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SUPPLY CHAIN RESILIENCE IN THE ELECTRICITY SECTOR

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Executive Summary

The dual need to reduce greenhouse gas emissions and to limit dependence on fossil fuels imported from third countries has sharply increased the demand for 'green' electricity. The rapid expansion of clean generation capacity, together with the modernisation and reinforcement of transmission and distribution grids, has exposed the European Union (EU) to new vulnerabilities. In particular, the EU remains highly dependent on imports for many clean technologies such as solar panels, batteries, and heat pumps. At the same time, increasing domestic capacity faces challenges such as a high import dependency rate for raw materials, skills shortages, long permitting procedures, and high electricity costs.

This paper examines whether the current regulatory framework is sufficient to address the key vulnerabilities of the electricity supply chain. Specifically, it analyses how public procurement rules and public demand can be more effectively leveraged to enhance supply chain resilience, and how procurement mechanisms can be designed to reward safety investments and resilience.

The main points of the paper are the following:

- Despite recent regulatory developments such as the Critical Raw Materials Act and the Net-Zero Industry Act, which represent a step in the right direction towards strengthening supply chain resilience, the current EU regulatory framework remains insufficient to address all main vulnerabilities. The main obstacles appear to be limited coordination and harmonisation among Member States and a relatively restricted role of the European Commission.
- Public Procurement represents a key strategic instrument for enhancing resilience. The forthcoming revision of the Public Procurement Directives offers an opportunity to increase harmonisation among Member States and provide clear guidance on how resilience can be promoted in practice, with particular attention to diversification, 'Buy European' requirements, collaborative procurement mechanisms, Public Procurement of Innovation, and the use of national security exclusion grounds.
- Resilience indicators reflecting key factors such as the degree of supplier diversification, geopolitical exposure, and the level of stockpiles could be incorporated in procurement procedures as selection or award criteria to incentivise firms' investments in security and risk-mitigation measures across the entire contractual supply chain. Emphasis is placed on the use of stress tests. To avoid imposing excessive burden on contracting authorities, the paper explores the establishment of specialised bodies responsible for measuring, monitoring and certifying the levels of resilience of contractors.

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1. Introduction

Climate objectives and recent geopolitical crises, such as the war in Ukraine, have highlighted the urgency of reshaping Europe's energy mix. The dual need to reduce greenhouse gas emissions and to limit dependence on fossil fuels imported from third countries has sharply increased the demand for 'green' electricity.

A true decarbonisation and energy independence requires a profound expansion of decarbonised electricity generation, combining both renewable energy sources (including wind, hydropower, solar energy, and solid biofuels) and nuclear power. According to the International Energy Agency (IEA, 2025), renewable electricity generation increased by 8.4% in 2024 and is expected to continue growing at an average annual rate of 7.2% between 2025 and 2027. Over the same period, nuclear power increased by 5% in 2024, and it is projected to remain relatively stable.

It is important to underline that, while electrification represents a central pillar of the energy transition, it is not the only area that needs appropriate policies. Other energy vectors, such as low-carbon molecules and heat, will continue to be necessary for sectors that are difficult to electrify. This paper focuses on electricity, given its central importance in decarbonisation and energy security.

1.1 Resilience in the Electricity Supply Chain

The ongoing transition towards an electrified and decarbonised energy system exposes Europe to new supply chain vulnerabilities. In particular, expanding renewable and decarbonised generation capacity and modernising and reinforcing transmission and distribution grids have exposed the EU to novel dependencies on foreign technological components and critical raw materials (CRMs). At the same time, structural bottlenecks persist, such as a lack of specialised manufacturing capacity, long and fragmented permitting procedures, and insufficiently coordinated investments in generation and grid infrastructure.

Before digging into the analysis, it is worth mentioning that the electricity sector has specific characteristics that make the issue of resilience different from other sectors.

For instance, resilience in the electricity sector is peculiar due to temporal constraints, as disruptions have immediate system-wide effects, making it difficult to allow shocks to be absorbed over time. Another specific characteristic is related to the networked nature of electricity systems: due to this interconnectivity, disruptive events can trigger cascading failures that propagate across borders much faster than in other energy systems (Baldursson & von der Fehr, 2025). Additionally, resilience in the electricity sector is shaped by infrastructure-heavy systems that require very high upfront capital investments and long-term planning (*ibidem*).

In this context, strengthening supply chains' resilience, defined as the ability of the supply chains to anticipate, absorb, recover from, and adapt to disruptive events[1], is essential to ensure a reliable and

[1] In this paper, resilience is defined in line with the definition adopted in the CERRE Issue Paper Series, in particular that proposed by Baldursson & von der Fehr (2025).

affordable decarbonisation pathway. For analytical purposes, this Issue Paper distinguishes three key phases of the electricity supply chain:

1. Procurement and manufacturing of technological components and CRMs;
2. Construction and installation of infrastructures;
3. Operational phase.

These three phases involve different actors and entail specific risks. Although they are all relevant and interconnected, they offer different levers for policy intervention. For the purpose of this Issue Paper, the scope is limited to the procurement and manufacturing phases.

