous generation [17].

This model has historically worked well because conventional power plants inherently provided system inertia, voltage support and fault current as a by-product of their rotating machinery. However, as renewable penetration increases and synchronous generation declines, these stabilizing properties become less available in the system.

GFM technologies represent a different operational paradigm. Instead of synchronizing with an external reference, they actively establish and regulate voltage and frequency. In doing so, they can emulate some of the stabilizing functions traditionally provided by synchronous generators and support system operation in weaker grid conditions [17].

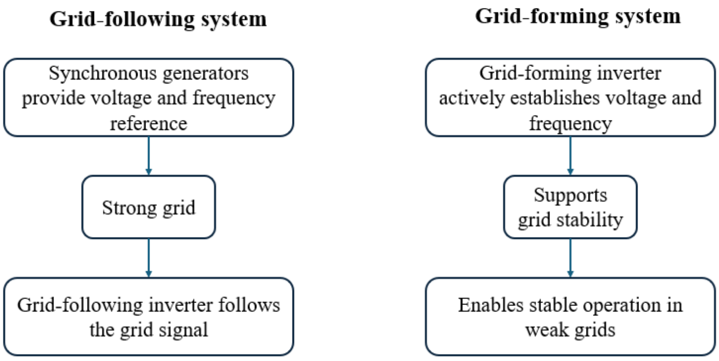

Figure 2. Conceptual difference between grid-following and grid-forming inverter operation. Author's elaboration based on [17].

As illustrated in Figure 2, the key distinction is that grid-following resources depend on an already stable and strong grid, whereas grid-forming technologies actively contribute to maintaining that stability. This shift has important implications for market design, since stability becomes an explicit capability that may need to be defined and procured through dedicated mechanisms rather than remaining an implicit by-product of generation technologies, by reinforcing the necessities stated in section 2.

Data from European transmission system operator (ENTSO-E) projects that Spain will experience periods where instantaneous renewable generation covers approximately 80% to

100% of demand [18]. To operate securely during these high-penetration hours without relying on thermal plants, Spain's market design must urgently establish technical standards and compensation mechanisms to incentivize grid-forming capabilities.

3.1.2. Battery energy storage systems (BESS)

BESS are highly flexible assets capable of responding to control signals rapidly, making them ideal for addressing the fast dynamics required in low-inertia grids [19].

Spain's solar photovoltaic (PV) installation numbers and even more ambitious targets will significantly alter the net demand shape, reducing the duration of peak demand. BESS are well positioned to act as a primary flexibility tool, but, as explained for GFM, Spanish regulators must ensure that market rules allow these assets to stack revenues across both energy markets and stability services without facing investment and revenue challenges [16].

3.1.3. Advanced wind and solar plants

Rather than operating purely as passive energy generators, advanced wind and solar PV plants can actively support network stability and strength. Implementing GFM controls in wind and solar plants allows the power system to survive extreme disturbances (like system splits) without relying on synchronous generators [18].

Given Spain's large wind and solar resource base, converting the existing and future generators into active grid supporters is a massive opportunity.

3.1.4. Hybrid plants

Installing renewable generation together with battery storage creates a highly synergistic asset that blends clean energy production with dispatchable flexibility.

Hybrid plants benefit from shared asset structures, reducing soft costs while sharing hardware like inverters. For solar PV, the storage component can also capture energy that would otherwise be wasted due to undersized inverters [16].

To efficiently integrate Spain's renewable pipeline, hybrid plants may offer a cost-effective way to combine renewable generation with flexibility and stability-related capabilities. Regulatory frameworks must be updated to allow shared point-of-interconnection agreements and multi-use applications.

3.1.5. Synchronous condensers and STATCOMs

Synchronous condensers (SCs) are traditional rotating machines operating without a prime mover, while STATCOMs are static power electronic devices. Both are deployed specifically to inject or absorb reactive power and boost system strength [18].

Unlike wind, solar, or BESS, SCs are generally considered "must-run" or dedicated network infrastructure assets whose primary purpose is grid security, not energy market trading [18].

They are expensive capital investments that do not produce active power to sell in wholesale markets. Furthermore, to be effective during severe faults, SCs must be spatially distributed evenly across the network, limiting economies of scale.

While GFM technology matures, SCs offer an immediate, proven technological bridge. For remote areas in Spain with high concentrations of renewable energy but weak transmission links, targeted SC deployments can resolve local voltage and stability constraints.

3.1.6. Comparative assessment of modern assets

The future Spanish grid will not rely on a single perfect asset to replace the stability services of synchronous generators. Instead, a heterogeneous portfolio of assets will be required.

Advanced wind and solar plants can contribute to stability services at large scale. However, doing so often requires operating below their maximum output to keep reserve capacity available. This means that part of their potential generation may need to be curtailed, so appropriate compensation mechanisms are necessary. On the one hand, BESS and hybrid plants seem to offer the most agile and attractive solutions through value stacking, provided regulation allows for obtaining revenues from several services. On the other hand, SCs can act as localized foundational support in weak network pockets while power-electronic solutions mature. A comparison of the contribution of these technologies is presented in Table 3.

Table 3. Indicative contribution of modern assets to stability services.

Technology	Frequency support	System strength	Restoration / black start	Commercial maturity	Relevance to specific grid areas
Grid-Forming BESS	High (Fast & Synthetic)	Medium	High	High (rapidly evolving)	Distribution & Transmission
Advanced Wind & Solar	Medium (Requires headroom)	Medium	Low	Medium	Distribution & Transmission
Hybrid Plants	High (Buffer provided)	Medium	High	Medium	Transmission & Distribution
Synchronous Condensers	High (Physical inertia)	High	High	High	Transmission

3.2. Commercial realities: costs, bankability and warranties

While modern assets like GFM inverters and BESS are technically capable of providing essential stability services, technical capability does not automatically translate into investable market participation. For project developers, the transition to a low-inertia grid requires navigating complex commercial realities, including high upfront capital costs, strict warranty limitations, and the need for revenue visibility. Securing project financing inherently relies on predictable cash flows and rigorous risk allocation to reduce uncertainty.

Consequently, unlocking private capital for grid stability assets depends almost entirely on designing a market framework that bridges the gap between engineering readiness and commercial bankability [16], [19]. The commercial factors that affect this investment are summarised in Table 4.

Table 4. Commercial factors affecting the investment on modern stability assets, based on [16] and [19].

Commercial factor	Why it matters	Risk for investors if poorly designed	Implication for market design
Revenue visibility	High capital expenditure (CAPEX) requires long-term certainty to secure project finance and achieve bankability.	Uncertain revenues weaken bankability.	Markets must offer long-term stability contracts to provide bankable revenue streams.
Contract duration	Projects with high upfront costs need time to recover investment.	Very short-term signals may not support financing.	Longer procurement horizons may be needed for some services.
Value stacking	Storage often depends on combining several services to improve project economics.	If stacking is restricted, projects may become uneconomic.	Regulation should allow compatible multi-service participation.
Warranties	Warranty coverage depends on compliance with operating conditions.	Dispatching assets dynamically for market revenues may breach strict operational warranty limits, leaving owners exposed to total loss of coverage.	Procurement and service design should consider warranty constraints.
Operational priority	Assets may not be able to deliver every service at the same time.	Reliability obligations may conflict with commercial dispatch.	Regulators must mandate a clear hierarchy of services, clarifying how critical services are prioritized.

Technical readiness alone will not be enough. As future services are opened to batteries, hybrids and advanced inverter-based resources, Spain will also need clearer testing, monitoring and settlement rules. This issue is particularly visible in the benchmark cases examined in section 4.

4. International Benchmarking and Lessons Learned

4.1. Selection criteria and relevance for Spain

In order to choose the best model for Spain, an international benchmarking has been developed. The key idea in this benchmark is to find relevant countries with applicable models to the Spanish market. To support case selection for the international benchmarking, a screening map is developed in Figure 3 using three criteria. First, countries are assessed according to their renewable electricity share in 2023, taking Spain's 50.3% renewable share of electricity production as the reference point. The renewable electricity production share has been analysed in the International Renewable Energy Agency [20]. Countries with significantly higher renewable share than Spain have also been considered, as long as their GDP is not too small (for example, many African countries), since they could have some service that could help deal with the future Spanish situation. Second, countries are positioned according to the extent to which explicit stability-related or advanced ancillary-service measures can be identified in their power-system framework. Third, bubble size reflects nominal GDP [21], used as a proxy for market scale and economic relevance. This approach allows the study to distinguish between countries that are merely interesting comparators and those that combine structural relevance, institutional sophistication and sufficient scale to serve as meaningful benchmark cases for Spain.

In Figure 3, the horizontal axis shows the share of renewable electricity generation in 2023. The vertical axis represents the explicitness of stability-related or advanced ancillary-service frameworks, based on an author-assigned qualitative score from 0 to 3 (see Appendix A). Bubble size represents nominal GDP (current US$).

