Ensuring System Stability in Europe: **The Role of Energy Storage in Providing Inertia**

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Ensuring System Stability in Europe: The Role of Energy Storage in Providing Inertia

Position Paper

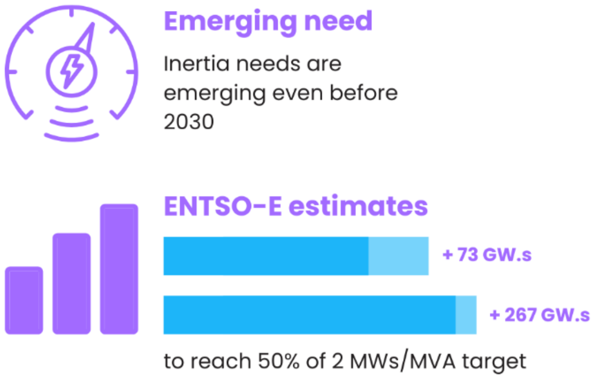
Executive Summary

The European power system is becoming increasingly vulnerable to system stability challenges. As traditional synchronous machines are progressively being accompanied by inverter-based renewable energy sources (IBRs), such as PV and wind turbines, the overall system inertia is declining significantly. This reduction limits the system's ability to withstand sudden frequency deviations and voltage disturbances, increasing the risk of instability. As highlighted by an ENTSO-E report "Project inertia II", every Member State should aim to maintain a minimum inertia constant of 2 MWs/MVA for at least half of the year by 2035, to safeguard operational security while advancing decarbonisation.

Despite these needs, the European Union still lacks a harmonised framework for assessing inertia needs and, consequently, procuring inertia. Transmission System Operators (TSOs) apply diverse assessment methodologies and rely on various delivery models: network-based or market-based approaches. This fragmentation hinders market development and restricts investments in the deployment of existing assets and energy storage solutions that could prevent the decline of system inertia.

Overall, European Union and national policymakers should adopt a harmonised framework for the assessment of inertia needs, aiming to procure it as a service through cost-efficient and technology-neutral auctions and tenders. In particular, Energy Storage Europe identifies the following measures as needed to ensure non-discriminatory market-based mechanisms for inertia procurement.

Graphic 1: Emerging Inertia Needs in Continental Europe



Graphic 2: Current EU Market Framework for Inertia Provision

Current Situation

- Lack of a harmonised EU framework for inertia assessment &procurement
- TSOs use diverse methodologies
  - Network-based
  - Market-based
- Fragmented markets
- Limited investments in assets and Energy Storage
- Risk ofdeclining system inertia

Recommended EU Approach

- Adopt harmonised framework for assessing inertia needs
- Pocure inertia as a service
- cost-efficient, technology-rev-neutral auctions & tenders

Specific Measures Identified by Energy Storage Europe

- Ensure non-discriminatory, market-based mechanisms

Sources:

- *Graphic 1: based on: https://www.entsoe.eu/2025/01/23/entso-e-releases-the-latest-work-from-project-inertia-which-studies-the-evolution-of-the-inertia-levels-in-the-long-term-horizons-in-the-continental-europe-synchronous-area-and-the-challenges-emerging-from-their-decrease/*
- *Graphic 2: Energy Storage Europe elaboration*

Focus: The Questions this Paper Aims to Address

1. What are the system capabilities needed to ensure grid stability?

2. How do Energy Storage technologies provide system stability capabilities?

3. How do TSOs assess Member States' inertia needs?

4. What is Europe’s current inertia sourcing models, and which one best enables cost-efficient energy storage deployment?

5. Which policies are needed for the rollout of Energy Storage systems procuring inertia?

Context: Why System Stability Needs Energy Storage in the Surge of Inverter-Based Resources?

As wind and solar energy have become more widespread, the share of system inertia that was traditionally provided inherently by synchronous generators has been decreasing. Their large rotating masses stored kinetic energy, resisting sudden frequency changes and slowing the **Rate of Change of Frequency (RoCoF)[1].** giving slower-acting resources time to respond and preventing cascading failures or blackouts. Alongside inertia, synchronous machines also provide voltage control and short-circuit current, which are critical for grid stability.

Inverter-based resources (IBRs), such as wind and solar plants that rely on power electronics, are increasingly being added to power systems alongside traditional synchronous generators for the provision of active power. This combination has resulted in a decrease in system inertia, increasing vulnerability to frequency instability.

This combination has also led to growing deployment of several **mechanical-inertia technologies** such as synchronous condensers, Pumped Hydro Energy Storage (PHES), Compressed Air Energy Storage (CAES), Liquid Air Energy Storage (LAES), Static Synchronous Compensators (STATCOMs), and flywheels. They provide immediate mechanical stabilisation: having their inertia fixed in magnitude and duration, they often require a complementary fast frequency response measure to be added, even if not strictly needed.

Finally, batteries, connected via power electronics to IBRs, emulate rotating mass behaviour and deliver **synthetic inertia** through advanced control systems. Although not identical to mechanical inertia, battery response times[2] are very fast and adaptive, making them a key component to actively stabilise renewable-dominated or weak-grid systems.

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[1] RoCoF is the speed at which frequency changes in Hertz per second (Hz/s).

[2] Response time is the time that a power system needs to deliver a service (inertia) after a frequency disturbance. Reaction time is the required time that the first significant frequency control needs to activate before delivering the response. It is characterised by an instantaneous or almost instantaneous automatic release of energy to stabilise frequency.

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1. Overview of System Stability Capabilities for Grid Stability

1.1 Introduction

Both **synchronous machines** and **IBRs,** especially when supported by an ESS-based solution such as battery storage, provide a set of system stability capabilities, including those previously mentioned (e.g., voltage control and short-circuit current), which ensure grid stability and prevent system splits.

Until recently, synchronous machines were the main providers of system stability services. With the introduction of inverter-based resources (IBRs) such as PV and wind plants, the grid is facing a decrease in system inertia. This is because most IBRs' resources use **grid-following (GFL) inverters**. GFL inverters synchronise themselves to the grid and track its frequency and voltage. While they can provide basic system stability capabilities such as voltage and frequency control, their inertia contribution is minimal and only reactive to already existing frequency changes.

Another type of inverters is the **grid-forming (GFM) ones**. GFM, when paired with a battery storage system (or a supercapacitor, but only for inertia), can establish its own voltage and frequency reference, which enables them to provide all of the same capabilities as traditional synchronous generators (albeit with reduced capabilities per unit). More specifically, grid-forming inverters allow power devices to independently maintain a slow and controlled variation of voltage and frequency, playing a crucial role in maintaining system stability.

Therefore, different assets (synchronous generators or IBRs with GFL or GFM inverters) present different system capabilities.

1.2 System Stability Capabilities

This chapter details the main system stability capabilities and the role of Energy Storage Systems (ESS) technologies in providing them, whether they are synchronous generators or IBRs supported by a GFL or GFM inverter.

Capability	Short description	Role of ESS in system stability
Voltage control	Provides fast reactive power response to limit voltage change.	All ESS technologies deliver rapid voltage control within milliseconds.
Inertia	Stabilises frequency based on RoCoF.	Different ESS technologies can provide different types of inertia, of which mechanical and synthetic are the two macro-categories.
Black Start	Restores the grid without an external power source.	Several ESS technologies can restore grid voltage and frequency after disturbances.
Short-Circuit Strength	Counterbalance fault current to protect equipment.	All ESS technologies with the exception of ESS with GFL inverters can deliver short-circuit power to counterbalance fault current.
Oscillation Damping	Modulates output to prevent oscillations from an equilibrium.	All ESS help stabilise a wider range of frequency oscillations.

Table 1: Overview of system stability services and ESS role in providing the system stability capabilities.