1.2 Key dependencies and bottlenecks

The procurement phase covers the acquisition of renewable and decarbonised technologies and of all their components necessary to build power plants and grid infrastructures. Today, the EU is dependent on third countries for the supply of essential components such as batteries, heat pumps, and solar panels (Bruegel, 2025). Table 1 shows EU net exports (or net imports) with the rest of the world and with China.

Table 1: EU Net Export of Clean Technologies (in million euros).

Clean Technology	EU Net Export	EU Net Export with China
Batteries	-17.000	-21.100
Heat Pumps	-470	-691
Hydro	266	-2
Solar	-9.400	-10.500
Wind	2.300	-229
Nuclear	913	101

Source: Bruegel, European clean tech tracker dataset, September 2025.

Expanding domestic capacity of these technologies requires access to raw materials such as lithium, cobalt, copper, and rare earth elements, whose global supply chains are also dominated by a few foreign suppliers. According to the European Commission data (2023), China is the leading global supplier for twenty-five CRMs (six of which are at the extraction stage). Other major global suppliers include South Africa, Australia, the United States, Brazil, the Democratic Republic of Congo, Türkiye, Iran, and Russia.

These high dependency levels, both for technology components and CRMs, expose the EU to security risks. Indeed, external actors can leverage them to exert economic pressure through tariffs or export controls. In April and October 2025, China introduced two waves of export control on rare-earth elements, which have negatively affected the EU. Moreover, complex global supply chains increase exposure to systemic shocks, such as wars, pandemics or other geopolitical conflicts, that affect trade.

Even though increasing domestic extraction and processing of CRMs is essential, the EU faces significant structural constraints. Geological availability limits where extraction can occur, and

stringent EU environmental and permitting regulations further constrain mining activities. For instance, obtaining a mining permit in the EU typically requires 10-15 years (OECD, 2025).

Beyond the scarcity of CRMs, scaling up domestic manufacturing capacity for key technological components entails further challenges. These include high investment costs and long lead times, elevated energy and labour costs, limited vertical integration across the value chain, shortages of specialised skills and equipment manufacturers, and market immaturity in certain sectors where future demand remains uncertain. (IEA, 2023a; Enel, 2023).

Table 2: List of Strategic Raw Materials and Critical Materials.

Strategic Raw Materials	Additional Critical Raw Materials
Bauxite/alumina/aluminium	Antimony
Bismuth	Arsenic
Cobalt	Baryte
Copper	Beryllium
Gallium	Coking coal
Germanium	Feldspar
Lithium (battery grade)	Fluorspar
Magnesium metal	Hafnium
Manganese (battery grade)	Helium
Graphite (battery grade)	Niobium
Nickel (battery grade)	Phosphate rock
Platinum group metals	Phosphorous
Rare earth elements for permanent magnets	Scandium
Silicon metal	Strontium
Titanium metal	Tantalum
Tungsten	Vanadium

Source: Annex I and Annex II of the CRMA.

Note: Under the Critical Raw Materials Act (CRMA), Strategic Raw Materials are a subset of Critical Raw Materials.

The construction phase involves the installation of new generation facilities, transmission and distribution lines, storage systems, and related infrastructure. Today, one of the main bottlenecks in this phase is related to shortages of specialised workforce (IEA, 2023a).

Another key bottleneck concerns the long and complex permitting procedures that postpone the start of renewable and grid projects by several years. In this context, a recent CERRE paper, '*Speeding up Renewable Energy Permitting: Overcoming Implementation Challenges*' (Banet et & Donati, 2024) specifically examines the implementation barriers associated with permitting procedures.

Finally, the operational phase covers all activities carried out once power plants and grid infrastructures are functioning, from electricity generation and storage to its transmission and

distribution. In this phase, several resilience challenges might arise. Physical threats such as terrorism, sabotage, or climate-related events could damage infrastructure. Meanwhile, cyberattacks on energy utilities have increased in recent years, especially because of the wider use of smart grids by Transmission System Operators (TSOs) and Distribution System Operators (DSOs) (IEA, 2023b).

With regard to renewable sources, most are intrinsically intermittent, as wind and solar cannot be controlled and are increasingly affected by extreme and unpredictable climate events. Differently, hydropower remains the only dispatchable renewable resource (together with nuclear) when associated with large reservoirs. However, its expansion is strictly limited by the scarcity of suitable new sites, as most potential locations are already equipped. This intermittency poses significant obstacles in ensuring a stable and continuous electricity supply, making storage systems and constant grid management essential.

As a result, Europe's energy network is undergoing a complex transformation, as it must accommodate variable generation while ensuring security of supply and coping with climate-related risks. These issues are addressed in two recent CERRE contributions (Banet & Le Coq, 2025; Baldursson & von Der Fehr, 2025).

1.2.1 Key Research Questions

This Paper addresses the following questions:

1. Does the EU have the relevant toolbox of regulatory measures across the public and private spheres to address concerns about supply chain resilience in the EU?
2. How can EU public procurement rules and demand be leveraged to incentivise the relevant actors?
3. To what extent is the contractual chain stress-tested against supply chain risks, and how can procurement mechanisms be designed to reward safety investments and resilience while addressing issues concerning the so-called energy safety verification paradox[2]?