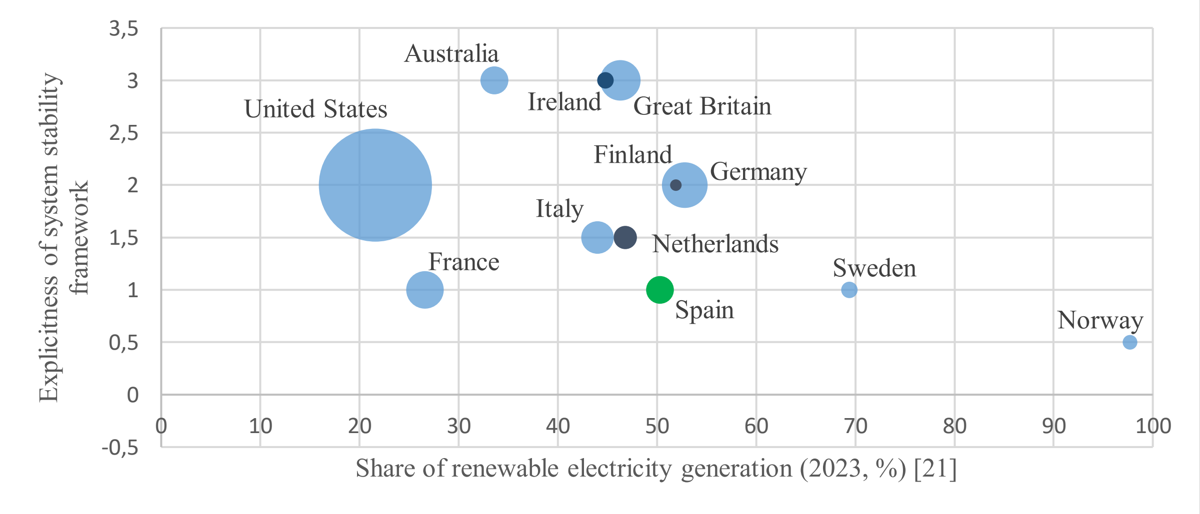

Figure 3. Screening of benchmark candidates based on renewable electricity share, stability-framework explicitness and economic scale.

A first insight from the chart is that several European countries, including Great Britain, Germany, Ireland, the Netherlands, Italy and Finland, show renewable shares that make them potentially relevant points of comparison for Spain. However, renewable share alone is not enough. Countries such as Norway and Sweden, despite their very high renewable shares, rely heavily on hydropower and therefore do not face the same stability challenge associated with a system dominated by inverter-based renewable generation. In the same way, market size also matters, since larger systems are generally more useful when looking for lessons that could be applied at Spanish scale.

Therefore, the vertical axis is particularly important in narrowing the choice. The criteria followed for rating each country is defined in Appendix A. Great Britain, Ireland and Australia stand out because they appear among the most explicit cases in terms of identifiable mechanisms for low-inertia and high-renewables operation. Within that group, Great Britain appears as the strongest benchmark at first sight, since it combines a relatively similar renewable context with greater market scale and a clearly defined procurement approach for stability-related services. Ireland is also highly relevant, although its smaller size makes it somewhat less directly comparable. Finland could also appear interesting because of its renewable profile, but its system context is less useful for this study. Australia, although less similar to Spain in renewable share, is selected as a third case to analyse, because its isolated system and explicit focus on system strength and planning may still provide valuable lessons for Spain.

Germany is also relevant in this screening because it combines a relatively comparable European market context with a more explicit technical roadmap for future system stability. Its System Stability Roadmap addresses the secure and robust operation of a future electricity system based on 100% renewable energy sources and highlights the need to replace the stabilising properties historically provided by conventional power plants through alternative means [28].

On that basis, the benchmarking section focuses on Great Britain, Ireland, Australia and Germany as the four main cases.

4.2.Great Britain: turning system stability into an investable market service

Great Britain is the clearest example of a market-based approach to stability. It shows how system stability can be turned from an implicit by-product of conventional generation into an explicit and investable service. In the traditional model, synchronous power plants provided inertia and related stability attributes automatically while producing electricity. As renewable penetration increased, the National Energy System Operator (NESO) concluded that this approach was no longer sufficient and progressively developed a Stability Market to procure such services more directly [22].

The key lesson is commercial as much as technical. By defining stability as a remunerated service, the British model created a clearer market signal for technologies capable of supporting the system beyond simple electricity production. This is important because it makes stability more visible and bankable, which is essential for investment in a lower-inertia system [22].

This logic is already producing measurable results. In November 2024, NESO awarded the first contracts under the Mid-Term (Y-1) Stability Market, with an anticipated contract value of £25.4 million and expected consumer savings of £47.3 million [23]. For Spain, the British case gives an example of how stability services can be explicitly valued and procured, in order to manage high-renewable's penetration.

4.3.Ireland: making high-renewables operation commercially workable

Ireland is a relevant benchmark because it approached the stability challenge from an operational perspective rather than only through a dedicated stability market. Through the DS3 Programme, EirGrid and SONI explicitly framed the issue as how to operate the power system securely while increasing renewable penetration, instead of assuming that the traditional system architecture would remain sufficient [24]. This was driven by the country's high wind-penetration objectives in the country, as shown in Figure 4, as well as their isolation from other countries, which gave them no access to larger networks that tend to be more stable.

Figure 4. Renewable Energy Targets in the EU (2020) [24].

In practical terms, the Irish model did not simply set a higher limit for non-synchronous generation and stop there. The DS3 Programme combined operational changes, revised technical requirements and a dedicated system-services workstream designed to put in place the "correct structure, level and type of services" needed for secure operation at higher levels of non-synchronous generation [25]. The objective of this framework was to enable the system to operate securely with up to 75% system non-synchronous penetration (SNSP), which made Ireland one of the earliest systems to organise its transition around the explicit definition and remuneration of system services rather than around energy volume alone. The value of 75% represents an increase from a previously established 50% SNSP limit, allowing the system to significantly increase non-synchronous penetration [24].

This was partially achieved by introducing explicit remuneration for a range of system services required to operate a high-renewables grid. These include services such as fast frequency response, primary frequency response, ramping capability, steady-state reactive power and dynamic reactive power [25].

This is particularly relevant for Spain because the transition challenge is no longer only about adding more renewable capacity, but about ensuring that the system has the right technical and commercial arrangements to operate securely under a very different generation mix.

4.4. Australia: planning system security for the energy transition

As renewable penetration increased, the Australian Energy Market Operator (AEMO) began assessing potential system security risks associated with large volumes of inverter-based generation, including future requirements for system strength, inertia and Network Support and Control Ancillary Services [26].

System strength refers to the ability of the power system to maintain stable voltage conditions and operate reliably following disturbances, while inertia helps slow rapid changes in frequency after a disturbance. When these capabilities are insufficient, additional renewable projects cannot be safely integrated into the grid. In response, the Australian framework requires network operators to address identified gaps and ensure that sufficient system strength, inertia and related services are available before further inverter-based generation can connect [27].

In practice, this approach means that system stability is addressed through forward-looking planning rather than relying solely on market signals. If a region is expected to experience shortages in system strength, inertia or other security services, solutions such as synchronous condensers, network reinforcements or additional technical requirements for new projects may be required before further renewable generation can connect. For Spain, the Australian case illustrates a third possible pathway for managing stability challenges: ensuring that the physical capabilities required for secure operation are planned and delivered in advance as part of the overall system development strategy. It also gives a more localized approach compared with the Irish and British ones.

4.5. Germany: defining a system-stability roadmap

Germany is relevant for Spain because it shows how a large European power system can prepare for future stability needs before they become a binding constraint. Its System Stability Roadmap is built around the objective of achieving secure and robust operation with 100% renewable energy sources [28]. This makes it a useful reference for Spain, where renewable penetration is also increasing quickly.

The main lesson from Germany is that stability reform is not only about creating new market products. The roadmap recognises that, as conventional power plants are phased out, the stabilising properties historically provided by synchronous generators will need to be replaced by other resources, including renewables, storage, loads and grid assets [28]. In that sense, Germany treats stability as a coordinated system challenge, not only as a procurement issue.

Grid-forming inverters are especially important in this approach. The roadmap identifies them as a key technology for future system stability and links their deployment to pilot testing, technical requirements and connection rules [28]. This is also supported by the German TSOs, which argue that current grid-following control concepts will not be sufficient in a future system with a very high share of converter-based generation [29].

For Spain, Germany is therefore useful as a complementary European reference. It does not replace Great Britain, Ireland or Australia as a main benchmark, because it is less focused on a mature stability market or a clear system-strength planning model. However, it reinforces that Spain should not only decide which stability services to procure, but also define a roadmap for technical requirements, testing, responsibilities and implementation milestones.

4.6.Transferability to Spain through a CAGE framework

The benchmark cases analysed above are useful not because they can be copied directly, but because they reveal different ways of translating stability needs into workable institutional solutions. To assess how far these approaches could be adapted to Spain, this study applies a simplified CAGE framework shown in Table 5. The model is used as a practical tool to assess transferability across four dimensions: cultural, administrative, geographic and economic distance.