The key characteristics of system services capabilities, including grid-forming capabilities, are detailed as follow:

- **Voltage control** provides fast reactive power to limit voltage change. Both synchronous and non-synchronous technologies support the traditional voltage control (as also done by GFL), bringing the reactive power of the unit to the desired value in a few hundred milliseconds.
    - Synchronous machines, such as synchronous condensers, can provide immediate voltage control when activated through control system.
    - ESS-based technologies supporting GFM solutions, such as batteries, behave as a controlled voltage source behind an impedance, providing a quasi-immediate voltage control when the grid voltage is changing by relying on voltage measurement.
- **Inertia** is the physical tendency of an object to resist changes in its state of motion[3]. More specifically, as a system stability capability in electricity systems, it stabilises frequency when a Rate of Change of Frequency (RoCoF) variation occurs. The provision of inertia helps reduce the RoCoF or the extent of change and it leaves time for other frequency response mechanisms to be activated. Based on the technology providing this service, inertia can be:
    - **Mechanical**, is the capability of rotating masses to resist rapid changes in grid frequency. They store kinetic energy as a buffer, providing stability to the electricity grid by slowing down frequency deviations following sudden changes in load or generation (they slow the Rate of Change of Frequency (RoCoF). When the inertia is provided specifically through a synchronous machine, like a synchronous condenser or generator, it can be defined as "synchronous".
    - **Synthetic**[4], is the capability of ESS-based GFM technologies or other technologies like E-STATCOM with GFM control, such as batteries, to emulate mechanical inertial response through automatic control strategies. These technologies inject active power into the grid as a response to frequency variations. Therefore, the active power changes without relying on any external frequency measurement and in an instantaneous way[5]. In cases where GFL inverters provide synthetic inertia, this relies on frequency measurement to be activated, delaying the frequency change by around 100 milliseconds, which is not sufficient in the case of a very low inertia system or high RoCoF.
- **Black Start** restores the grid by energising de-powered sections of the grid by establishing voltage and frequency references without the need for an external source. This allows system restoration after a total or partial blackout.
    - Several ESS technologies based on synchronous machines (e.g., PHES, CAES, etc), do not require an external current source to initiate the black start.
    - ESS-based technologies supporting GFM inverters (such as batteries) determine the voltage and frequency reference independently, allowing grid sections to be restored consequently. This includes energising transformers, energising long runs of unloaded transmission lines, re-synchronising the grid section, and ramping up the load.
- **Short-Circuit Strength** contributes to counterbalance fault current by balancing short-circuit power in a controlled manner, aiming to support grid functions and avoid failure of the grid equipment.
    - It is traditionally provided by synchronous machines, including synchronous condensers.

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[3] Inertia, also known as mechanical inertia, is an object's tendency to resist changes in its motion. It appears in two main forms: **continuous inertia** and **rotational inertia**. Continuous inertia describes an object's tendency to remain at rest or move in a straight line at constant speed, while **rotational inertia** (or **moment of inertia** or **angular inertia)** describes its resistance to changes in rotational motion. Both depend directly on the object's mass and how that mass is distributed.

[4] In this paper, the term "synthetic inertia" follows the definition in draft NC RfG 2.0 and in ENTSO-E report "GRID FORMING CAPABILITY OF POWER PARK MODULES" (2025). Namely, "synthetic inertia" means a prescribed electrical dynamic performance provided by a PPM or an HVDC system at its PoC with the purpose to emulate the equivalent dynamic effect of the inertia provided by a synchronous PGM.

[5] This paper refers to the term "instantaneous" as indicate in ENTSO-E report "GRID FORMING CAPABILITY OF POWER PARK MODULES" (2025): the paragraphs requesting an "instantaneous" reaction are considered as undefined requirements unless when accompanied by further criteria defining quantitatively what instantaneous means.

    - ESS-based technologies supporting GFM solutions, such as batteries, can emulate this function through carefully designed current injection schemes. While the absolute fault current magnitude may be lower, the fast response and controllability of grid-forming inverters, when supported by a battery or another non-synchronous machine, can increase short-circuit power thanks to their ability to operate in low-inertia networks.

- **Oscillation damping** refers to the ability of a power system or device to reduce power or frequency oscillations that occur after a disturbance, ensuring system stability and preventing prolonged or growing swings.
    - All synchronous machines can actively contribute to oscillation damping by injecting stabilising power responses in real time, thanks to a Power System Stabiliser control.
    - ESS-based technologies supporting GFM solutions can provide[6] a fast-stabilising response to counterbalance frequency oscillation. GFL units can also damp oscillations, but to a smaller extent than grid-forming units.

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[6] When supported by Power Oscillation Damping (POD) control strategy, used in power systems to reduce or prevent unwanted oscillations, which can destabilize the grid.

2. Energy Storage Technologies Providing System Stability Services

2.1 System Stability Services

Currently, among the European countries, the capabilities listed in Chapter 1 can be provided as a system stability service. This is because, according to a proposed ENTSO-E definition, system stability services define the short-term active control of assets that influence system balance or grid power flows.

This chapter will detail the different Energy Storage assets providing system stability services, according to how they provide inertia: mechanical vs synthetic.

Considering different technological maturity levels, essential characteristics of the technology, such as Technology Readiness Level (TRL), time deployment, and other system stability capabilities provided, are depicted below.

2.2 Energy Storage Systems Providing Mechanical Inertia

As previously discussed, mechanical inertia is derived from the kinetic energy stored in rotating masses built on a synchronous generator asset. When a disturbance occurs, these masses respond abruptly to frequency changes, minimising the RoCoF. Following this, a controlled and sustained active power injection/absorption is needed to restore frequency.

2.2.1 Synchronous Condensers

With the decrease of traditional synchronous generators, synchronous condensers (SCs) have become a mature option for delivering mechanical inertia, short-circuit current, and dynamic voltage to maintain system stability. They can be deployed as greenfield or brownfield projects.

- Greenfield SCs[7]:
    - They have a TRL 9.
    - Deployment time exceeds 30 months.
    - They provide reactive power support (voltage and frequency control) and deliver inherently mechanical (synchronous) inertia instantaneously.
- Brownfield SCs[8]:
    - They have a TRL 9.
    - Deployment time is of 6–24 months.
    - They provide reactive power support (voltage and frequency control) and deliver inherently mechanical (synchronous) inertia instantaneously.

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[7] In addition to the above figures, Artelys - European Commission's Assessment of Policy Options for Securing Inertia report (page 46) indicates deployment costs (investment costs) of a classic synchronous condenser range from €46,000–€144,000 per MWs of inertia.

[8] In addition to the above figures, Energy Storage Europe members indicate deployment costs are 20–50% cheaper than greenfield units.

2.2.2 Other ESS Technologies Providing Mechanical Inertia

Other Storage-based technologies capable of providing mechanical inertia typically rely on turbine-driven generation or rotating machinery.

- **Pumped Hydro Energy Storage (PHES)** generates electricity through turbines during discharge, using water stored at an elevation.
  - It has a TRL 9.
  - Greenfield deployment is capital-intensive, requiring significant civil engineering and taking up to 7-10 years to complete, but are already deployed in numerous Member States. Brownfield PHES deployment should be analysed in a case by case, but it is usually less capital intensive, limited or no civil engineering required and can take up to 3-5 years to complete.
  - It provides mechanical inertia, voltage control, short-circuit strength, and black-start capability, with frequency stabilisation within milliseconds.
- **Compressed-Air Energy Storage (CAES):** stores compressed air in underground caverns or vessels and drives turbines to generate electricity, often using natural gas for reheating.
  - It has a TRL 8–9 for conventional systems.
  - Deployment is geology-dependent, requiring 3–5 years, with site-specific costs. They provide mechanical inertia, frequency and voltage control, black-start capability (when connected to synchronous machines), and short-circuit current, with milliseconds response times.
- **Adiabatic CAES:** captures compression heat for carbon-free operation. It requires salt caverns, limiting location flexibility.
  - It has a TRL 7.
  - Deployment is geology-dependent, requiring 3–5 years, with site-specific costs.
  - They provide mechanical inertia, frequency and voltage control, black-start capability (when connected to synchronous machines), and short-circuit current, with milliseconds response times.
- **Liquid-Air Energy Storage (LAES):** stores air as a cryogenic liquid in insulated tanks and reconverts it to electricity through expansion turbines.
  - It has TRL 6–7.
  - Deployment is achievable within 2–4 years, but still limited in large-scale rollout.
  - They provide mechanical inertia, frequency and voltage control, black-start capability (when connected to synchronous machines), and short-circuit current, with milliseconds response times.
- **Thermal Energy Storage (including Carnot Batteries):** stores electricity as high-temperature heat in solid or molten form to drive turbines and generate electricity.
  - It has a TRL 8.
  - Deployment at an industrial scale is achievable within 2–4 years, with moderate costs and flexible siting, often benefiting from the reuse of coal or gas plant assets, which reduces environmental impact.
  - It provides mechanical inertia, short-circuit current, voltage control, black-start capability, and fault ride-through, with turbine-driven response times in milliseconds.