[2] This paradox highlights the difficulty of distinguishing between genuinely robust systems and those that have simply not yet been exposed to severe stress conditions. The absence of safety incidents or supply disruptions may indicate either robust safety systems and resilient supply chains or simply that the system has not been tested under extreme conditions.

2. Regulatory Toolbox

The following sections examine the main tools, their potential contribution to supply chain resilience, and their principal limitations. Overall, the current regulatory toolbox remains fragmented and insufficient to address the key vulnerabilities and bottlenecks that characterise the decarbonised sector supply chains. Over the past years, multiple instruments have been adopted, largely reactive to external shocks, and insufficiently supported by coordinated actions by Member States (MS). As a result, their combined potential to reinforce supply chain resilience is significantly constrained.

2.1 EU Tools for Supply Chain Resilience

Moving away from fossil fuels and increasing the share of green electricity, without exposing MS to new supply chain risks, requires a coordinated effort. The Union's strategy of "open strategic autonomy" (European Commission, 2021) pursues two complementary objectives. On one hand, it aims at safeguarding the resilience of global supply chains by maintaining commitment to openness and developing new, diversified trade partnerships. On the other hand, it aims at reducing excessive reliance on third countries in strategic sectors (including energy) by increasing capacity for EU alternatives.

In light of this dual strategy, existing EU tools can be grouped into three categories:

1. instruments to strengthen the resilience of global supply chains;
2. instruments to expand the EU domestic capacity of clean technologies and CRMs;
3. instruments that *indirectly* support supply chain resilience and domestic capacity.

2.1.1 Instruments to strengthen the resilience of global supply chains

Strengthening the resilience of global supply chains is essential to ensure that the EU can continue to benefit from the advantages of global trade, such as specialisation and lower production costs, while safeguarding its strategic interests. However, these benefits must be balanced against the risks of excessive dependency and the emergence of quasi-monopolies in global markets. Preexisting tools, as well as more recent EU initiatives, aim to address these challenges and accomplish these objectives.

The **EU Public Procurement Directives**[3], including Directive 2014/25/EU (Utility Directive), also covering the energy sector, contain some provisions that could, in theory, support supply chain resilience. These provisions incentivise, without posing obligations, contracting authorities to use non-price criteria, such as environmental and social ones. Despite not being expressly included in the Directive, the European Commission has clarified that supply chain resilience and security may be used as award criteria. In other words, measures of resilience can be taken into consideration when public procurement bids are evaluated.

[3] Directive 2014/24/EU, Directive 2014/25/EU, and Directive 2014/23/EU

Additionally, to avoid excessively high levels of dependencies in strategic sectors, the Utility Directive in Article 85 allows contracting authorities to reject bids if more than 50% of the value of the products originates from third countries that are neither parties to the World Trade Organisation (WTO) Government Procurement Agreement (GPA) nor covered by other procurement agreements. If they choose not to reject such bids, authorities must give preference to equivalent tenders with less than 50% third-country content, unless this would force them to accept technically incompatible or disproportionately costly equipment.

Despite their theoretical importance, these provisions are underused in practice (European Court of Auditors, 2023). Contracting authorities tend to focus on price to reduce public budgets, while non-price criteria often imply higher costs. As foreign technologies and inputs are usually cheaper, this dynamic encourages firms to outsource production, causing a vicious circle of dependency.

The Public Procurement Directives also provide for additional instruments. First, centralised and joint-procurement initiatives (including cross-border schemes) allow public buyers to pool demand, exploit economies of scale and monopsony power, and reduce prices. In times of crisis, they also help reduce the negative effects of buyers' competition, such as the exclusion of smaller buyers. Second, pre-commercial procurement and innovation partnerships can be used to accelerate the development and deployment of new alternative technologies that rely on fewer critical inputs. Despite their potential to strengthen supply chain resilience, especially when used in a complementary way, these instruments remain significantly underused. Their relevance and the obstacles that currently limit their uptake will be discussed in greater detail later in the Paper.

Other than general provisions for public procurement, the EU has recently undertaken more specific actions for CRMs and clean technologies supplies. Since 2020, fifteen new partnerships on raw materials have been signed between the EU and third countries[4]. Additionally, the **Critical Raw Materials Act (CRMA)**[5] entered into force in May 2024[6].

Among the measures intended to strengthen supply chain resilience, the CRMA requires the European Commission to monitor and carry out stress tests (at least every three years) for each strategic raw material supply chain, based on impact assessment scenarios. To support the European Commission, MS should report information on CRMs projects and monitor key market operators. Triennial risk assessments of their supply chains must also be conducted by large companies, as identified by competent national authorities, using strategic raw materials. However, many provisions still require implementation.

While monitoring and stress tests are necessary, these tools may be insufficient. First, the triennial frequency may not be enough, given the sudden geopolitical shocks. Second, EU-level stress tests may neglect vulnerabilities that affect only a few MS. Moreover, the quality of the assessment relies heavily

[4] As of December 2025, the EU has partnerships with Argentina, Australia, Canada, Chile, Democratic Republic of the Congo, Greenland, Kazakhstan, Namibia, Norway, Rwanda, Serbia, Ukraine and Zambia. The EU also has additional relations with, Brazil, China, Colombia, Japan, Mexico, Peru, United States, Uruguay, the EuroMed countries and the African Union.