Table 5. CAGE assessment of transferability to Spain.

Dimension	Great Britain	Ireland	Germany	Australia	Main implication for Spain
Cultural	**Low distance**	**Low distance**	**Low distance**	**Medium distance**	Limited barrier to learning from any case.
Administrative	**Medium**	**Low**	**Low**	**High**	Ireland and Germany are easiest to align with EU-style regulatory logic.
Geographic / system structure	**Medium**	**Medium**	**Low-Medium**	**High**	Australia is less directly comparable due to network structure and localized challenges. Germany is more comparable institutionally and geographically, while GB and Ireland's isolation is also high.
Economic / market scale	**Low**	**Medium-High**	**Low**	**Medium**	Great Britain and Germany are closest in terms of commercial relevance and scalable market design.
Overall transferability	**High**	**High**	**High**	**Medium**	Spain should combine elements rather than copy one model.

Table 5 shows that the benchmark cases differ not so much in cultural distance. Great Britain appears as the most commercially relevant benchmark because its system size and market-based approach are closer to Spain's likely needs, even if its post-Brexit institutional framework creates some administrative distance. Ireland and Germany are the closest cases in terms of operational logic within a high-renewables European context, although Ireland's smaller scale and greater electrical isolation reduce direct comparability. Germany is highly transferable from an administrative and institutional perspective, because it operates within the European regulatory environment and provides a clear example of how technical requirements, grid-forming capabilities and implementation milestones can be organized through a national roadmap. Australia is the least directly transferable case, but it remains valuable because it highlights the importance of forward-looking system security planning in concrete regions with high shares of inverter-based generation, with a more localized approach.

Overall, the CAGE assessment suggests that Spain should not aim to replicate any benchmark model in full. Instead, the most transferable elements are likely to be the British logic of capability-oriented procurement, the Irish logic of clearly defined system services, the German logic of roadmap-based technical preparation and institutional coordination, and the Australian logic of anticipating security needs in certain locations through system planning.

5. Policy and Market Design Options for Spain

5.1.Overview of the policy options and evaluation criteria

Based on the gap analysis and the international benchmarking presented in the previous sections, 2.2 and 4 respectively, three policy pathways can be identified for Spain. These pathways differ in the degree of explicitness with which stability is defined, procured and remunerated, and in the balance between market signals and central system planning. Option A consists of an incremental reform of the current Spanish framework; Option B introduces explicit stability products procured through competitive mechanisms; and Option C combines forward-looking system planning with targeted procurement for explicit stability services.

5.2.Option A: Gradual improvement of the current Spanish framework

Option A consists of an incremental reform of the current Spanish ancillary-services architecture rather than a full redesign. Under this approach, Spain would retain the existing combination of balancing services, non-frequency services and operational procedures already used by the system operator and would improve them progressively to better fit the current high-renewables power system. This idea could be useful as a starting point because the current framework is functional and already includes mechanisms such as aFRR, mFRR, RR, voltage control, black start, technical constraints management and active demand response [14], although these mechanisms are not yet organised around a fully coherent stability-service design (see sections 2.1.3and 2.2). REE's current ancillary-services framework still operates through a mix of balancing mechanisms and technical-constraints processes, and Law 24/2013 assigns REE responsibility for continuity and security of supply [12].

In practical terms, Option A would not create a dedicated stability market. Instead, it would refine the mechanisms that already exist. This would include clearer technical definitions within current services, targeted updates to operating procedures, better telemetry and performance verification, and broader participation by storage, hybrid plants, demand response and advanced inverter-based resources where technically feasible. This logic follows directly from the diagnosis developed in section 2.2, in which it is said that Spain’s main gaps concern product definition, fragmented procurement and remuneration, weak investment signals, and limited monitoring and verification. It also responds to section 3, which shows that modern assets can technically provide stability-related services but require clearer technical standards and access rules in order to do so effectively.

Institutionally, Option A is the least disruptive reform path. MITECO would continue to define the overall policy direction, CNMC would update methodologies and approve targeted regulatory adjustments, and REE would keep operating the system through existing channels while gradually modernizing qualification, settlement and dispatch arrangements. This makes the option quite feasible in the near future because it builds on the current Spanish governance structure instead of replacing it. It is also broadly consistent with the European principle that system services should be procured through transparent and non-discriminatory competitive processes whenever possible [8], while still allowing operational and regulated arrangements where a full market redesign is not yet mature.

However, the same features that make Option A politically and administratively feasible also limit its long-term effectiveness. Because it keeps the current architecture largely intact, it would only partially solve the problems identified in section 2.2. Product definition would improve, but many stability attributes could still remain only partly explicit. Monitoring and settlement would become stronger, but procurement would remain heterogeneous. Most importantly, investment signals for new providers would probably remain weaker than under more explicit reform options. As discussed in section 3.2, new stability assets require revenue visibility, appropriate contract duration, compatibility with value stacking and clear operational priorities in order to become bankable. A gradual-improvement model can help at the margin, but it is less likely to create the durable, investable revenue framework required for large-scale deployment of grid-forming resources, hybrid plants or dedicated system-strength solutions.

5.3.Option B: Introduction of explicit stability services with competitive procurement

Option B represents the most market-oriented reform path for Spain. Under this approach, stability would cease to be treated mainly as an implicit by-product of synchronous generation or as a capability only partially embedded within existing balancing and non-frequency arrangements. Instead, the Spanish framework would move towards the explicit definition, qualification, procurement and remuneration of stability-related products through dedicated competitive mechanisms. This logic responds directly to the diagnosis developed in section 2.2, which shows that the current Spanish system still relies partly on implicit synchronous support and remains fragmented in product definition, procurement, investment signals and verification. In that sense, Option B is designed to transform stability from a diffuse operational need into a set of bankable services with clear technical and commercial value.

In practical terms, Option B would require Spain to define specific products linked to system needs such as inertia or inertia-like response, fast frequency support, dynamic reactive current support, voltage support in weak-grid areas, restoration capability and potentially system-strength services in specific locations. The key principle is that these services would no longer be remunerated indirectly through adjacent market participation or through the residual presence of synchronous generation, but through transparent competitive procurement processes open to eligible providers. This approach is strongly aligned with the broader European principle already introduced in section 2.1.1, according to which system services should be selected through transparent, non-discriminatory and competitive processes whenever possible. It also fits the central challenge stated in section 1.1.1: if Spain wants to maintain security of supply at the lowest total system cost, it must determine how to procure stabilizing capabilities explicitly rather than rely on a framework built for an earlier generation mix.

The strongest international reference for this option is Great Britain. As explained in section 4.2, the British case is relevant because it shows how system stability can be turned from an implicit by-product of conventional generation into an explicit and investable service. NESO progressively developed a Stability Market precisely because the traditional model was no longer sufficient as renewable penetration increased. For Spain, this is highly relevant because one of the core weaknesses identified in section 2.2.3 is the absence of durable investment signals for emerging providers. Option B addresses that weakness directly by creating explicit revenue streams linked to measurable capability rather than relying on short-term and operationally derived revenues.

Ireland provides a complementary benchmark for Option B. As described in section 4.3, the DS3 Programme did not merely raise the acceptable level of non-synchronous generation; it also introduced a dedicated system-services workstream to establish the “correct structure, level and type of services” required for secure high-renewables operation. This is closely linked to the point made in section 3.1, in which it is stated that modern assets such as grid-forming, BESS, advanced wind and solar plants, hybrid plants and other inverter-based resources can provide important stability functions, but only if market design translates technical capability into explicit and accessible service products.

However, Option B is also the most demanding option in terms of implementation complexity. It requires Spain to define service products with sufficient technical precision, establish qualification protocols, design performance verification and settlement rules, and determine how location-specific needs should be reflected in competitive procurement. Therefore, its logic is attractive, but in Spain it probably asks for more regulatory maturity than the system can deliver quickly. As the gap analysis in section 2.2 already notes, broader stability attributes are harder to monitor and verify than conventional balancing actions, especially once service provision expands to batteries, hybrids, demand response and inverter-based generation. Furthermore, if products are introduced too quickly or too narrowly, there is a risk of thin markets, limited competition or product-design mistakes that could weaken the efficiency gains expected from competition.

For this reason, Option B should be interpreted as the most explicit and commercially ambitious reform pathway, but also as the one that requires the greatest regulatory maturity. It is strongest if the priority is to create a clear price signal for investors. Nonetheless, when the immediate priority is administrative simplicity or when some critical needs are so dependent on location or difficult to address through standard market mechanisms, it is not such a good option. This is also consistent with section 4.6, where the transferability analysis concludes that Spain can learn from the British logic of procuring stability-related capabilities and the Irish logic of clearly defined system services, but should avoid copying any one benchmark in full. Option B therefore represents the purest “market solution” among the three options.