2.3 Energy Storage Systems Providing Synthetic Inertia

As synchronous generators are retiring, or their capacity factor/running hours are much lower, synthetic inertia from inverter-based resources (IBRs) is increasingly deployed. an ESS-based technology with GFM control providing synthetic inertia can provide a very fast response, requiring detection of a frequency deviation before responding with active-power injection, and it needs an energy buffer available to provide this service. It is programmable, scalable, and can be deployed rapidly, making it particularly suitable for grids with high penetration of RES.

2.3.1 Battery Energy Storage Systems (BESS)

- Battery Energy Storage Systems (BESS): they support inverter-based resources (IBRs) by emulating synchronous-machine behaviour through power electronics and advanced control. Their programmable frequency response enables sustained frequency support beyond initial RoCoF mitigation, effectively bridging the gap until slower resources activate.[9]
  - They have a TRL 9 at utility scale.
  - Deployment time is achievable within 1 year.
  - They provide fast frequency response, black-start capability, voltage control, and synthetic inertia with reaction times typically in the range of a few milliseconds to a few tens of milliseconds, depending on control settings.

2.3.2 Other ESS-Solutions Supporting IBRs

- IBRs, such as wind turbines and PV with grid-forming inverters when paired with buffers like supercapacitors or small-scale flywheels:
  - They have a TRL of 7–8.
  - Deployment time is still largely dependent on the renewable plant construction.
  - They complement synchronous inertia by providing synthetic inertia other than flexible, agile, and fast-response support in weak grids.

2.4 Integration Of Different ESS Technologies to Provide Inertia

The integration of synchronous ESS solutions with the addition of a battery or supercapacitor ensures that the synchronous solution provides inertia, in addition to grid-stability capabilities such as voltage control. This combination of synchronous technology and BESS is particularly valuable in weak grids or during emergency conditions where traditional protection schemes may otherwise fail. Some examples are as follows:

- **Synchronous condensers paired with BESS support:**
  - They have a TRL of 7–8.
  - Deployment time is still largely dependent on the synchronous condenser units.
  - They provide voltage and frequency control with mechanical inertia and black start capabilities enhanced by the battery’s fast response, which has been assessed at under 20 milliseconds.
- **Synchronous condensers paired with flywheels support:**
  - They have a TRL of 8-9.

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[9] In addition, Energy Storage Europe members indicated the deployment costs of a Battery Energy Storage System as of €150–200/kWh.

  - Deployment time ranges from up to 30 months for greenfield and up to 20 months for brownfield projects.
  - They provide voltage and frequency control with mechanical inertia significantly enhanced by the flywheel support. Unlike synchronous condensers with BESS support**,** they cannot provide black start capability. Inertia's response time has been assessed as under 20 milliseconds.
- **E-STATCOMs, such as a static synchronous compensator (STATCOMs) with BESS or supercapacitor support[10]:**
  - They have a TRL of 9.
  - Deployable time is within 12–24 months.
  - They provide synthetic inertia in addition to voltage control and reactive power with a fast response time of under 50 milliseconds, allowing them to be as fast as synchronous condensers due to initial inertia power response bounded only by a physical reaction.

Hybrid Flywheels with BESS support: flywheels are electromechanical devices that store energy in the form of kinetic motion and release it back to the grid through an inverter interface.

- When paired with BESS:
  - They have a TRL of 6-7.
  - Deployment time is largely dependent on the flywheel unit construction.
  - Deployment costs are high, due to their mechanical complexity e.g., high-speed rotation, thermal stresses).
  - They provide mechanical inertia from flywheels with the sustained power delivery and voltage control supported by batteries.

Technology	Voltage	Inertia (Mech./Synth.)	Black Start	Short-Circuit Strength	Oscillation Damping
Synchronous Condenser (Greenfield)	☑	☑ (Mechanical)	✗	☑	☑
Synchronous Condenser (Brownfield)	☑	☑ (Mechanical)	✗	☑	☑
Pumped-Hydro Energy Storage (PHES)	☑	☑ (Mechanical + potentially synthetic with a controller)	☑	☑	☑
Compressed-Air Energy Storage (CAES)	☑	☑ (Mechanical)	☑	☑	☑
Liquid-Air Energy Storage (LAES)	☑	☑ (Mechanical)	☑	☑	☑

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[10] In addition to the above figures, Artelys - European Commission's Assessment of Policy Options for Securing Inertia report (page 49) indicates deployment costs (investment costs) of an E-STATCOM with converter addition option at 39 k€/MWs.

Thermal Energy Storage (Carnot Batteries)	☑	☑ (Mechanical)	☑	☑	☑
GFM Battery Energy Storage System	☑	☑ (Synthetic)	☑	☑ (Emulated)	☑
Wind/PV + GFM inverter (with supercapacitor)	☑	☑ (Synthetic)	☑ (Limited)	☑ (Emulated)	☑
Synchronous Condenser + BESS	☑	☑ (Hybrid Mech.+Synthetic)	☑ Upon technical requirements for generators	☑	☑
Synchronous Condenser + Flywheel	☑	☑ (Enhanced Mechanical)	✗	☑	☑
STATCOM + Supercapacitor (E-STATCOMs)	☑	☑ (Synthetic)	✗	☑ (Emulated)	☑
Hybrid Flywheel + BESS	☑	☑ (Hybrid Mech.+Synth.)	☑	☑	☑

Table 2. Overview of ESS technologies providing system stability capabilities: This table presents various synchronous and non-synchronous Energy Storage technologies and indicates the specific system stability capability that each technology is technically capable of providing.

While the energy storage technologies analysed in Chapter 2 efficiently support the system stability capabilities described in Chapter 1, this paper focuses specifically on inertia: how its technical needs are assessed and how it can be procured.

Assessments and procurement options for other system stability services will be addressed in future publications.

3. How to Assess Inertia Needs

3.1 Introduction

After reviewing system stability services and the Energy Storage technologies available to provide them, the specific needs of Member States and the technical criteria for their assessment should be considered. However, a detailed technical analysis of these capabilities falls outside the scope of this paper, which predominantly focuses on inertia. As a result, the analysis of other stability capabilities will be addressed at a later stage.

This chapter focuses on the role of Transmission System Operators (TSOs) in defining Member States' inertia needs, and the technical criteria used for their assessment. It also provides an overview of current inertia need assessments across Member States, where available, since a common EU-level framework for assessing inertia needs is still missing.

3.2 TSOs' Role in Defining Inertia Needs

TSOs play a key role in identifying the technical criteria for the assessment of inertia and security of supply needs, while managing real-time electricity flows, balancing supply and demand, and planning grid investments. They are also essential in integrating assets and energy storage technologies across EU Member States for the supply of inertia. More specifically, TSOs contribute to:

1. **Identifying system indicators** (e.g., **RoCoF, inertia shortfall**, voltage stability, Short Circuit Ratio).
2. **Setting technical requirements for the assessment and provision of inertia,** including updating national grid codes based on the upcoming revision of the Network Code on Requirements for Generators.
3. **Structuring the European country's methodology** for assessing inertia needs.

3.2.1 System Indicators to Assess Inertia Needs

Inertia needs are evaluated using various system indicators, which TSOs use to monitor changes in system stability. The main key indicators for assessing inertia needs are:

- **Rate of Change of Frequency (RoCoF):** aimed at assessing the inertia needed. RoCoF is inversely proportional to system inertia and, if too high, can trigger generator protections or cause system splits.

  Most European TSOs use a critical RoCoF limit of **1 Hz/s as a threshold**, based on past system events and the limits of frequency measurement[11]. This threshold is also supported by ENTSO-E's recommendations.

  However, defining a RoCoF threshold does not provide an estimate of a Member State's RoCoF. Indeed, the estimate of a Member State's RoCoF *per se* depends on its total system inertia, the size of the power disturbance, and the duration of the disturbance, calculated based on TYNDP scenarios[12]

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[11] While the operational limit and withstand capability are usually determined in a 500-ms time window (ENTSO-E technical report).

[12] The Ten-Year Developed Plans (TYNDP), published every two years by ENTSO-E under Regulation (EU) 2019/943, map Europe's transmission and flexibility needs over the next 10–30 years.

and system splits. By collecting these elements, the Member State's RoCoF can be estimated, which can differ significantly across the EU, as the Member States' inertia needs vary.

- **Inertia floor, namely the minimum amount of kinetic energy:** defines a minimum system inertia level to ensure frequency stability, which, according to ENTSO-E recommendations, sets a minimum inertia system level equivalent to a constant inertia of 2 seconds, to be met at least 50% of the time in 2035 and 90% in long term. This is because the power system requires sufficient kinetic energy to maintain a stable Rate of Change of Frequency (RoCoF) after a major disturbance event.