[5] Regulation (EU) 2024/1252, OJ L 132, 3.5.2024, p.1

[6] The CRMA sets ambitious benchmarks for domestic capacity of strategic materials to be reached by 2030: 10% of the annual needs for extraction, 40% for processing, and 25% for recycling. In addition, no more than 65% of EU annual requirements for a single raw material at any given stage should depend on a single third country.

on data from firms' self-reporting, the administrative capacity of national authorities, and publicly available information.

The Act does not mandate strategic CRMs stockpiles but requires MS to report on existing stocks in their territory. Once it has collected information from MS, the European Commission sets benchmarks indicating safe levels of strategic stocks and may issue opinions to MS on stock management and coordination. In December 2025, the European Commission adopted the RESourceEU Action Plan, envisaging the establishment of the European Critical Raw Material Centre, with the mandate to secure access to CRMs and facilitate strategic stockpiles, and undertake joint purchasing operations. Other than for CRMs, the EU stockpiling strategy (European Commission Press corner, 2025) also promotes stockpiles for energy equipment, such as power generators and high-voltage equipment.

However, strategic stockpiling has economic and operational limits, particularly for DSOs. As we already mentioned, impacts from natural disasters (such as storms, floods, or wildfires) cannot be fully prevented, and an increase in the stock level to cover high short-term demand is not always possible for cost-intensive materials. Indeed, emergency orders can face lead times of up to three years, and technical differences may limit mutual support between DSOs due to local requirements. Flexibility in terms of reallocation of already ordered, produced, or stored products between DSOs may be required to achieve resilience.

Clearer guidance on stockpiling is expected for 2026. Stress tests, stockpile requirements, and how these instruments can be promoted through public procurement will be further discussed in the following sections.

The Act also provides for the establishment of the Raw Materials Mechanism. Built on the previous experience of the Aggregate EU for gas, the platform aims to link buyers (public and private) and sellers of strategic raw materials. In November 2025, the first round of registrations was opened.

With regard to clean technologies, the **Net-Zero Industry Act (NZIA)**[7] introduced an important innovation in public procurement[8]. Specifically, it requires contracting entities to apply the following mandatory non-price requirements when procuring net zero technologies:

- A requirement on environmental sustainability (in the form of a technical requirement or a contract performance condition).
- At least one additional requirement to choose among three different possibilities:
    - a contract performance condition related to social or employment considerations;
    - a requirement to demonstrate compliance with cybersecurity;
    - a contractual obligation to deliver the project fully and on time, which may imply an obligation to pay an appropriate charge if this obligation is not fulfilled.
- A requirement for resilience contribution.

[7] Regulation (EU) 2024/1735, COM(2023) 161, SWD(2023) 68.

[8] The NZIA establishes a legal framework aiming to support net zero industries and the development of net zero technologies. According to the Act, the Union should increase domestic manufacturing capacity to reach at least 40% of the Union's annual needs by 2030. In addition, the EU should reach 15% of world production by 2040 for each technology.

Regarding resilience contribution, when the European Commission formally recognises a high reliance on one third country for a net zero technology final product or component (i.e., share above 50%, or a 10 percentage point increase for two years reaching 40%), public buyers must add the following contractual obligation to their procurement contract:

- For the entire duration of the contract, no more than 50% of the value of the net-zero technology (or of the value of the specific component) may be supplied by that third country.
- Upon request, the contractor must provide evidence of the first requirement.
- An obligation to pay a charge of at least 10% of the value of the technology if the first requirement is not respected.

When the European Commission recognises excessive reliance on a third country, similar conditions also apply for auctions concerning the deployment of renewable energy sources. The Commission Implementing Regulation (EU) 2025/1176 specifies resilience-related requirements in much more detail compared to public procurement, with different requirements based on the technology concerned. Table 3 summarises the key applicable rules (i.e., the final product rule and the main components rule).

Table 3: Resilience requirements for renewable energy auctions.

Technologies	Final product rule	Requirements on specific main components
Photovoltaics	Not assembled in that third country	Min. 4 components do not originate in that third country
Onshore wind	Do not originate in that third country	Max. 3 components originate in that country
Offshore wind	Do not originate in that third country	Max. 4 components originate in that country
Electrolysers	Do not originate in that third country	Max. 2 components originate in that country
Heat pumps	Do not originate in that third country	Max. 1 component originates in that country
Other net zero technologies	Do not originate in that third country	/

Source: Commission Implementing Regulation (EU) 2025/1176.

Despite its aim to avoid excessive reliance on a single country, the NZIA contains multiple structural problems. A first issue stems from the design of the reliance mechanism, which functions as a defensive and ex-post tool, activated only after the overall dependency rate for a specific technology reaches problematic levels. For this reason, the intervention of the European Commission might arrive when supply chain concentration has already become a structural problem. In addition, because the determination of 'excessive reliance' is based on aggregate EU market data, individual contracting entities have no incentive to diversify until the European Commission formally activates the threshold.

A second problem concerns the limited practical application of the resilience requirement. The Act includes multiple circumstances in which contracting entities can avoid applying the resilience

provision, for instance, in the absence of valid alternatives or disproportionate costs (which are presumed whenever diversified options exceed the dominant supplier's prices by more than 20%). Considering that the EU's dependence on certain third countries (especially China) is driven mainly by lower costs, these exemptions are likely to be applied frequently, thus significantly reducing the mechanisms' impact.