5.4. Option C: Hybrid model combining system planning and targeted procurement

Option C represents a hybrid reform pathway that combines forward-looking system planning with targeted competitive procurement. Under this approach, Spain would not rely exclusively on market discovery to reveal all future stability needs, nor would it treat all stability capabilities as purely regulated network obligations. Instead, the framework would distinguish between two categories of needs. First, some capabilities depend heavily on where they are delivered and are difficult to procure competitively. For these needs, pure market mechanisms may be inefficient, and planned or regulated delivery may be required. Second, there are stability services that can be more effectively procured through targeted competitive mechanisms once products, qualification rules and location-specific needs are sufficiently clear.

The need for this hybrid model emerges directly from the weaknesses identified in the current Spanish framework. As explained in section 2.2, Spain already operates a mixed architecture of balancing services, regulated services and operator-led procedures, but important stability attributes such as inertia, short-circuit strength and fast reactive current support are still only partially explicit, while procurement remains heterogeneous and investment signals remain weak. In addition, some future services will depend not only on energy volume but also on location, technical performance and availability. This is especially important because, in low-inertia and weak-grid conditions, the value of a capability depends heavily on where it is delivered, not only on whether it exists somewhere in the system. Option C responds to this challenge by accepting that some needs should first be identified through planning and deep assessment before deciding whether they should be competitively procured, regulated, or both.

The Australian benchmark is particularly relevant for the planning component of this option. As discussed in section 4.4, the Australian framework addresses system strength, inertia and related services through forward-looking security planning rather than relying solely on market signals. Where gaps are expected, solutions such as synchronous condensers, network reinforcements or additional technical requirements can be required before more inverter-based generation connects. For Spain, this lesson is especially important in weak-grid areas or transmission nodes with high-renewable concentration, where stability needs may be too urgent to be left entirely to price transparency. In those cases, Option C would allow REE, under the broader policy direction of MITECO and the regulatory supervision of CNMC, to identify critical needs in advance and ensure they are delivered through planned or regulated channels when competition is unlikely to be sufficient on its own.

At the same time, Option C does not abandon market mechanisms. It incorporates the central lesson from Great Britain, where stability was turned into an explicit and bankable service through competitive procurement, and from Ireland, where the transition to high-renewables operation was organized around clearly defined and remunerated system services. It also takes from Germany the idea that the transition must be supported by a roadmap of technical requirements, testing procedures and clear responsibilities, especially for grid-forming resources. In the Spanish case, this could apply to services such as fast frequency response, dynamic reactive support, some restoration services, and other explicitly defined capabilities that can be provided by batteries, hybrid plants, advanced renewable generators or other resources. In that sense, Option C preserves the commercial advantages of Option B but uses them more selectively.

This hybrid structure is also better aligned with the technological diversity described in section 3. The project shows that the future Spanish grid will require a heterogeneous portfolio of assets rather than a single replacement for synchronous generation. Grid-forming, BESS, hybrid plants and advanced wind and solar plants can provide valuable dynamic services, especially where regulation allows value stacking and explicit access to service revenues. Option C reflects this reality better than the other options because it does not force all assets into the same institutional logic. Instead, it allows infrastructure-like assets to be planned where necessary while enabling more flexible and innovative providers to compete where effective competition is real.

Option C is not the best option on every single criterion. Its strength is that it avoids the main weaknesses of the other two options. It improves product explicitness and investment visibility more than Option A, while reducing the thin-market and implementation risks associated with a fully explicit market design under Option B. This comes directly from the conclusions already reached by the transferability analysis in section 4.6, which states that the most transferable elements for Spain are the British logic of dedicated procurement mechanisms, the Irish logic of clearly defined system services, the German logic of roadmap-based technical preparation and institutional coordination, and the Australian logic of anticipating security needs through system planning.

Its main drawback is governance complexity. A hybrid model requires clear institutional coordination to determine which needs are planned and which are procured competitively, how location-specific assessments are made, who defines criticality, and how overlap between regulated and competitive channels is avoided. Without a well-defined governance framework, the model could become overly complex or not clearly define responsibilities between policymakers, regulators and the system operator.

6. Strategic Assessment of the Options

6.1. Assessment method and decision criteria

For this section a structured qualitative assessment has been developed. Rather than estimating the detailed system costs for each option, the analysis evaluates the relative performance of each option against a common set of five criteria: total system cost, preservation of effective competition and price risk, bankability for new providers, regulatory feasibility and long-term strategic fit. This comparison is especially relevant in the current context, as the April 2025 Iberian blackout [5] and the subsequent ENTSO-E final report [6] reinforced the need to strengthen system resilience while keeping the Spanish framework aligned with the European principle of transparent, non-discriminatory and competitive procurement [8].

In this context, for each criterion several characteristics have been analysed, which have been weighted in accordance with their importance in the general topic. For further understanding of the development of the criteria see Appendix B. Then, each characteristic has been quantified with a score from 1 to 5, using the benchmarking logic defined in Table 6.

Table 6. Scoring scale for measured characteristics.

5	Excellent / strongest fit for Spain
4	Good
3	Mixed / workable
2	Weak
1	Very weak / high risk

The assessment developed in this section is based on the analytical foundations established in the previous sections of the study. First, the gap analysis in section 2.2 identified the main weaknesses of the current Spanish framework, namely product-definition gaps, procurement and remuneration gaps, weak investment signals, and limited monitoring and verification. Second, section 3 assessed both the technical capabilities of modern assets and the main commercial factors affecting their deployment, including revenue visibility, contract duration, value stacking, warranty constraints and operational priority. Third, the international benchmarking in section 4 provided evidence on how other jurisdictions have addressed similar challenges through dedicated procurement mechanisms, clearly defined system services, roadmap-based technical preparation and forward-looking system planning. Finally, section 5 translated these lessons into three policy options for Spain, whose relative strengths and trade-offs are assessed in this section through a structured comparative framework.

6.2. Main comparative results under the balanced assessment

This section presents the main comparative results of the balanced assessment, under which the five evaluation dimensions are weighted equally in order to compare the three policy options on a consistent basis. This assessment does not aim to estimate exact future system costs for each option, but rather to compare the relative strengths and weaknesses of the three reform pathways through a structured decision framework.

Within this balanced lens, the analysis is organized around five dimensions: cost drivers and system cost implications; competition and price risk implications; investment signals, bankability and financing implications; regulatory feasibility and implementation complexity; and strategic resilience and long-term transition fit. For each dimension, this section evaluates a set of underlying characteristics with different internal weights, so the discussion below reflects not only the final score of each option, but also the relative importance of the factors that drive that result.

The detailed scoring tables are included in Appendix B, where each matrix also summarizes the main rationale behind the scores assigned to each option.

6.2.1. Cost drivers and system cost implications

This dimension was assessed mainly based on procurement efficiency and locational efficiency, while implementation cost, transition cost, investment efficiency and system operation cost were also considered. The detailed scoring matrix is presented in Appendix B1.

Under this dimension, Option C achieves the strongest result, with 79/100, clearly ahead of Option A and Option B, which both obtain 63/100. The main reason is that the hybrid model combines two advantages at the same time. It preserves competition where market discovery is useful, but it also allows planning-led intervention where needs are highly dependent on location. This improves cost targeting and reduces the risk of inefficient investment.

Option A performs relatively well on implementation and transition cost because it builds on the current Spanish framework and avoids major institutional redesign. However, it performs worse on location-specific efficiency and on the risk of delayed or inefficient investment. Option B performs better on location-specific efficiency, but loses points because of higher implementation complexity and because narrow service areas may not always support efficient competition.

Overall, the results suggest that the most attractive option from a system-cost perspective is not the one with the lowest short-term disruption, but the one that best combines market discipline with system planning. That is why Option C ranks first in this dimension.

6.2.2. Competition and price risk implications

This dimension was assessed mainly through market openness and the risk of weak competition. Price transparency was also an important consideration, while technology neutrality and adaptability over time were included as supporting factors. The detailed scoring matrix is presented in Appendix B2.

Under this dimension, Option B obtains the strongest result, with 82/100, followed by Option C with 75/100 and Option A with 47/100. Option B performs best because it is the most explicit market-based model. It is better suited to open participation to a wider set of providers, improve price transparency and make the value of stability services more visible.

Option C also performs well, especially because it limits exposure to thin-market problems in services in specific areas. However, since the assessment does not rely only on competition, and it is slightly less open and less market-driven than Option B, it is outperformed by it. Option A performs weakest because many stability attributes remain only partly explicit, which reduces both transparency and the scope for effective competition.

Overall, this dimension shows that Option B is the strongest solution if the main objective is to maximize competition and improve price signals, while Option C offers a more balanced but less fully marketized approach.

6.2.3. Investment signals, bankability and financing implications

This dimension was assessed mainly on the basis of revenue visibility, as this is the most important factor for investment attractiveness. Contract horizon was also considered closely, while value stacking, operational clarity and warranty fit were included as additional factors. The detailed scoring matrix is presented in Appendix B3.