Even though several other system indicators for the assessment of inertia needs have been developed, the above-mentioned can be considered as the essential ones. Moreover, of these system indicators, Rate of Change of Frequency (RoCoF), and Inertia Floors are being more frequently considered by Member States to assess inertia needs, as indicated by the examples presented in Chapter 4.

3.2.2 Setting Technical Requirements for the Assessment and Provision of Inertia

As previously mentioned at point 2 of chapter 3.2, the TSO, in collaboration with the National Regulator Authority (NRA) also plays a key role in defining how much inertia is needed, setting standards for its assessment.

This assessment includes revising national grid codes and updating grid connection standards so that specific users, such as generators and storage operators, have set clear technical requirements and responsibilities for providing inertia.

More specifically, the revision of national grid codes ensures that generators and storage operators' equipment can provide inertia and contribute to grid stability, sometimes on a mandatory basis. Several countries have already tightened their grid codes to require ESS-based storage systems supporting IBRs to deliver a minimum capacity of inertia.

Member States, other than revising their network codes, are expected to implement the upcoming EU Network Code on Requirement for Generators – RfG (Commission Regulation (EU) 2016/631), which sets out the grid connection requirements at all voltage levels and for new generators, including ES-based storage systems supporting IBRs.

In particular, the RfG sets technical requirements for a range of system stability services, including inertia for frequency stabilisation, with particular regard to new requirements for synthetic inertia from ESS-based solutions. These new requirements are expected to allow the newly-built assets to support the grid, by counterbalancing the loss of system inertia caused by the increasing share of inverter-based resources (IBRs) such as PV and wind turbines. As a result, the RfG requirements consider newly built non-synchronous generators and battery storage systems. In particular, the RfG 2.0 is foreseen to refine four generator categories (Types A–D) and clarify the system services they must provide, with obligations increasing from Type A to Type D[13]. For Types C and D, Member States may also require additional energy storage beyond the unit's inherent storage, which can be provided as a market-based service.

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[13] The Network Code on Requirements for Generators 2.0 defines 4 categories of generators and for each category sets out specific grid connection requirements. The categories are A, B, C, and D defined on the basis of voltage level of their connection point and their maximum capacity, as follows:

- **Type A** includes power generating modules that have a maximum capacity of 0.8 kW or more.
- When maximum capacity of a power-generating module is **below** a default threshold of 10 MW (which can be amended by the TSO), the categories B, C, and D are defined considering only their maximum capacity. The thresholds vary for each synchronous area and can be changed by the TSO. **The NC RfG provides the maximum thresholds**. As an example, considering Continental Europe, generators of **type B** shall have a maximum capacity at or above 1 MW, **type C** shall have a maximum capacity at or above 50 MW, **type D** shall have a maximum capacity at or above 75 MW.
- When maximum capacity of a power-generating module is **above** a default threshold of 10 MW, a generator of **type B** has a connection point below 110 kV and a maximum capacity at or above 1 MW, a generator of **type C** has a connection point below 110 kV and a maximum capacity at or above 50 MW, a generator of **type D** has a connection point at 110 kV or above or has a connection point at below 110 kV and its maximum capacity is at or above 75 MW.

3.2.3 European Countries' Methodology

As previously mentioned at point 3 of chapter 3.2, TSOs are envisaged to implement methodologies for the assessment of inertia needs in their respective European country considering also additional requirements for particular locational needs and geographical limitations (e.g.: islands or less interconnected systems). Nevertheless, a common approach to assessing inertia needs has not yet been established at the European level, leaving each European country to define its own criteria and methodology to assess inertia needs.

The table below summarises how 7 European countries assess inertia needs, based on the previously indicated inertia system indicators.

Country (TSO)	Assessment of inertia needs
Finland (FinGrid)	Inertia, measured as kinetic energy, has been estimated to require a volume of 145-170 GWs per year, based on seasonal and local needs.
France (RTE)	Monitoring of synchronous generation activity; inertia gaps identified in the system needs, but assessment requirements are under study.
Germany (TSOs: TenneT, TransnetBW, Amprion, 50Hertz)	Tools and methodologies for assessing low system strength conditions.
Greece (IPTO)	Ongoing studies address inertia and system-strength requirements.
Ireland (EirGrid)	Minimum requirement of 23,000 MWs inertia floor.
Italy (TERNA)	Ongoing studies addressing inertia needs as the amount of additional inertia needed by 2030 to limit RoCoF variations.
United Kingdom (NESO)	Ongoing field analysis estimating a minimum system inertia required at 120 GWs.

Table 3: Overview of 7 European countries assessing inertia needs based on different system indicators and technologies providing inertia.

Sources: Requirement for minimum inertia in the Nordic power system, (ENTSO-E) Low Carbon Inertia Services, (EirGrid) A Techno-Economic Assessment to Define Inertia Needs of the Italian Transmission Network in the 2030 Energy Scenario (Fresia et al.) Clean Power 2030 Annex 3: Operability and operations analysis (NESO). Information from the remaining EU Member States (France, Germany, Greece) has been provided by Energy Storage Europe Association's members.

As can be noticed from the above table, the TSOs criteria to assess inertia needs diverge significantly among EU member states, leaving space to define their own methodology.

4. Sourcing Inertia in Europe: Direct vs Indirect Supply Options

4.1 Inertia direct supply options in Europe: two approaches

This chapter aims to describe two approaches to source inertia into the grid, such as:

- **Network-component approach[14]:** inertia delivered through all synchronous assets connected to the grid, providing other system stability services (e.g.: voltage control) and inherently sourcing inertia to the system. These synchronous assets can be either generators or grid assets[15], including TSO-owned assets[16].
- **Market-based approach:** inertia procured by TSO and delivered through all synchronous and non-synchronous assets connected to the grid developed by different third-party providers.

4.1.1 The Network-component approach: TSOs supplying inertia

Based on the existing procurement approaches defined in chapter 4.1, the network-component approach is detailed below accordingly to actors involved, technology focus, delivery characteristics, with its advantages and limitations.

The European legislation on common rules for the internal market for electricity (EU Directive 2019/944 & EU Regulation 2019/943) does not allow TSOs to provide inertia with *fully integrated network components*[17]. However, some *fully integrated network components* owned by the TSO for ensuring a secure and reliable operation of the transmission or distribution system (e.g.: voltage control), can also provide inertia as an inherent capability because of their technological features (i.e., a synchronous condenser to provide voltage control can also provide inertia to the system). In this regard, the TSO, by incorporating assets into the system, can also deliver inertia to the system in an inherent manner. Similarly, all synchronous generators are also providing inertia to the system.

Several TSOs in the EU have already invested in synchronous condensers, which are primarily used for ancillary services such as reactive power control but can also provide inertia.

Actors involved

In the network-component model, TSOs are the central actors responsible for delivering inertia through TSO-owned grid assets, along with procuring it from third parties. TSOs can provide inertia through TSO-owned grid assets, as far as the technology that provides grid stability and ensures secure and reliable operation of the system can also inherently deliver system inertia.

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[14] This concept was proposed by the German TSO Amprion in the study “Marktgestützte Beschaffung von Momentanreserve”, 2023

[15] As defined by Article 2(10) of Regulation (EU) 2019/943: on the definition of balancing, Inertia is considered as a balancing service. More specifically, ‘balancing’ includes per definition all actions and processes, in all timelines, through which a TSO ensures, in an ongoing manner, maintenance of the system frequency within a predefined stability range and compliance with the amount of reserves needed with respect to the required quality. Based on Article 2(51) of Directive (EU) 2019/944, ‘fully integrated network components’ means network components that are integrated in the transmission or distribution system, including storage facilities, and that are used for the sole purpose of ensuring a secure and reliable operation of the transmission or distribution system, and **not for balancing** or congestion management.

[16] As defined by Article 2(10) of Regulation (EU) 2019/943: on the definition of balancing, Inertia is considered as a balancing service and cannot be provided by a TSO as a service with their own fully integrated network components. More specifically, ‘balancing’ includes per definition all actions and processes, in all timelines, through which a TSO ensures, in an ongoing manner, maintenance of the system frequency within a predefined stability range and compliance with the amount of reserves needed with respect to the required quality.

[17] DIRECTIVE (EU) 2019/944 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 June 2019 on common rules for the internal market for electricity.

Technology focus

Typical technologies include synchronous condensers and repurposed thermal units transformed to synchronous condensers, and are always excluded from active energy supply (including balancing or congestion management services). These technologies are usually deployed in specific grid locations analysed, planned and selected by the TSO to provide grid stability and ensure secure and reliable operation of the system, like voltage control, but, at the same time, also providing inertia to the system.