By January 2026, the European Commission had not formally recognised what 'excessive reliance' means, therefore, the applicability and consequences of these provisions have not yet been tested. Moreover, it is important to underline that the Act does not apply to third countries that are part of the GPA or similar procurement agreements.

2.1.2 Instruments that expand the EU domestic capacity of clean technologies and CRMs

Both the CRMA and the NZIA establish a category named *strategic projects,* intended to strengthen the security of supply. Under the NZIA, strategic projects are initiatives that play a critical role in strengthening the technological and industrial resilience of the Union's net-zero technologies. Under the CRMA, strategic projects aim to reduce strategic dependencies and diversify CRMs sources.

Although both acts are still in their early implementation phase and only a limited number of projects have been granted the strategic status[9], some structural weaknesses of these tools are already apparent and are likely to reduce their potential to produce meaningful effects.

A first problem appears to be a lack of coordination among MS and the limited steering role of the European Commission (Tagliapietra et al. 2023). For instance, while under the CRMA, strategic projects are formally recognised by the European Commission, the NZIA delegates this power to national competent authorities, therefore leading to potentially heterogeneous interpretations among MS.

Although both regulations grant Strategic Projects accelerated permitting and priority status within administrative or judicial procedures, the implementation remains dependent on MS actions.

Similarly, the Acts require multiple uncoordinated actions by MS. For example, MS have to adopt national programmes containing measures to incentivise the use of recycled CRMs, or the use of pre-commercial procurement to develop new technologies. However, these obligations are formulated in broad terms and lack clear guidance, benchmarks, or enforcement mechanisms. Additional measures, such as regulatory sandboxes or national manufacturing capacity expansion plans, also suffer from limited EU coordination.

Another fundamental aspect is the lack of dedicated and coordinated financing. CRM Strategic Projects may benefit from the help of a Board (including national banks, financial institutions, the EIB, and the EBRD) to have access to finance. However, under both acts, strategic projects do not benefit from a newly established fund but may use existing funds, such as the European Development Fund

[9] By June 2025, the European Commission had recognised sixty strategic projects under the CRMA (including thirteen located in third countries). A second round of applications closed on January 15, 2026. Under the NZIA, eight projects have been granted strategic status (specifically, three in Germany, three in Sweden, one in Hungary, and one in Bulgaria).

and Cohesion Fund. Without coordinated and joint investments, these projects are unlikely to generate the scale needed to grow.

2.1.3 Instruments that indirectly support supply chain resilience and domestic capacity

Alongside tools that directly target resilience or the expansion of domestic capacity, recent rulings of the European Court of Justice (ECJ) and EU-level instruments reveal a tendency of EU institutions to adopt a more restrictive approach towards non-EU countries.

In this regard, in **two recent rulings**[10], the **ECJ** affirmed that the principle of non-discrimination and equal treatment applies only to operators originating from third countries that are GPA parties or have concluded a bilateral procurement agreement with the EU. Bidders originating from other third countries may still be admitted, but they do not enjoy a right to equal treatment. Their participation must be decided on a case-by-case basis by contracting entities and cannot be replaced by a national law requiring to exclude or admit bidders from those third countries. Following these rulings, some MS (e.g., Sweden) have expressed their intention to revise their national procurement laws, to limit the right of equal treatment to those countries[11].

Among other instruments, it is worth mentioning the **Foreign Subsidies Regulation** (FSR)[12], the **International Procurement Instrument (IPI)**[13], and the **Anti-coercion Regulation**[14]. By correcting competitive distortion and ensuring an equal playing field, these instruments could indirectly create better conditions for EU-based alternatives and contribute to strengthening supply chain resilience.

The FSR aims to avoid situations in which foreign companies that receive foreign financial contributions from their government may benefit from unfair advantages when competing in the Internal Market. Pursuant to the Regulation, the European Commission can examine any foreign financial contribution. If the European Commission finds a distortion of the Internal Market, it may accept commitments to remove it, impose redressive measures, or prohibit the award to that operator.

The IPI aims to secure equal and reciprocal access between the EU and third countries in public procurement markets. When the European Commission identifies discriminatory restrictions against EU bidders in a foreign market, it may adopt measures that limit or condition the access of economic operators from that third country to the EU public procurement market. The Anti-Coercion Regulation was designed to avoid and respond to economic coercion by third countries. It enables the European Commission to adopt response measures (such as trade restrictions or measures restricting access to public procurement procedures) when a third country engages in coercive behaviour and fails to cease such actions following EU diplomatic efforts.