Under this dimension, Option B achieves the highest score, with 86/100, slightly ahead of Option C at 83/100, while Option A remains far behind at 40/100. Option B ranks first because it provides the clearest investable revenue model. By explicitly defining and procuring stability services, it improves revenue visibility and creates a more bankable framework for emerging providers such as grid-forming, BESS, hybrid plants and advanced inverter-based resources.

Option C also performs strongly, since it still allows procurement for capability-oriented services that are suitable for competition while offering a clearer hierarchy between critical and market-based needs. This makes it slightly more workable from an operational perspective, but its revenue signal is somewhat less explicit than under Option B. Option A scores weakest because it remains more dependent on fragmented and partly implicit revenue streams, which are less supportive of long-term financing.

Overall, the results show that explicit service remuneration is the strongest basis for bankability, which explains why Option B ranks first and Option C remains a close second.

6.2.4. Regulatory feasibility and implementation complexity

This dimension was assessed mainly through the degree of regulatory change required and likely implementation speed. Institutional complexity, technical readiness, EU compatibility and stakeholder acceptability were also taken into account. The detailed scoring matrix is presented in Appendix B4.

Under this dimension, Option A performs by far the strongest, with 95/100, followed by Option C with 63/100 and Option B with 43/100. This result reflects the fact that Option A is an incremental reform path. It builds directly on the current Spanish framework, requires fewer institutional changes and can be implemented more quickly than the other two options.

Option C ranks in the middle because it introduces a more complex governance model but still allows gradual implementation within the existing institutional structure. Its main weakness is that it requires clear coordination since the beginning between planning and market. Option B scores lowest because it demands the greatest regulatory effort, including new product definitions, qualification rules, settlement methods and verification arrangements.

Overall, this dimension confirms that Option A is clearly the most practical short-term reform path, even if it is not the strongest long-term solution.

6.2.5. Strategic resilience and long-term fit

This dimension was assessed mainly through adaptability over time and the extent to which each option closes the main market and investment gaps identified in section 2.2. Support for very high renewable hours and local system security were also important considerations. The detailed scoring matrix is presented in Appendix B5.

Under this dimension, Option C achieves the strongest result, with 91/100, ahead of Option B at 85/100 and well above Option A at 47/100. Option C performs best because it combines strong adaptability with better treatment of highly location-specific security needs. This makes it particularly suitable for a Spanish system with rising renewable penetration and a declining synchronous base.

Option B also performs very strongly, especially in closing market and investment gaps through more explicit service design. However, it is slightly weaker than Option C in dealing with local system-security needs and in managing the balance between competition and planning over time. Option A performs weakest because, although it improves the current framework, it does not fully address the deeper structural challenges of a high-renewables system.

Overall, this dimension points clearly to Option C as the strongest long-term pathway for Spain.

6.2.6. Overall results

Under the balanced assessment, Option C emerges as the strongest overall pathway, with a weighted result of 78.2/100, compared with 71.8/100 for Option B and 58.4/100 for Option A.

This result is not driven by one single criterion. Rather, Option C achieves the highest overall score because it combines first-place performance in cost drivers and in strategic resilience with consistently strong results in the other dimensions. Option B ranks first in competition and price risk, and also in investment signals, bankability and financing. Option A ranks first only in regulatory feasibility and implementation complexity, where its incremental nature makes it the easiest option to implement.

The balanced assessment therefore points to a clear trade-off. Option A is the most practical short-term reform path, but it does not solve the structural weaknesses of the Spanish framework deeply enough. Option B provides the clearest market signal and the strongest investment case, but it is more demanding to implement and more exposed to design risks. Option C offers the most robust overall combination of cost discipline, location-specific security and long-term adaptability, which explains why it achieves the highest overall score under the balanced lens.

6.3. Sensitivity analysis and robustness of the recommendation

To test whether the recommendation depends excessively on the balanced weighting scheme, a sensitivity analysis was carried out using alternative decision lenses reflecting different policy priorities. In addition to the balanced case, four additional lenses were considered: feasibility-first, investment-first, security-first and competition-first. Table 7 summarizes the resulting scores and rankings under each lens, while the detailed weighting assumptions used for each case are reported in Appendix C.

Table 7. Sensitivity analysis results under alternative decision lenses.

Decision lens	Option A	Option B	Option C	Winner
Balanced	58.4	71.8	78.2	Option C
Feasibility-first	74.3	59.5	72.0	Option A
Investment-first	54.2	75.5	80.6	Option C
Security-first	56.3	74.2	81.6	Option C
Competition-first	56.0	73.6	78.0	Option C

The sensitivity analysis shows that the recommendation in favor of Option C is broadly robust. Option C remains the highest-ranked pathway in four of the five decision lenses considered: balanced, investment-first, security-first and competition-first. This indicates that the hybrid model performs strongly not only under an even weighting of criteria, but also when the analysis gives greater importance to long-term resilience, investment attractiveness or competitive outcomes.

The only lens under which Option C does not rank first is the feasibility-first case. Under that lens, Option A becomes the preferred option, which is consistent with the earlier assessment of regulatory feasibility and implementation complexity. When the main priority is short-term practicality, lower institutional disruption and faster implementation, the incremental reform pathway becomes more attractive than the more ambitious alternatives.

Option B does not emerge as the top-ranked option under any of the lenses, but it remains a strong performer when greater emphasis is placed on market-based outcomes and investment conditions. This confirms that Option B has clear strengths in explicit price transparency and bankability. Nevertheless, in the investment-first scenario, even though bankability plays an important role, the weight of long-term fit is also undeniable, making Option B perform worse than expected.

Overall, the sensitivity analysis reinforces the robustness of the main recommendation. The fact that Option C remains the highest-ranked option in most scenarios suggests that its advantage is not driven by a single arbitrary weighting choice, but by its ability to combine several policy objectives in a relatively balanced way. At the same time, the analysis also clarifies the conditions under which another pathway could be preferred. More specifically, if policymakers place disproportionate emphasis on short-term feasibility and regulatory simplicity, Option A could be justified as a transitional choice. However, if the objective is to identify the most robust overall framework for Spain's 2026–2040 transition, the results continue to support Option C as the strongest recommendation.

7. Indicative implementation and economic assessment of Option C

7.1. Evidence base and modelling inputs

After choosing an option, this option should be translated into a consistent implementation. For doing so, publicly available benchmarks have been used; including the Spanish baseline indicator, used to define the starting point of the system in 2025; external benchmark evidence for competitive procurement and planning-led investment; and finally, a small set of assumptions, used to develop the model over time. The role of these inputs is not to imply a one-to-one transferability from Great Britain or Australia to Spain, but rather to provide transparent external calibration points for an indicative policy model. They are used only to calibrate the order of magnitude of two different layers: competitive procurement, informed by NESO, and planning-led locational reinforcement, informed by AEMO.

Spanish baseline indicators are taken from REE's summary of the Spanish electricity system in 2025, which reports electricity demand of 256.1 TWh, renewable generation of 56.6% including self-consumption, storage power of 3,427 MW, and total installed capacity of 150.8 GW including self-consumption [2]. Competitive-procurement benchmarks are taken from the British Mid-Term (Y-1) Stability Market operated by NESO. In round 1, NESO awarded contracts worth £25.4 million for 5.0 GVA·s of procured inertia [23], while round 2 awarded contracts worth £10.3 million for 7.3 GVA·s [30]. Planning-layer cost benchmarks are taken from AEMO's Victorian system-strength studies [31]. The 2025 study reports A$673.1 million for five new synchronous condensers under option portfolio 3, and assumes annual operating and maintenance costs equal to 1% of capital expenditure. All foreign-currency inputs are translated into euros using Deutsche Bundesbank's Exchange rate statistics for 2025 [32].

Moreover, Table 8 reports the selected modelling assumptions for the central case. The detailed conversion logic and all derived benchmark metrics are reported deeply in Appendix D1.

Table 8. Selected modelling assumptions for the central case.

Assumption	Selected value	Unit	Rationale
Demand growth p.a.	1.2	%	Assumption reflecting moderate electricity-demand growth under electrification and continued renewable deployment in Spain [2].
Real discount rate	3.5	%	Real program-level discount rate aligned with public-sector appraisal practice and with the social discount rate used in the UK Green Book for years 1–30 [33].

7.2. Base deployment path and implementation logic (2026–2040)

A key modelling choice concerns the scaling of the competitive procurement layer. The British Stability Market is not transferred to Spain on a one-to-one basis. Instead, it is used as an indicative calibration point for plausible procurement scale. This is justified because the comparator system is somewhat larger, but still of the same general order of magnitude. In 2025, electricity demand in Spain reached 256.1 TWh [2], while NESO's 2025 annual review for Britain reports 288 TWh of energy through the network [34]. The British benchmark is therefore used to inform an order-of-magnitude procurement range rather than to imply identical service needs. On that basis, the Spanish base path begins below the scale observed in the British tenders and then grows progressively as the framework matures.