These machines deliver continuous inertia by default, regardless of real-time system conditions or market signals.

TSOs sometimes pursue innovation through bilateral partnerships with technology suppliers and through pilot projects, such as in the following example. In this case, grid validation will occur with these chosen technologies first.

Delivery characteristics

This model allows the TSO to: In this model and under specific circumstances, the TSO can source inertia together with other grid services. The provision of inertia as well as other grid services is fully centralised under the TSO, which can also be the owner of the asset deployed and the system service provider. This model allows the TSO to:

- **Fully manage inertia supply**: by handling the full process of securing inertia, from planning to investment. In this case, the TSO supplies directly inertia into the grid. This ensures clear accountability, reduces uncertainty, and limits the need for coordination between multiple parties. It also allows TSOs to strategically place assets, guaranteeing sufficient inertia across all control areas and avoiding over-reliance on market mechanisms.
- **Slong-term costs:** by amortising inertia-providing over decades and often delivering multiple other system stability services, such as voltage control and fault current support. Centralised planning keeps costs predictable and enables faster deployment in critical areas where market participation may be limited, supporting reliable system operation.
- **Lower cost of capital and enhanced reliability:** by having a risk-averse approach, they prioritise system stability and reliability, having usually also access to a lower cost of capital than private investors.

Advantages of the Network-component approach in delivering inertia

The network-component model offers various advantages:

- **High certainty and system reliability**: Embedding inertia directly into the grid ensures critical thresholds (e.g., RoCoF ≤ 1 Hz/s) are respected even during extreme events, reducing operational risk and lowering the risk of load shedding, while mechanical inertia provides instantaneous support without control delays. It also minimises the need for extensive collaboration among multiple stakeholders.
- **Strategic, multi-service planning**: Investments can be aligned with network development plans, targeting weak system locations and stacking multiple services (inertia, fault current, reactive power) within a single asset, ensuring continuous availability where needed.
- **Simplified deployment in low-liquidity markets:** The approach provides clear governance, predictable allocation, and faster deployment in systems with limited market participation.
- **Reducing reliance on fossil plants and cost savings**: by installing synchronous condensers and repurposing decommissioned thermal infrastructure, the TSOs decrease the grid's dependence on fossil backups, avoiding costly redispatch, limiting new emissions, and reducing economic costs for consumers.

Limitations of the Network-component approach in delivering inertia

The network-component approach presents various limitations, such as:

- **Long-term, continuous inertia provision:** Synchronous assets provide inertia continuously, even when not immediately needed, typically for decades. As a result, inertia is delivered even in hours when inertia contributions from market dispatched assets in spot or balancing markets may already be sufficient, which can lead to inefficient over provision. This can slow the adoption of more flexible alternatives, such as inverter-based resources (IBRs) supported by BESS and other energy storage technologies.
- **Market and regulatory limitations:** Inertia as a service provided by non-traditional energy storage technologies is not yet fully recognised in current frameworks. Market development is still at the pilot stage, and lengthy approval processes delay validation and wider deployment. Costs of synchronous assets are bundled into regulated network charges, limiting transparency for consumers and reducing competitive pressure to find cost-efficient or innovative solutions over the long term.
- **High capital requirements with some exceptions:** Investment costs for greenfield synchronous assets can be significant, although brownfield projects (e.g., synchronous condensers or repurposed CCGTs supported by ESS thermal units) can reduce costs.

4.1.2 Case Study: the Italian TSO Sourcing Inertia while Securing System Stability

In the following case study, the TSO facility is supporting the system stability in the Codrongianos area in Sardinia (Italy). The purpose of the TSO-owned synchronous condensers is primarily to provide reactive power exchanged with the grid to be constantly and very accurately regulated, to improve voltage profiles while providing significant contributions to the grid's short-circuit power. Synchronous condensers also provide a significant inertia contribution to the electricity grid, making it more stable and avoiding sudden voltage or frequency changes.

Based on the listed delivery approaches mentioned in chapter 4.2, the Italian case study is depicted below as an example of the network-component approach.

Case study:

The Italian TSO supplying inertia while securing system stability (voltage control)

Actors involved	The Italian TSO Terna, and one technical delivery firm (Ansaldo Energia) of the synchronous condensers owned by Terna.
Technology focus	The technology focus is the Codrongianos synchronous condensers: two 2-pole units using round-rotor generators originally designed for thermal power plants. The project reuses decommissioned infrastructure from the Porto Torres area, making it a brownfield synchronous condensers solution for delivering inertia. The two machines allow to stabilise and safely manage the electricity grid, regulating the voltage and minimising the sudden changes due to the intermittence of the production of renewable sources. Specifically, the synchronous condenser represents a particular application of electric generators which, connected to the Terna transmission grid, exchange reactive energy with the grid and increase the short-circuit power. **They can also provide inertia to the electricity grid, making it more stable**. The synchronous condensers supplied to Terna are also equipped with the "flywheel system", an innovation designed and built by Ansaldo Energia, capable of increasing the overall inertia of the rotating system, minimising technical losses.
Delivery characteristics	Terna, the Italian TSO transmission system operator, considers inertia as a **structural requirement of grid planning.** According to Terna, grid-forming capabilities such as inertia can only be delivered through the TSO as the inertia provider. The technology selected was synchronous condensers (brownfields in this case).

	Since inertia is considered as a structural requirement of the Italian grid planning, the **2025 Terna Grid Development Plan** identifies regional inertia shortfalls and responds through targeted infrastructure. This reflects **the Italian network-based approach**, with the TSO (Terna), which is both the commissioner and the management entity of the technologies to provide reactive power and additionally inertia. While BESS and other ESS gain market access via MACSE (a capacity auction for storage to enhance supply security), inertia provision as a service *per se* is not explicitly supplied through this mechanism.
Outcomes	Between 2014 and 2016, Terna converted two 2-pole round-rotor thermal generators into 250 MVAr synchronous condensers in Codrongianos, Sardinia, reusing existing grid connections and high-voltage infrastructure to avoid incurring greenfield costs. Each provides ~1.7–1.8 s inertia constant, delivering fuel-free stabilizing inertia, dynamic reactive power, voltage control, and short-circuit strength. By 2016, Codrongianos became a core asset for Sardinia's renewables-heavy, HV-interconnected system. Following the above-mentioned network-based approach, Terna recently commissioned two synchronous condensers with flywheels in Brindisi (500 MVAr reactive power, 3,500 MWs inertia). It also awarded contracts for five more 250 MVAr condenser–flywheel systems by 2030 in Sicily, Sardinia, and southern Italy, adding >20 GWs total rotational inertia.

Table 4: Case study presenting how the Italian TSO secure inertia, based on the actors involved, the technologies, the specific delivery characteristics and the outcomes of the delivery procedure.

4.1.3 The Market-Based Approach: TSOs Remunerating Inertia

Based on the delivery approaches defined in chapter 4.1, the market-based approach is detailed below according to actors involved, technology focus, delivery characteristics, with its advantages and limitations.

Actors involved

The market-based approach defines inertia as a competitive service, procured through technology-neutral tenders in which different Energy Storage systems compete under the same performance requirements. In this model, the TSO does not build or prescribe infrastructure but instead specifies the need and selects the most efficient providers from third parties.

Technology focus

Eligible technologies are the most diverse among the existing procurement policy options, and they often include synchronous condensers, pumped hydro Energy Storage, LAES, CAES, COES, Thermal Energy Storage and BESS solutions, are also eligible options.

Delivery characteristics

Different from the network-component model, the market-based framework allows a broad set of providers to compete equally, with the aim of minimising costs and allocating the provision of inertia to the best provider on the market. More specifically, this model foresees:

- **Needs-based and efficient inertia procurement:** by setting inertia requirements according to system conditions, such as using inertia floors, minimum levels, or performance requirements, avoiding over-procurement and lowering costs while accelerating deployment of ESS technologies providing grid-forming services.

- **Integration of existing or repurposed assets:** by opening the procurement to existing, repurposed or newly-built assets, reducing overall investment needs
- **Flexible procurement mechanisms with limitations:** by procuring via auctions, long-term contracts, or near real-time markets.