[10] Case C-652/22 (2024) and Case C-266/22 (2025)
[11] Press release from Ministry of Finance, Inquiry proposes amended procurement rules to protect Sweden from antagonistic states, Published 25 November 2025
[12] Regulation (EU) 2022/2560, OJ L 330, 23.12.2022, pp. 1–45
[13] Regulation (EU) 2022/1031, OJ L 173, 30.6.2022, pp. 1–16
[14] Regulation (EU) 2023/2675, OJ L, 2023/2675, 7.12.2023

Despite their theoretical importance, these instruments' impact has been limited. Firstly, they are reactive tools, activated only once the European Commission finds a distortive or unfair behaviour. The FSR puts additional administrative burden on economic operators, and in the first year of application, only two in-depth investigations on public procurement were opened (one of which concerned solar PV supplies in Romania). In both cases, the bids were withdrawn before the European Commission's final decision. Similarly, the IPI has been adopted only once, restricting the participation of Chinese companies in EU public procurement for medical devices, while the Anti-coercion Regulation has not been formally activated. Although this lack of activation could, in theory, indicate that the instruments have been effective as a deterrent, recent developments in international trade raise doubts about their practical effects.

The **Carbon Border Adjustment Mechanism** (CBAM)[15] entered into force on January 1st, 2026. From this date, operators intending to import high-carbon-intensity materials (for instance, steel, cement, pipes, and aluminium) as well as electricity from non-EU countries, are required to purchase CBAM certificates, the cost of which depends on the tonne of greenhouse gas emission embedded in the imported products. By ensuring that foreign products bear similar carbon costs to EU goods, CBAM aims to reduce carbon leakage. Additionally, these provisions may foster resilience by encouraging EU internal production of high-carbon-intensity goods, reducing competitive disadvantages faced by EU manufacturers, and supporting domestic supply.

Environmental and social criteria also play an indirect role. As mentioned above, the Public Procurement Directives and the NZIA incentivise the use of green and social requirements. Beyond procurement, the EU has introduced several energy and carbon footprint labels, including for clean technologies, CRMs, and batteries. These labels are intended to increase transparency and can contribute to strengthening the reputation of goods placed on the EU market. In theory, the use of green requirements and labels could support domestic EU-based industries, since suppliers in the EU are often better positioned to meet higher sustainability standards. However, green products often come with a premium price, that may be easily passed through to end-users, making consumers' affordability a key concern. In this regard, recent studies on public procurement highlight a trade-off between green public procurement, strategic autonomy, and fiscal stability (Lappe & Nicoli, 2025).

Taken together, these instruments illustrate the breadth of EU initiatives aimed at strengthening supply chain resilience and domestic capacity. However, their effectiveness remains constrained by fragmented implementation, limited coordination across levels of governance, and a predominantly reactive design. This raises the question of how public procurement, as a more direct and operational policy lever, can be used to address supply chain vulnerabilities in a more targeted and ex ante manner.

To summarise, it is evident how the EU is expanding and integrating the current legislative framework to address supply chain vulnerabilities and strengthen resilience. However, these regulatory instruments remain constrained by fragmented implementation and limited coordination across MS. In this context, public procurement may function as a policy tool to translate resilience objectives into contractual requirements.

[15] Regulation (EU) 2023/956, OJ L 130, 16.5.2023, pp. 52–104

3. Public Procurement for Supply Chain Resilience

Public procurement represents an important industrial policy tool. As discussed above, procurement rules and public demand can be used to influence the market structure and support broader policy objectives, including supply chain resilience. However, resilience cannot be achieved solely through the efforts of contracting authorities, since it depends on the robustness of the entire chain of actors involved.

In this part, the focus is on how the existing public procurement framework can be better used or adapted to promote resilience. Part IV will then propose a model for monitoring and stress-testing supply chain resilience and analyse how to integrate it into procurement procedures.

3.1 Public Procurement Rules and Demand

When dealing with public procurement, it is important to distinguish between two different levels: buyer-level measures and contractor-level measures.

At the buyer level, resilience can be incentivised in two complementary ways. First, contracting authorities can promote resilience by deciding how to procure goods (for example, by choosing between standard or innovationon procurement, opting for collaborative procedures, or subdividing the contract into lots). In general, authorities retain discretion in selecting the most appropriate procedural tools, but it is essential that they are adequately informed on how these choices could affect resilience.

Second, public procurement rules could directly require contracting authorities to adopt specific resilience measures. For example, procurement frameworks could be modified to require or incentivise multi-sourcing, caps on a single-country exposure, regional supplier diversification, or, when objectively justified and proportionate, minimum EU sourcing. Such requirements would be feasible, especially for contracting entities such as TSOs and DSOs, which directly procure grid components and technological equipment (transformers, cables, IT and control systems) to expand and modernise grid infrastructures.

However, in many other circumstances, such requirements on contracting operators would be either impossible to apply or ineffective. For example, when a public authority launches a tender for the installation of solar panels or heat pumps for its buildings, the contract does not involve materials procurement but rather supply and installation. Similarly, when an authority issues a tender for electricity, which includes the contractual obligation to develop new renewable capacity over time, the public buyer does not purchase the underlying components, which are acquired by the private operator.

For these reasons, it is essential that public buyers are also able to influence the supply chains of the contractors, even when they do not procure materials directly. This can be achieved through four types of procurement instruments:

- selection criteria (assess bidder’s ability to perform);

- technical requirements (define mandatory features of deliverable);
- award criteria (assigns additional points in the scoring rule);
- contract performance conditions.

Any measure should comply with the principle of proportionality and non-discrimination and should be framed in a way compatible with the Internal Market and international trade obligations.