In this scenario, the path defined in Table 9 has been developed. 2026 is treated as a preparation year. This is consistent with the German roadmap logic, where technical specifications, responsibilities and implementation milestones are defined before large-scale deployment is expected. Between 2027 and 2030, the model assumes an initial build-out phase with four planned assets deployed in specific locations and a gradual increase in competitive procurement from 3 to 7 GVA·s. Between 2031 and 2034, four additional planned assets are added while procurement rises to 9 GVA·s. From 2035 onwards, only two additional assets are planned, since the framework is treated as mature, with competitive procurement stabilizing around 9 to 10.5 GVA·s. The logic is therefore to front-load the most critical locational reinforcements and then rely increasingly on recurring procurement as the framework matures. The logic is summarised in Table 9 and the full year-by-year deployment path used in the model is reported in Appendix D2.

The ten SC-equivalent units should not be read as an exact engineering estimate of Spain's total stability requirement. They represent a national-scale planning layer calibrated from the AEMO benchmark and adapted to a larger system, while preserving the hybrid logic of Option C, in which only the most critical weak-grid or system-strength needs are addressed through planned assets, and the remaining requirement is progressively covered through competitive procurement and inverter-based resources.

Table 9. Summary of the base deployment path and implementation logic (2026-2040).

Period	Planned assets added	Competitive procurement path	Main interpretation
2026	0	0 GVA·s	Preparation year
2027–2030	4	3 to 7 GVA·s	Initial build-out and first competitive procurement rounds
2031–2034	4	7 to 9 GVA·s	Selective reinforcement and market deepening
2035–2040	2	9 to 10.5 GVA·s	Mature framework with stable procurement layer

7.3. Indicative economic results and commercial implications of Option C

In this section the information gathered in sections 7.1 and 7.2 is used in order to measure the commercial implications and economic impact of the preferred hybrid pathway. Under this approach, Option C results in a total program cost of €1,221.0 million over 2026–2040 on an undiscounted basis and a gross present value of €974.2 million. Expressed relative to projected electricity demand, this is equivalent to an average program cost impact of around €0.29/MWh, while the peak annual cost reaches €118.4 million during the main build-out period. By 2040, the base path includes ten planned synchronous-condenser-equivalent units and 10.5 GVA·s of competitively procured stability volume. In the model, one SC-equivalent unit is not a proposed engineering specification for Spain, but a cost-calibration unit based on the AEMO synchronous-condenser benchmark. It is used to size the planning layer consistently, not to prescribe the exact asset design. These results should therefore be interpreted as program-level calibration outputs rather than as precise forecasts of future Spanish system-security expenditure.

Table 10. Indicative program-level economic results for Option C.

Metric	Value
Gross program cost (undiscounted, €m)	1,221.0
PV of program cost, 2026–2040 (€m)	974.2
Average gross cost impact (€/MWh)	0.29
Peak annual gross cost (€m)	118.4
Total planned SC-equivalent units added	10
Competitive procurement volume in 2040 (GVA·s)	10.5

Analyzing the total cost, more than half of the total undiscounted cost comes from the planning layer's upfront capital expenditure, while about one third comes from competitively procured stability services. Annual operating and maintenance costs remain comparatively low. This pattern is consistent with the logic of Option C, in which the framework is initially driven by targeted reinforcement in weak grid areas and market opening, while later becoming more operational and procurement-led once the most critical local needs have been addressed. In this sense, the base case suggests that the hybrid model is front-loaded in capital terms but becomes structurally lighter after the first years. The estimated cost share is presented in Table 11.

Table 11. Composition of total gross costs for the program.

Component	Total gross cost (€m)	Share of total
Planning CAPEX	768.5	62.9%
Planning O&M	71.5	5.9%
Competitive procurement	381.1	31.2%
Total	**1,221.0**	**100.0%**

The annual pattern of costs reinforces this interpretation. The most capital-intensive years are those in which new planned assets are added, especially between 2027 and 2034 and again in 2036 and 2037. After that point, annual program costs fall and stabilize in a lower range, broadly reflecting recurring procurement and the operating cost of previously installed locational assets. This is relevant for the economic interpretation of Option C because it shows that the model does not imply a permanently high-cost burden.

In addition to the gross-cost central case, an illustrative observed-savings case based on the consumer-savings ratios reported in the two NESO Mid-Term (Y-1) Stability Market rounds [23], [30] is displayed in Table 13. In this case, the implied savings-to-procurement-cost ratio is 2.57x, applied only to the competitive procurement line and not to the planning layer. This ratio has been obtained as the aggregate reported consumer savings divided by the aggregate contract cost across the two NESO rounds, which resulted in the ones in Table 12.

Table 12. Applicable ratio for NESO Mid-Term (Y-1) Stability Market rounds [23], [30].

Reported savings (£ million)	Contract cost (£ million)	Ratio
47.3	25.4	1.86x
44.4	10.3	4.31x

Under this assumption, the model produces a present value of indicative savings of €736.2 million but cumulative net benefits do not become positive before 2040, implying no payback. This result is consistent since the investment in system reliability is not performed in order to have economic benefits, even though NESO is able to measure customer benefits.

The summary of the results is available in Table 13.

Table 13. Illustrative observed savings.

Metric	Value
Selected observed-savings ratio	2.57x
Gross program cost (undiscounted, €m)	1,221.0
PV of program cost, central case (€m)	974.2
PV of indicative observed savings (€m)	736.2

7.4. Implementation and governance implications

Under Option C, the practical challenge is not only to define new stability arrangements, but also to coordinate planning, regulation and system operation over time. The hybrid model therefore requires a clearer institutional division of roles than the current framework.

For MITECO, the main role is strategic. The ministry would need to provide the overall policy direction for the reform and define the long-term objective of moving from the current fragmented framework to a hybrid model in which critical location-specific needs can be addressed through planning, while services suitable for competition are progressively procured through transparent market-based mechanisms.

For CNMC, the main role is regulatory. This includes developing the qualification rules, remuneration principles, cost-recovery arrangements and monitoring requirements needed to support the new framework, while ensuring consistency with transparency and non-discrimination principles.

For REE, the main role is operational. Under the preferred option, the system operator would need to identify where location-specific stability needs are most critical, distinguish between those better addressed through planning and those suitable for procurement, and progressively strengthen testing, telemetry and verification arrangements.

In practice, Option C is less a cost problem than a governance problem. Its implementation depends on a phased governance process in which planning and procurement evolve together over time, rather than on a single one-off market redesign.

8. Conclusions

8.1. Main Conclusions

This project aimed to answer the following question: how should Spain redesign stability-related ancillary services so that a high-renewables power system remains secure without losing cost discipline or undermining competition.

The main conclusion is that Spain does not face a technology problem as much as a market-design and governance problem. The system already has access to technologies that can support future stability needs, including grid-forming resources, BESS, hybrid plants, advanced wind and solar assets, and synchronous condensers. The challenge is that the current framework does not yet translate those capabilities into clear products, credible revenues and workable investment signals. In that sense, the issue is not whether stability can be delivered, but whether the regulatory and procurement framework is ready to buy the right capabilities in the right places and under the right incentives.

The main gaps are not the absence of ancillary services as such, but the limited explicit definition of some stability attributes, weak remuneration and investment signals for new providers, and the lack of stronger monitoring and verification arrangements. This matters because, as the generation mix becomes less synchronous and more inverter-based, stability can no longer be treated as an implicit by-product of conventional generation.

The international cases point in the same direction. Great Britain shows the value of making stability an explicit and investable service. Ireland shows that high-renewables operation becomes more workable when system services are clearly defined and remunerated. Germany shows the importance of preparing technical requirements, grid-forming capabilities and implementation milestones before stability constraints become critical. Australia shows that some security needs are too localized and too system-critical to be left entirely to market discovery. For Spain, the relevant lesson is not to copy any one model wholesale, but to combine targeted procurement of stability-related capabilities with forward-looking planning and a clear technical roadmap.

On that basis, Option C emerges as the strongest overall pathway. It is not the simplest option, and it is not the most purely market-based one either. Its strength is that it reflects the reality of the problem better than the alternatives. Some future stability needs will be suitable for competitive bidding, while others will be highly locational and will require a planning-led response. Option C is therefore the option that best balances cost targeting, investment visibility, implementation realism and long-term system resilience.

From a managerial perspective, the key constraint is not program cost alone, but execution. The indicative modelling suggests that the preferred pathway is material but manageable in cost terms, with a central-case program cost of €1,221.0 million over 2026–2040, a present value of €974.2 million and an average impact of around €0.29/MWh. These figures should be read as indicative estimates rather than precise forecasts. More importantly, they suggest that the real difficulty is not whether Spain can afford a better stability framework, but whether it can define bankable products, allocate responsibilities clearly and build credible procurement, monitoring and verification rules.