Advantages of the market-based approach in delivering inertia

The market-based approach presents different advantages, such as:

- **Efficient and transparent service delivery:** by ensuring inertia is provided by the most cost-effective participants, with clear prices that reflect real-time system needs
- **Flexible, needs-driven procurement:** by selecting the best procurement option, other mechanisms are tailored to both short-term and long-term system requirements. Procurement volumes can be adjusted to avoid over-provision when the system already has sufficient inertia.
- **Multi-service and cross-border opportunities:** by securing multiple system stability services, such as inertia, voltage control, and congestion management. It also allows for participation from cross-border providers and supports the integration of existing or repurposed assets.
- **Promotes innovation and technology upgrades:** By encouraging competition between traditional and new entrants, the market framework fosters innovation.
- **Embedding inertia into new investments:** by including inertia obligations in new renewable and storage projects, lowering long-term costs.

Limitations of the market-based approach in delivering inertia

The market-based approach presents some limitations, such as:

- **Complexity in design and operation**: Locational requirements and integrating multiple services create significant administrative and technical challenges, leading to high transaction and administrative costs overall.
- **Dependence on market maturity and liquidity**: Efficiency relies on sufficient market liquidity (especially challenging in small or isolated systems), while short-term incentives may discourage long-term investment, risking under-provision of stable inertia assets.
- **Recommended risk mitigation:** European Commission’s Directorate-General for Energy suggests reserve price ceilings and benchmarking bids against TSO-owned asset costs; if offers exceed thresholds, TSOs can use their own infrastructure to ensure supply and control costs.

4.1.4 Case Study: The British TSO Procuring Inertia

Based on the procurement approach mentioned in chapter 4.1, the British case study is below depicted as an example of market-based approach.

Case study:

The British TSO procuring inertia

Actors involved	British TSO National Energy System Operator (NESO) and third-party providers, where the TSO redefines inertia as a market-based service by developing a dual procurement model to secure a basis level of supply with rolling year-ahead auctions to adjust volumes more flexibly. The counterpart actors are third-party providers of ESS/BESS solutions.

Technology focus	The technology focus is a fully technologically neutral approach for its Stability Pathfinder 2 contracts and Market auctions, which include greenfield and brownfield synchronous condensers, pumped hydro power plants, and BESS solutions.
Delivery characteristics	NESO ensured system security through a minimum inertia requirement, initially set at 140 GWs, this floor was reduced to 120 GWs in 2024 as confidence in delivery grew. While the revision of the British grid codes, with the inclusion of other ESS and BESS technologies, along with the launch of the Stability Pathfinder 2, opened the way for inverter-based solutions to operate on equal terms with traditional synchronous machines. The Pathfinder programme procured different amounts of inertia, voltage control and short-circuit level, between 2020 and 2023, in three phases: • **Phase 1** concluded in January 2020 with the award of contracts for the provision to the GB grid of a total of 12.5 GWs of inertia over six years, for £328 million. • **Phase 2** saw the awarding (in April 2022) of ten contracts (totalling £323 million) to four companies for the provision of 6.75 GWs of inertia in Scotland. • **Phase 3** tender process (in 2023) with the awarding to six companies of contracts worth a total of £1.3 billion for the supply of 17,084 MWs of inertia across England and Wales. While the first Stability Market auction for 2025/26 secured 5 GWs at £25.3 million, an outcome estimated to save consumers £47 million compared with the counterfactual model, a second auction in 2026/27 is targeting 15 GWs. To guarantee system adequacy, NESO enforces strict eligibility rules, including fixed inertia constants, high-voltage connections, independence from energy dispatch, and around 90% annual availability.
Outcomes	A very well-known outcome of this model is the commissioning of the 2-phases Blackhillock project, a grid-forming battery Energy Storage system in Scotland (UK) aiming to deliver, once it is fully online, 300 MW/600 MWh of energy. The first phase went online in March 2025, delivering the first 200MW as Europe's first transmission-connected battery certified to deliver inertia. The Blackhillock project provides synthetic inertia, voltage control, fault ride-through, and short-circuit strength. Operating under performance-based contracts that combine availability payments with penalties for non-delivery, the project ensures consumers pay only for verified contributions while investors gain long-term certainty. It is expected to deliver £170 million in consumer benefits over 15 years, while preventing 2.6 million tonnes of CO_2 emissions.

Table 5: Case study presenting how the British TSO procures inertia, based on the actors involved, the technologies, the specific delivery characteristics and the outcomes of the delivery procedure.

4.2 Inertia Indirect Procurement in Europe: The Capacity Mechanism and the Balancing Service Markets

Some European countries can also source inertia indirectly through other market options, such as:

a) Capacity procurement mechanism;

b) Frequency response service from balancing markets.

In both markets, the supply of inertia is based on a "temporary assessment" accordingly to geographical or seasonal inertia needs, aiming to supply inertia in case of shortfalls.

More specifically:

a) The capacity procurement mechanism (e.g., the Italian "Mechanism for the Acquisition of Storage Capacity" - MACSE) aims to secure energy storage capacity, through long-term contracts awarded via competitive auctions.

   This type of mechanism is designed to integrate large amounts of renewable energy, including solar and wind IBRs supported by an ESS-based solution, into the grid by providing a system to store excess electricity produced during times of overgeneration and release it when needed. Winners of the contracts provide their capacity to the national TSO, in exchange for stable, predictable payments. The capacity offered can also be used by the TSO for balancing the frequency and limiting RoCoF, indirectly sourcing inertia in the grid.

   The capacity procurement mechanism cannot be considered as a direct procurement of inertia, since its procurement objective is to ensure resource adequacy and not system stability. As a result, there are no pre-established contractual obligations for the specific provision of inertia, which fails to incentivise the deployment of energy storage systems designed to explicitly provide inertia.

b) Balancing services, and more specifically frequency response services (e.g.: as a joint market product in the Nordic power system, such as the Finnish FFR market) are market products that play a key role in stabilising frequency by counteracting power imbalances and restoring frequency deviations from 50 Hz. Indeed, both synchronous machines and IBRs supported by a grid-following (GFL) and grid-forming (GFM) inverters with ESS-based units can deliver these services, even if GFL units present some time-reaction limitations.

Frequency response services are divided into:

- **Frequency Containment Reserve (FCR)** provides, according to the different EU Member States' definitions, the fastest automatic response within seconds.
- **Fast Frequency Reserve (FFR)** provides a very rapid, pre-contracted response designed to arrest fast frequency drops in low-inertia conditions, bridging the gap before traditional automatic reserves activate. The needed FFR volume depends on the prevailing inertia in the power system and the size of the reference incident.
- **Frequency Restoration Reserve (FRR)** delivers a slower, sustained correction once the system is stabilised.

TSOs provide and evaluate these services through continuous testing and monitoring to ensure timely, proportional activation according to system needs, including sourcing inertia in case of local or seasonal shortfalls.

Nevertheless, every frequency response service requires a minimum amount of time to initiate a response, relying entirely on inertia to limit the Rate of Change of Frequency (RoCoF) during this critical interval. Therefore, frequency response services cannot be considered as a direct procurement of inertia; while they depend on the time buffer inertia provides to function effectively, their primary aim is frequency restoration through active power provision, rather than instantaneous containment. Consequently, because these services value the restoration phase rather than the initial stability, they do not incentivise the roll-out of Energy Storage systems aiming to explicitly procure inertia.

Neither the capacity mechanism nor the balancing markets procure inertia as a system stability service; therefore, it is not possible to consider them as direct procurement options for supplying inertia.

5. Recommendations

1. How to Assess and Address Inertia Needs?

Currently, as defined in Chapter 3, inertia needs are not assessed with a harmonised methodology across the European Union, leaving it to individual Member States' methodologies. This leads to regulatory inconsistencies, making it challenging for countries within the same synchronous area to evaluate system stability needs in a coordinated and consistent manner. To limit regulatory gaps at the European level in relation to the assessment of inertia, a common European methodology is needed. Therefore, Energy Storage Europe recommends implementing the following measures:

- **Develop a European common system indicators methodology for the assessment of inertia needs.** This European common system indicators methodology for the assessment of inertia needs, as recommended by ENTSO-E report "Project inertia II", should monitor operational inertia and define a minimum inertia criterion per Member State (H > 2 MWs/MVA for more than 50% of the year by 2035).
- **ACER should review the results** of the European common system indicators methodology for assessing inertia needs every two years and publish its findings in a recommendation study.

To identify and share information about Member States' inertia needs, Energy Storage Europe recommends implementing the following measures:

- **Identify the relevant inertia needs**, by the TSOs and NRAs of EU Member States of the same synchronous area, based on the ENTSO-E recommendation for a European common system indicators' methodology for the assessment of inertia needs and on the minimum inertia criterion.
- **Integrate the Transparency Platform** with a section dedicated to inertia needs across Europe. This platform should be publicly accessible to both TSOs and third parties. It should include: the total inertia needs of EU member states, RoCoF limitation, inertia floor, and the expected system inertia decrease of the European Synchronous areas.