Considering both dimensions, the European Commission needs to provide clearer guidance to contracting entities on how to incentivise resilience through procurement, both within the forthcoming revision of Public Procurement Directives and through dedicated implementation guidance.

The following sections examine how public procurement can be structured to encourage more resilient outcomes, comprehending:

- Diversification
- Buy European Requirements
- Public Procurement of Innovation and Collaborative Procurement
- National Security Screening and Exclusion Grounds

3.1.1 Diversification

Diversification is one of the most effective levers to mitigate supply chain risks (Ahn & Joel Tan, 2025). However, imposing a diversification clause is challenging. Many clean technologies and CRMs are concentrated in a few countries, and finding alternatives on the market could be extremely costly, if not impossible. As public buyers mainly rely on prices to award a tender, diversification is often neglected. Therefore, the NZIA's approach of introducing binding requirements on contracting entities' procurement choices in cases of excessive dependency on a third country represents a meaningful shift in the regulatory framework.

However, as outlined in part II, markets' structural characteristics limit their application. These obstacles, mainly high costs and limited supplier availability, often incentivise buyers to prioritise short-term savings over long-term resilience. Therefore, a different system relying on an ex-ante preventive mechanism capable of limiting free-riding behaviour among contracting entities and economic operators should be designed.

Multi-sourcing could be used as a tool to support diversification. By dividing the contract into lots and awarding them to different suppliers, contracting authorities could reduce excessive reliance on a single operator. This could stimulate competition by allowing the participation of alternative suppliers that would be unable to compete for larger contracts. However, a careful design is required to mitigate the risk of collusive behaviour among bidders, which increases with the number of lots (Grimm et al., 2006).

As supply chains are complex and multi-tiered, diversification requires strict control to ensure real diversification and prevent suppliers from exploiting loopholes in the system. To avoid duplication of

efforts, both for monitoring diversification at the contracting authority level and for contractors, enforcement could be delegated to a third independent authority (see part IV).

Finally, it is important to note that diversification considerations may concern not only exposure to a single country. Other aspects should also be taken into account, for instance, excessive dependence on a single economic operator or production site or on a single technology (which eliminates alternatives if certain inputs become scarce).

3.1.2 Buy European Requirements

The current regulatory framework does not contain any provision on 'Buy European' requirements. Nevertheless, the European Commission has announced its intention to introduce 'Made in Europe' criteria both for public and private procurement in the forthcoming Industrial Accelerator Act and in the revision of the EU Public Procurement Directives. The objective of a potential 'Buy European' policy for clean technologies and energy-intensive sectors (e.g., steel, metals, chemicals) would be to stimulate demand for domestic products and foster the emergence of leading European industries.

Designing a Buy European framework is complex and requires careful consideration from both legal and economic perspectives. Instruments that grant explicit preferential treatment based on the origin of goods face significant constraints under the GPA and other international commitments. From an economic standpoint, the evidence on domestic-preference treatment is mixed and often unfavourable. A recent study on Buy American laws finds limited evidence that Buy American provisions constitute an effective industrial policy (Bombardini et al., 2024). Additional research also points in the opposite direction. Dixon (2017) shows that reducing protectionist measures could increase the efficiency of government procurement, ultimately benefiting the private sector through tax cuts. Kutlina-Dimitrova (2017) showed that expanding the coverage of the GPA could raise GDP among GPA parties by USD 4-5 billion and welfare by USD 8-10 billion.

Overly stringent Buy European requirements could therefore reduce competition, increase pressure on public budgets, and primarily benefit private industries' profits. If such mechanisms were introduced, they should be designed in a way that preserves adequate levels of competition among firms.

At the same time, domestic preference measures are not only linked to industrial development. By creating EU alternatives, they can also support diversification and reduce excessive reliance on a few third countries. Therefore, such measures might be justified in strategic technologies where supply is highly concentrated, and the EU has the potential to scale up production. In these cases, diversification alone may be insufficient, as foreign alternatives are limited. In these cases, a targeted Buy European approach, introduced not through rigid origin-based obligations but through award criteria, could be implemented.

3.1.3 Public Procurement of Innovation (PPI) and Collaborative Procurement

Technological innovation is recognised as a key risk-mitigation strategy, especially in sectors where diversification and onshoring are costly and infeasible (OECD, 2023). As mentioned, under the NZIA, MS are encouraged to promote PPI, including through cross-border joint procurement procedures.

Indeed, the combined use of PPI and joint or centralised procedures (i.e., collaborative procurement) offers high returns, as demand size and economies of scale are crucial to enhance the effects of PPI. Moreover, centralised procurement also allows for the concentration of skilled human resources. (Chiappinelli et al., 2025). As a lack of expertise among public buyers seems to limit procurement outcomes (Decarolis et al., 2019), centralisation would therefore constitute an additional benefit.

The advantages of collaborative procurement, however, go well beyond innovation. Even for standard procurement procedures, it allows public buyers to exploit monopsony power, reduce prices, and avoid inefficiencies arising from buyers' competition. This is particularly important in view of the European Grids Package. Without coordination, simultaneous large-scale procurement by TSOs and DSOs risks driving up prices and intensifying bottlenecks. In these cases, collaborative procurement, especially for components with a high degree of standardisation, could strengthen supply chain resilience. To balance the benefits of aggregation with the need to maintain competition and avoid over-dependency on single suppliers, collaborative procurement could be combined with appropriate subdivision of contracts into lots (Grimm et al., 2006).