Overall, this study concludes that Spain should move progressively away from a framework in which stability is still partly implicit and unevenly remunerated, and towards a hybrid model in which critical location-specific needs are addressed through planning while services suitable for competition are procured explicitly through transparent market-based mechanisms. This would be more consistent with the technical realities of a high-renewables system, more credible for investors, and more robust for policymakers managing Spain's 2026–2040 energy transition.

8.2. Potential social and environmental impact

The recommended reform has relevance beyond electricity market design, because system stability is directly linked to the quality, reliability and continuity of electricity supply. In that sense, a better-designed stability framework helps reduce the risk that the energy transition weakens system security, thereby protecting consumers, businesses and public services that depend on a reliable electricity system, giving the project a clear social dimension. The social value of reform therefore lies not only in technical efficiency, but also in supporting a more resilient and dependable power system during a period of rapid structural change. This makes the project especially relevant to Sustainable Development Goal (SDG) 7, particularly in its broader objective of ensuring access to reliable, sustainable and modern energy [35].

The project also contributes to SDG 9, since its preferred option strengthens the institutional and economic conditions needed to modernize electricity infrastructure. The analysis shows that future stability will depend on a more diverse portfolio of technologies, including grid-forming solutions, battery storage, hybrid plants and other advanced inverter-based resources, together with targeted network-support assets in weak-grid locations. This supports the development of more resilient infrastructure and encourages innovation in the way electricity systems are operated and financed.

Finally, the project is strongly connected to SDG 13, because the continued expansion of renewables is presented throughout the study as a structural and necessary component of Spain's long-term energy and climate strategy. In this sense, the redesign of stability-related ancillary services does not reduce emissions directly by itself, but it creates enabling conditions for a higher share of low-carbon electricity to be integrated securely into the system. That makes it an indirect but important contribution to climate action.

The three main SDGs related to this project are summarised in Figure 5.

Figure 5. SDGs related to this project.

At the same time, the project also acknowledges that sustainability benefits are not automatic. The recommended hybrid model involves governance complexity, new monitoring requirements and targeted investment in some infrastructure-like assets. Its positive impact will therefore depend on careful implementation, transparent regulation and an appropriate balance between planning and competition. If these conditions are met, the proposed reform can generate social value through greater reliability, economic value through clearer investment signals, and environmental value by making Spain's high-renewables transition more secure and credible.

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Appendix A. Qualitative scoring criteria for stability-framework explicitness

Score	Interpretation	Example countries
0.5	Structurally different systems where stability challenges are less relevant due to synchronous generation dominance	Norway
1	Stability addressed mainly through traditional balancing and frequency-control services	France, Sweden, Spain
1.5	Emerging advanced measures but no dedicated stability framework	Netherlands, Italy
2	Targeted advanced mechanisms addressing low-inertia operation	Finland, United States, Germany
3	Explicit and structured stability or system-strength frameworks	United Kingdom, Ireland, Australia

The explicitness score used in this study is a qualitative and comparative indicator. It does not measure the overall quality of a country's electricity market, nor does it imply that one system is "better" in absolute terms than another. Instead, it reflects the extent to which stability-related needs are translated into identifiable and explicit service arrangements, particularly in relation to low-inertia operation, system strength, frequency support, and other non-frequency security needs in high-renewables systems. A higher score therefore indicates that the country has moved further away from relying mainly on traditional balancing arrangements and implicit synchronous support, and further towards structured products, procurement mechanisms or planning frameworks specifically designed to address emerging stability challenges. This is how explicitness has been considered for each country:

- **Spain (Score 1.0):** Spain has a functioning ancillary-services framework, including balancing services, voltage control, black start and technical-constraints management. However, stability attributes such as inertia, system strength and grid-forming capability are not yet organised as explicit, standardised and bankable stability products.
- **France (Score 1.0):** France is given the same score as Spain because the RTE framework reviewed mainly refers to traditional frequency ancillary services, such as FCR, aFRR and tertiary reserve [36]. These services are well established and can be provided by certified participants, but they do not show the same explicit focus on inertia, system strength or grid-forming procurement as the leading benchmark cases. For this reason, France is treated as a mature ancillary-services system, but not as an advanced stability-framework benchmark.
- **Italy (Score 1.5):** Italy is slightly above Spain and France because Terna has developed a Fast Reserve pilot to address faster frequency-stability needs under increasing

renewable penetration and declining synchronous generation. The service is explicitly defined as a fast, bidirectional active-power response with full activation within one second, and Terna proposed procurement through forward contracts and competitive bidding [37]. However, this remains more limited than a full stability-market or system-strength planning framework, so Italy is classified as an emerging advanced-measures case rather than a fully explicit stability framework.

- **Netherlands (Score 1.5):** The Netherlands is also classified as an emerging case. TenneT NL has developed a Synchronous Inertia Dashboard to monitor close-to-real-time and historical synchronous inertia, and Dutch analysis identifies increasing inertia shortfalls as inverter-based renewables replace conventional generation [38]. This shows more explicit diagnostic and monitoring activity than Spain. However, it is still mainly a measurement, analysis and pilot-oriented approach, rather than a mature national stability procurement or planning framework.
- **Germany (Score 2.0):** Germany is more advanced because it has a formal System Stability Roadmap aimed at secure and robust operation with 100% renewable energy sources [28]. This case is explained in the main text.
- **Finland (Score 2.0):** Finland is also placed at 2.0 because Fingrid has introduced explicit grid-code specifications for grid energy storage systems, including requirements related to grid-forming capabilities, stability, fault ride-through, voltage control, modelling and commissioning tests [39]. Fingrid has also publicly framed converter-dominated system stability as an active area of technical work [40]. This makes Finland more explicit than Spain in technical requirements, although it is still more of a grid-code and technical-specification framework than a complete stability procurement market.
- **United States (Score 2.0):** The United States is scored above Spain because FERC and NERC have introduced more specific reliability requirements for inverter-based resources, especially around voltage and frequency ride-through [41]. This shows a more explicit technical treatment of how renewables and batteries should behave during grid disturbances. However, the US electricity system is highly regional and does not have one single national stability market comparable to Great Britain, Ireland or Australia. Therefore, it is classified as an advanced technical-requirements case, but not as a full stability-framework benchmark.

- **Sweden (Score 1.0):** Sweden participates in the Nordic frequency-control framework, which includes reserves such as FCR, FRR and FFR. These services are explicit, but they are mainly reserve-based frequency-control mechanisms rather than a dedicated national framework for inertia, system strength or grid-forming procurement [42]. Batteries and other flexible assets can also participate in Nordic reserve markets, but this still reinforces the idea of a reserve-market framework rather than a full stability-service architecture [43].
- **Norway (Score 0.5):** Norway is included in the screening because it has a very high renewable share, but it is less comparable to Spain because its power system is strongly hydro-dominated and part of the Nordic synchronous system. The Nordic framework manages stability mainly through frequency-control reserves and inertia monitoring, including FFR for low-inertia situations [42]. Although batteries can participate in Nordic reserve markets [43], Norway does not represent a dedicated stability-market or system-strength planning benchmark for Spain.
- **Great Britain (Score 3.0):** Great Britain is assigned the highest score because it has already developed explicit stability procurement mechanisms. This case is explained in the main text.
- **Ireland (Score 3.0):** Ireland is assigned the highest score because the DS3 framework explicitly defined and remunerated system services required for high non-synchronous renewable operation. This case is explained in the main text.
- **Australia (Score 3.0):** Australia is assigned the highest score because it has an explicit system-strength and system-security planning framework. This case is explained in the main text.

Appendix B. Detailed scoring matrices and criterion-level rationale

Appendix B1. Cost drivers and system cost implications

Criterion	Weight	Option A	A rationale	Option B	B rationale	Option C	C rationale
Procurement efficiency	25%	3	Existing mechanisms avoid full redesign but remain fragmented.	4	Explicit tenders improve economic discovery for services suitable for competition.	4	Uses competitive tenders where possible and planning where needed.
Implementation and administrative cost	15%	5	Lowest short-term institutional effort.	2	Needs new products, qualification rules and redesign.	3	Moderate effort because some capabilities stay in planned channels, but partial redesign.
Location-specific efficiency (targeting system needs in specific grid areas)	20%	2	Weak on targeting local needs.	4	Can procure location-specific products explicitly.	5	Planning layer best suited to identify where security services are needed.
Transition and redesign cost	15%	5	Most compatible with current Spanish architecture.	2	Higher redesign cost in early years.	4	Moderate transition cost with gradual adoption.
Risk of inefficient investment (over/under procurement)	15%	2	Risk of delayed and reactive investment.	3	Better signals but risk in narrow markets.	4	Balanced and more efficient investment.
System operation cost	10%	2	Higher inefficiencies over time.	3	More efficient but potentially costly.	3	More efficient and with less inefficiencies but potentially costly.