2. How to Recognise the Role of All ESS Technologies Providing Inertia?

Currently, as defined in Chapter 3, not all ESS technologies are equally recognised at the EU level as inertia providers. The lack of a harmonised acknowledgment hinders the deployment of all Energy Storage Solutions on a fair level-playing field.

Moreover, as defined in Chapter 3 the technical rules that apply to new generators and storage systems for providing inertia are expected to be implemented by each Member State's relevant system operator. This defines which assets can be used, and under what conditions, so that one or more generators can be recognised at the national level as providers of different system stability services.

To ensure all existing assets, including Energy Storage technologies, are equally recognised for the provision of inertia, Energy Storage Europe recommends implementing the following measures:

- **Recognise the role of all existing assets, including Energy Storage technologies,** in long-term energy and decarbonisation planning.

- **Acknowledge the societal and policy advantages of Energy Storage systems,** aiming to ensure inertia provisions from multiple assets and in a technologically-neutral way.
- **Accelerate the adoption and publication of the amended Regulation on the Network Code on Requirements for Generators (NC RfG 2.0).** This should consider ACER's recommendation (ACER recommendation 03/2023), built on NC RfG 2.0 draft version targeting requirements for grid connection of generators, as well as ENTSO-E's first interim report on exhaustive GFM requirements (May 2025) and ENTSO-E's Phase II Technical Report on Grid Forming Requirements (November 2025, following ACER's recommendation.
- **Publish non-binding Implementation Guidance Documents (IGDs)** within six months after the NC RfG 2.0 entry into force by ENTSO-E, aiming to support Member States' implementation of the NC RfG 2.0 minimum requirements.
    - **ENTSO-E should include technical requirements related to the different Energy Storage systems** in their Implementation Guidance Documents (IGDs), aiming to ensure that all Energy Storage systems can contribute to the European energy security.
- **Member States should implement the amended NC RfG 2.0 within 3 years** from the entry into force, and subject it to a feasibility study.

3. How to Procure Inertia Across EU Member States?

Currently, as defined in Chapter 4, there is no common European framework for the procurement of inertia and its implementation.

Even though inertia could in principle be procured through revisions of connection requirements included in EU Member States' grid codes, DG ENER's in its report on the "Assessment of policy options for securing inertia" highlights several limitations to this approach.

As the deployment of inverter-based resources (IBRs) grows, ACER suggests introducing technical requirements for inertia capability to help maintain system stability. However, these inertia services could also be provided through market-based mechanisms rather than imposed as mandatory grid-code obligations[18]. Mandatory provision without compensation can discourage investment and tends to benefit only a narrow set of technologies.

As highlighted by DG ENER report, NRAs (and TSOs) should strictly oversee any new obligations, ensuring they are technically justified, proportionate, aligned with system needs, and developed transparently.

Based on DG ENER's analysis, Energy Storage Europe considers that the inertia procurement through the revision of national network codes prevents the most cost-efficient assets and storage solutions from competing on a level playing field.

For these reasons, Energy Storage Europe considers a market-based model as the best policy option for procuring inertia as a service, in a cost-efficient and technologically neutral way. Nonetheless, this should not preclude any national or regional TSOs from planning and investing in fully integrated component assets,[19]aiming to provide system strength solutions like reactive power, which could additionally deliver inertia provision, following the network-component model defined in Chapter 4.

To incentivise the procurement of inertia in a market-based approach, Energy Storage Europe recommends implementing the following measures:

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[18] With the exclusion of traditional synchronous machines, which inherently already provide mechanical inertia.

[19] To be compliant with the existing EU legislation: EU Directive 2019/944 and EU Regulation 2019/943.

- **Define EU common procurement guidelines to support national TSOs and NRAs to encourage dynamic procurement frameworks** that would allow national TSOs and NRAs to procure inertia, in the future, as a market-based product via cost-efficient technology-neutral auctions and based on non-discriminatory market-based mechanisms.
- **Ensure EU common minimum requirements for a fair tendering procedure for the future procurement of inertia.** This would increase transparency among EU Member States. These guidelines should include measures:
    - to guarantee reliability of the inertia procurement through the definition of minimum pre-fixed prices, pre-fixed delivery capacity requirements, and contractual obligations as well as penalties for non-compliance;
    - to ensure the adjustment of volumes locally and temporally, improving efficiency and reducing congestion risks by 2030;
    - to support multi-value asset participation, maximising investment returns and reducing investment costs, by enabling all existing assets and ESS technologies to deliver inertia alongside other grid support services, such as balancing services.
- **National TSOs and NRAs should not prevent the opening of future procurement of inertia** to existing assets or energy storage technologies, once this asset or the ESS-based technology has been considered as a cost-efficient option for providing a minimum required inertia capacity.

4. How to Support the Long-Term Deployment of Energy Storage Technologies Providing Inertia?

To incentivise investment grants and accelerate the deployment of energy storage technologies where market revenues alone are not sufficient, while ensuring technological neutrality and fair competition among ESS technologies, Energy Storage Europe recommends implementing the following measures:

- **To include all newly commissioned Energy Storage projects delivering inertia in the 10-year network development plan report (TYNDP).** The report should also consider overall system stability issues, provide a forecast of the expected system inertia decrease by 2030, 2040 and 2050, among different synchronous areas and EU Member States. This would provide a clear and comprehensive approach to better inform on long-term system challenges and inertia needs.
- **To include dedicated ESS capacity for the supply of inertia** in new projects to ensure fair competition and foster innovation under:
    - **The Innovation Fund**, through the support of cost-efficient technology-neutral auctions, with references to the deployment of ESS that provide inertia.
    - **The Connecting Europe Facility (CEF) Fund** to promote competitiveness, ensuring both reliability and cost efficiency.
    - **Other financial incentives**, such as multi-year contracts and tailored PPAs to ESS projects aiming to provide long-term investment security through also multi-year contracts.
- **To guarantee** that the allocation of State Aid for inertia provision supports fair and technology-neutral competition among eligible technologies.

6. Conclusion

Having identified the system services that provide inertia, the technologies capable of delivering them, and the overall inertia requirements, and having examined the existing procurement options, this Energy Storage Europe position paper focuses on how the EU can implement a cost-effective and technologically neutral approach to procuring inertia. It also outlines how such an approach can be firmly embedded within a harmonised European methodology for assessing and monitoring inertia needs across synchronous areas. More specifically, **the paper calls for EU-wide non-binding procurement guidelines that would support NRAs and TSOs in delivering inertia as a market-based service, procured via technology-neutral tenders with pre-defined product characteristics, delivery obligations and penalties for non-compliance.**

Moreover, national derogations that prevent the opening of inertia procurement to cost-efficient existing assets and all ESS solutions should be limited to ensure EU harmonisation. Nevertheless, TSOs would not be forbidden from sourcing inertia in a network-based approach to ensure system stability.

Finally, Energy Storage Europe calls the European Commission to accelerate the adoption of the amended NC RfG 2.0, so that all relevant synchronous and inverter-based assets can contribute to system stability on a level playing field.

7. Annex A – Additional Case Studies of Inertia Procurement

This annex will provide an overview of direct and indirect procurement options, one of them, the German case study has been officially opened to procurement on 22 January 2026.

Case study: **The German TSOs directly procuring inertia in 2026**	
Actors involved	Actors involved are the four regional TSOs (TenneT, TransnetBW, Amprion, 50Hertz), and third-party providers, with inertia procurement options opened to third parties on 22 January 2026.
Technology focus	From January 2026, the four German TSOs opened the procurement of inertia through technology-neutral tenders, open to: • Synchronous machines (including Thermal Energy Storage technologies) • IBRs (PV or wind) paired with BESS solutions • BESS solutions All technologies must be able to comply with and compete with synchronous machines' requirements in their provision of system stability services, including inertia. This follows the July 2025 agreement by German TSOs under EnWG §12(h) to remunerate such technology-neutral assets explicitly within the PRMC/Momentanreserve framework.
Delivery characteristics	In Germany, national studies project a sharp decline in inertia toward 2030, with frequent periods below the secure RoCoF limit of 1 Hz/s. Inertia’s procurement is opening toward a market-based model where technology-neutral assets can be technically recognised as inertia provided. More specifically, inertia procurement (managed by each of the 4 German TSOs for their respective zones) is envisaged by a TSO-predefined inertia price, even if regulators have not set an inertia floor either at regional or national level. Because of this, the price has not been defined by dynamic market flows, due to possible TSOs' re-adjustments of inertia prices, potentially concerning market demand and offer dynamics. Currently, the first set of prices predefined by the tender has been published on 22 January 2026, covering four product categories and according to their availability, to dispatch system stability services, including inertia. These categories vary from a basic product requiring 30% availability to a premium option with 90% availability, which is anticipated to command higher payments. For the premium product, the contract durations may last up to 10 years. Once an offer has been accepted, delivery must commence within three years. Because of this, it is expected that a complete market-based inertia procurement will not be achieved before 2028 at the earliest.

	Providers must commit to availability obligations and will be remunerated through standardised contracts and price sheets, creating a predictable revenue stream for grid-forming providers. These obligations and requirements are as follows: • **Continuous availability**: units must remain ready to deliver inertia at all times within the contracted period. • **Response criteria**: assets should provide an inertial response within the first 500 milliseconds after a contingency event. • **Contractual obligations**: participants commit to standardised contracts with availability-based remuneration, non-availability or underperformance would lead to penalties.
Outcomes	Some pilot projects on BESS solutions have already been tested in compliance with these requirements for the above-mentioned framework. Currently, the most successful example is the Altentreptow BESS solution, in Mecklenburg-Vorpommern area. This is a 10 MW / 20 MWh battery connected to the 110 kV distribution grid, under trial for participation in PRMC tenders. The system delivered synthetic inertia of approximately 2,400 MWs, with response times under 250 milliseconds. Testing confirmed that distribution-connected batteries could provide measurable system inertia, as well as contributing to peak frequency support during 15 high-variability events. PRMC trials showed that smaller batteries could bid successfully alongside TSO assets, highlighting their integration and flexibility.

Table 6: Case study presenting how the German TSOs procure inertia based on the actors involved, the technologies, the specific delivery characteristics and the outcomes of the delivery procedure.

Case study: **The Irish TSOs pricing inertia**	
Actors involved	Irish TSOs (EirGrid, SONI) and third-party providers, where TSOs decide the allowable inertia amount under specific requirements and tenders
Technology focus	The technology focus is subject to the tender procedure, awarding synchronous condensers in the first tender, but with the second one, which might be open to ESS/BESS if they meet inertia requirements.
Delivery characteristics	Ireland's model shift began with DS3 Programme (2011–2015) and System Services Review, identifying services for high-RES integration (e.g., reactive power to manage system voltages). In December 2014, the Irish approved the DS3's framework, including an increase in the annual system services budget from €60 million to €235 million, a doubling of System Service products from 7 to 14, and the adoption of a hybrid regulated tariff/auction procurement mechanism to be further explored to support EirGrid and SONI to supply the Irish system inertia needs. In 2021, the Irish inertia floor was set at 23,000 MWs, expecting to decrease to 17,500 MWs, matching 2030 targets, and limiting RoCoF to ±1 Hz/s. This allowed Irish TSOs to set minimum standards for inertia procurement:

	• **Low Carbon Inertia Services (**LCIS) Phase 1 (Dec 2023) competitively procured 10,000 MWs of inertia via 6-year contracts (max 2,000 MWs/project, €2.02/MWs/h cap), targeting synchronous condensers to boost efficiency by reducing fossil generator reliance. Only synchronous condensers were awarded, limiting ESS/BESS competition despite future needs: research estimates 37–40% grid-forming capacity required in a 100% converter-based system. This would also support the overall system inertia needs and limiting excessive RoCoF (up to 4Hz/s when there is a low synchronous penetration). • **LCIS Phase 2 (2026)** will target synchronous condensers with flywheels (900–4,000 MWs/unit), open to other ESS with Market Readiness Certificate (including reactive power, verified performance).
Outcomes	LCIS Phase 1 awarded four winners to deploy synchronous condensers expected to become online in 2027-2028: Quarry Lane Stability (Sligo, Statkraft Ireland subsidiary), Glencloosagh Energy (Kerry, Statkraft Ireland subsidiary), Buffy Letter (Galway), Green Frog Power (Wexford). They provide inertia, fault current, and reactive power support.

Table 7: Case study presenting how the Irish TSOs procure inertia, based on the actors involved, the technologies, the specific delivery characteristics and the outcomes of the delivery procedure.

Case study:

The Finnish TSOs indirectly procuring inertia through balancing markets

Actors involved	Finland, as part of the Nordic synchronous area, is facing growing challenges in securing system inertia, as western Finland is forecast to experience inertia shortfalls for more than six months of the year by 2027. Fingrid is indirectly procuring inertia via the procurement of balancing services (FFR) to third parties. Inertia, not being directly procured as a service *per se*, is supplied by third parties in the FFR day-ahead market, aiming to cover seasonal or locational shortfalls of inertia.
Technology focus	Until recently, Finland was delivering inertia through TSO-owners' structural investments in synchronous condensers, in some cases supported by flywheels. Finland is complementing these investments by opening the procurement of FFR also to other ESS and BESS technologies, such as Thermal Energy Storage solutions, hydro power plants with the support of a supercapacitor, and Battery Energy Storage systems supporting IBRs.
Delivery characteristics	To protect against excessive Rates of Change of Frequency (RoCoF), the Nordic TSOs introduced a minimum inertia requirement as kinetic energy of 145 GWs in summer and 170 GWs in winter in 2021. Yet studies show that available inertia may fall below these thresholds in several regions, requiring corrective investments. Due to these reasons, FinGrid, along with other Nordic countries, indirectly supplies inertia through balancing services (specifically FFR), to address inertia shortfall; besides this is not a direct procurement for the provision of inertia. More specifically, a Balancing Service Provider must prequalify their Reserve Units and sign the FFR market agreement to participate into the national market. FFR procurement depends on system inertia, occurring only during selected hours, typically ranging from 0–60 MW. Fingrid acquires FFR through a national hourly market, with bids submitted the evening before. Hourly reserve prices are set by the highest accepted bid. Once a third-party provider has won the bid, it can also source inertia, but only through the FFR market, therefore, not as a service *per se*.

	This results in having inertia shortfalls addressed by a balancing service whose primary goal is to provide Fast Frequency Response, and whose activation time is usually slower than the inertia reaction and response time.
Outcomes	About 250 MW of battery systems projects are currently commissioned across Finland as of mid-2025 by Fingrid, aiming to deliver FFR services. Of these projects, the Nivala project is a 70 MW/140 MWh BESS solution (developed by Ingrid Capacity together with Locus Energy) aims to provide fast frequency services, including 16,800 MWs of synthetic inertia, with response times of around 220 milliseconds, enabling mitigation of frequency Nadir by up to 0.06 Hz under high-variability grid conditions. Under commissioning in 2026 and with a 2-hour storage duration, the Nivala BESS solution can sustain energy support during peak demand or periods of intermittent RES-generation.

Table 8: Case study presenting how the Finnish TSO deliver inertia through balancing markets based on the actors involved, the technologies, the specific delivery characteristics and the outcomes of the delivery procedure.

8. Annex B – EU Legislation Acts Addressing Inertia

As defined in chapter 5, the European Commission, ENTSO-E, ACER and national TSOs and NRAs should update current legislative provisions to ensure the assessment and procurement of inertia by all Energy Storage Solutions. The table below presents the EU legislative basis that should be amended to realise these provisions, with special regard to the Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation (SOGL).

Content	EU legal basis
Establish a **common EU methodology** to assess inertia needs and ensure periodic review	SOGL (EU) 2017/1485 – **Art. 39(3)(a), 39(3)(b),** on updating ENTSO-E methodology.
Define and harmonise **minimum inertia requirements** for new generators and storage (update of connection requirements of grid codes)	Network Code on Requirements for Generators (NC RfG 2.0) – **Art. 21(5)(b), on removing any mandatory obligation for type C and type D generators to provide inertia when done by a third-party owner, if not remunerated.**

Table 9: EU legislative acts presenting articles of interest for opening the procurement of inertia on a market basis.

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About the Energy Storage Europe Association:

The Energy Storage Europe Association is the leading member-supported association representing organisations active across the entire energy storage value chain. The Association supports the deployment of energy storage to further the cost-effective transition to a resilient, carbon-neutral, and secure energy system. Together, Energy Storage Europe Association members have significant expertise across all major storage technologies and applications. This allows us to generate new ideas and policy recommendations that are essential to build a regulatory framework that is supportive of storage.

For more information, please visit www.energystorageeurope.eu

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