Appendix B2. Competition and price risk

Criterion	Weight	Option A	A rationale	Option B	B rationale	Option C	C rationale
Market openness	25%	2	Existing framework does not fully value new providers.	5	Strongest opening to BESS, hybrids and GFM resources.	3	Opens competition where technically meaningful.
Risk of weak competition	25%	4	Relies on broader existing mechanisms; fewer niche tenders.	2	Some locational stability markets can lack bidders.	4	Reduces risk by separating needs suitable for competition from those requiring planning.
Price transparency	20%	2	Limited price transparency for implicit stability value.	5	Best explicit price transparency through transparent tenders.	4	Good price transparency for competitive services.
Technology neutrality	15%	1	Still favours incumbent technologies because many capabilities remain implicit.	5	Products can be defined around performance, not technology.	3	Mostly technology-neutral, with planning exceptions for dedicated assets.
Adaptability over time	15%	2	Slow to adapt as renewable penetration deepens.	4	Adaptable if products are reviewed regularly.	5	Most flexible because it can shift boundary between planning and markets.

Appendix B3. Investment signals, bankability and financing

Criterion	Weight	Option A	A rationale	Option B	B rationale	Option C	C rationale
Revenue visibility	40%	2	Short-term and implicit revenues weaken investment possibilities.	5	Explicit contracts increase visibility.	4	Good revenue visibility where tendered; planned needs reduce uncertainty elsewhere.
Contract horizon	20%	1	Short horizons dominate existing framework.	4	Can provide medium-term bankable contracts.	4	Contract length fits the need.
Value stacking	15%	2	Fragmented rules can limit stacked revenues.	4	Better multi-service participation if market rules are well designed.	4	Most compatible with stacking while preserving system priorities.
Warranty fit	10%	4	Less aggressive service dispatch lowers warranty stress.	3	Dynamic dispatch may create warranty-management issues.	4	Better alignment with asset limits.
Operational clarity	15%	2	Priority across services remains unclear.	4	Explicit products force clearer obligations.	5	Hybrid governance can define hierarchy between critical and competitive services.

Appendix B4. Regulatory feasibility and implementation complexity

Criterion	Weight	Option A	A rationale	Option B	B rationale	Option C	C rationale
Need for regulatory change	25%	5	Minimal regulatory changes required.	2	Requires the newest definitions, methodologies and procedures.	3	Moderate change, phased introduction is feasible.
Implementation speed	20%	5	Fastest to implement.	2	Slowest due to redesign needs.	3	Intermediate; can be sequenced.
Institutional complexity	15%	4	Can run mostly inside existing institutional roles.	1	Heavy coordination across institutions.	2	Moderate complexity if governance split is explicit, but still heavy coordination.
Technical readiness	15%	5	Requires limited new capabilities.	2	Needs advanced testing and systems since the beginning.	3	Can phase technical requirements.
EU compatibility	15%	5	Fully aligned with current EU framework.	4	Compatible if designed transparently and non-discriminatorily.	5	Strong alignment with EU principles.
Stakeholder acceptance	10%	4	Least disruptive for stakeholders.	2	High disruption and high resistance is likely.	3	Better balance between innovation and practicality.

Appendix B5. Strategic resilience and long-term fit

Criterion	Weight	Option A	A rationale	Option B	B rationale	Option C	C rationale
Closes market and investment gaps	25%	2	Limited improvement of current gaps.	5	Strong explicit remuneration logic.	4	Strong, though not every need is fully marketized.
Supports very high renewable hours	20%	2	Least prepared for 80-100% instantaneous renewable hours.	4	Good if product design is complete.	4	Best combination of market and security planning for deep transition.
Local system security	20%	2	Weakest on local system needs.	4	Can target location but may face risks with thin markets.	5	Strongest local targeting through planning.
Adaptability over time	35%	3	Limited long-term adaptability.	4	Adaptable with periodic product redesign.	5	Most scalable and adjustable over transition phases.

Appendix C. Sensitivity analysis: alternative decision lenses and weighting assumptions

Dimension	Balanced	Feasibility-first	Investment-first	Security-first	Competition-first
Cost & system cost	20%	10%	15%	20%	20%
Competition & price risk	20%	10%	10%	10%	30%
Bankability & financing	20%	10%	35%	15%	20%
Regulatory feasibility	20%	55%	15%	15%	15%
Strategic resilience & long-term fit	20%	15%	25%	40%	15%

Appendix D. Supporting Modelling Assumptions and Results

Appendix D1. Source base, selected assumptions and derived metrics

Metric	Formula / value	Unit	Comment	Source
EUR per GBP	1.1671	EUR/GBP	Inverse of the 2025 annual average exchange rate	[32]
EUR per USD	0.8850	EUR/USD	Inverse of the 2025 annual average exchange rate	[32]
EUR per AUD	0.5708	EUR/AUD	Inverse of the 2025 annual average exchange rate	[32]
Base condenser CAPEX per unit	134.62	A$m per unit	673.1 / 5	[31]
Active condenser CAPEX per unit	76.85	€m per unit	AEMO benchmark translated into euros using the 2025 annual average EUR/AUD rate	[31], [32]
Condenser annual O&M as % of CAPEX	1.0	%	AEMO assumption applied to planning-layer assets	[31]
NESO unit price, round 1	5.08	£m per GVA·s-year	25.4 / 5.0	[23]
NESO unit price, round 2	1.41	£m per GVA·s-year	10.3 / 7.3	[30]
Base competitive procurement price (weighted average)	2.90	£m per GVA·s-year	Weighted average across rounds 1 and 2	[23], [30]
Active procurement unit price	3.39	€m per GVA·s-year	Weighted average translated into euros using the 2025 annual average EUR/GBP rate	[23], [30], [32]

Appendix D2. Year-by-year deployment path

Year	Base planned SC equivalents added	Base procured GVA·s	Comment
2026	0	0	Preparation year. No physical asset added yet.
2027	1	3	Initial pilot procurement (~half GB scale) and first locational asset.
2028	1	5	Expansion towards GB Round 1 benchmark (~5 GVA·s).
2029	1	6	Increasing procurement as market matures.
2030	1	7	Close to GB Round 2 scale (~7.3 GVA·s).
2031	1	7	One new unit.
2032	1	8	Selective reinforcement; increasing system needs.
2033	1	8	One new unit; Stable procurement level.
2034	1	9	Final reinforcement of the second build-out phase.
2035	0	9	No new unit; reinforce procurement.
2036	1	9.5	Late selective reinforcement; gradual procurement increase.
2037	1	10	Final planned reinforcement; mature procurement layer.
2038	0	10	Stable mature level.
2039	0	10.5	Slight increase with higher RES penetration.
2040	0	10.5	Stable mature system.

Appendix D3. Illustrative calculated savings yearly 2026-2040

Year	Demand (TWh)	Planned SC adds	SC in service	SC unit CAPEX (€m)	Planning CAPEX for SC (€m)	Planning O&M (€m)	Procured GVA·s	Unit price (€/GVA.s-yr)	Competitive procurement (€m)	Other cost	Total cost (€m)	Discount factor	PV (€m)	Total cost (€/MWh)
2026	259.2	-	-	76.85	-	-	-	3.39	-	-	-	100.0%	-	-
2027	262.3	1.0	1.0	76.85	76.85	0.77	3.0	3.39	10.2	-	87.78	96.6%	€84.8	€0.33
2028	265.4	1.0	2.0	76.85	76.85	1.54	5.0	3.39	16.9	-	95.32	93.4%	€89.0	€0.36
2029	268.6	1.0	3.0	76.85	76.85	2.31	6.0	3.39	20.3	-	99.48	90.2%	€89.7	€0.37
2030	271.8	1.0	4.0	76.85	76.85	3.07	7.0	3.39	23.7	-	103.63	87.1%	€90.3	€0.38
2031	275.1	1.0	5.0	76.85	76.85	3.84	7.0	3.39	23.7	-	104.40	84.2%	€87.9	€0.38
2032	278.4	1.0	6.0	76.85	76.85	4.61	8.0	3.39	27.1	-	108.56	81.4%	€88.3	€0.39
2033	281.7	1.0	7.0	76.85	76.85	5.38	8.0	3.39	27.1	-	109.33	78.6%	€85.9	€0.39
2034	285.1	1.0	8.0	76.85	76.85	6.15	9.0	3.39	30.5	-	113.48	75.9%	€86.2	€0.40
2035	288.5	-	8.0	76.85	-	6.15	9.0	3.39	30.5	-	36.64	73.4%	€26.9	€0.13
2036	292.0	1.0	9.0	76.85	76.85	6.92	9.5	3.39	32.2	-	115.94	70.9%	€82.2	€0.40
2037	295.5	1.0	10.0	76.85	76.85	7.68	10.0	3.39	33.9	-	118.41	68.5%	€81.1	€0.40
2038	299.0	-	10.0	76.85	-	7.68	10.0	3.39	33.9	-	41.56	66.2%	€27.5	€0.14
2039	302.6	-	10.0	76.85	-	7.68	10.5	3.39	35.6	-	43.25	63.9%	€27.7	€0.14
2040	306.3	-	10.0	76.85	-	7.68	10.5	3.39	35.6	-	43.25	61.8%	€26.7	€0.14