Therefore, collaborative procurement mechanisms should be activated more often. The European Commission should work to increase the use of existing instruments. Today, one of the main obstacles to their use appears to be a lack of harmonisation among MS, not only for national procurement laws, but also for administrative or R&D procedures. Such fragmentation increases costs both for buyers and suppliers. Therefore, a higher level of harmonisation is needed.

In addition to improving the use of existing instruments, the EU should consider establishing a specialised European body to support contracting entities in organising collaborative procurement, or to directly conduct joint procedures. A structure modelled on the health sector's Joint Procurement Agreement (JPA) could provide a valuable template. The JPA operates on a voluntary basis, with the Commission acting as the contracting authority on behalf of participating MS, preparing and publishing the tender documents, managing the evaluation process and negotiating with suppliers, in coordination with the Steering Committee (composed of one representative of each contracting party). Once the supplier is selected, MS signs the contract. Only in case of urgency, the Commission may be authorised to sign on its behalf.

For more innovative and strategic purchases, the reference model should instead be more agile and effective, such as that of the US agencies DARPA (now 'ARPA-Defense') or BARDA ('Biomedical Advanced Research and Development Authority', now 'ARPA-Health'). DARPA and BARDA are built on three main pillars: highly skilled technical authorities; high-level discretion in the selection of projects in which to invest; and access to large funding.

3.1.4 National Security Screening and Exclusion Grounds

The EU Public Procurement Directives establish both mandatory and non-mandatory grounds for excluding bidders from tender procedures. However, they do not provide a general basis that would allow authorities to ban specific operators who represent a threat to national security. Security-related aspects are addressed through a broader provision, which allows certain contracts to be excluded from the application of the Public Procurement Directives when security considerations are involved.

A targeted EU-level bidder screening mechanism for national security risks, analogous to Foreign Direct Investment (FDI) screening but adapted to public procurement, could allow us to consider security implications, without excluding the contract from the application of the Directives. In the electricity sector, this could be helpful, for example, for smart grid technologies (that could expose MS to cyberattacks and data control) or for those inputs that could be subject to export control. Such a mechanism is already adopted in third countries[16]. In this context, concerns are increasingly being raised over the heavy reliance on solar-panel inverters supplied predominantly by Chinese firms, with Huawei being the dominant supplier. As inverters are internet-connected, experts warn they could be remotely manipulated, potentially disrupting grid stability[17].

[16] For example, according to the UK Public Procurement Act (2023) if a contracting authority reasonably believes that a supplier or its key subcontractors may be influenced by a malign third-country government (e.g. through direct or indirect control), it may treat this as a national security risk and exclude the supplier from the tender or terminate the contract.

[17] Politico, "Europe's solar industry having a Huawei moment," Politico Europe, October 24, 2025.

4. Measuring and Implementing Resilience in Public Procurement

As mentioned, the overall resilience of the electricity market's supply chains depends on the resilience of each operator involved. This part proposes possible solutions for monitoring and stress-testing supply chain resilience, analysing how to integrate them in procurement procedures.

The analysis is structured into three steps:

1. An overview of relevant resilience indicators, including a focus on stress tests and their potential role in assessing supply chain resilience.
2. An examination of who may be responsible for measuring resilience and how.
3. An explanation of how resilience outcomes could be integrated into procurement procedures.

4.1 Resilience Indicators

The baseline for any resilience measurement is a clear understanding of which dimensions need to be assessed. To mitigate risks associated with supply chains, buyers may evaluate several aspects of their contractors to assess their resilience level, including the level of diversification and geopolitical exposure, the level of stockpiling, and the results of stress tests.

To do so, it is important that clear indicators are used. Examples of indicators that authorities may use are presented below.

Minimum stockpiles

To assess whether contractors and their suppliers can respond to disruptive events, authorities could consider their level of stockpiles. As a proxy, authorities could use a stock-coverage indicator, measuring how much a company would be able to satisfy a certain amount of the demand without having access to the necessary inputs for a certain amount of time. These measurements can be framed through the concept of redundancy, which refers to the amount of 'excess' resources held by a firm and its capacity to absorb the impact of disruptive events. For example, Borbon-Galvez et al. (2025) propose a composite resilience indicator that includes, inter alia, a days-of-coverage metric (ranging from <5 to 30+ days) as a proxy for the extent to which a company can fulfil demand in the absence of new supplies.

Supplier diversification

To assess minimum productive capacity and market responsiveness, authorities may consider the degree of supplier substitutability and geographic concentration of supply chains. For instance, the Herfindahl-Hirschman-Index (HHI) captures the level of concentration across producing countries and helps identify situations in which production is overly dependent on a limited number of regions. To assess supplier diversification, authorities have to account for the geopolitical exposure associated with key supplying countries. To empirically assess this dimension, Iacoviello and Caldara (2022)

developed the Geopolitical Risk Index as a measure of the likelihood of supply disruptions caused by conflicts or sanctions[18].

Other indicators may concern input origins and import dependencies, for instance, considering the share of extra-EU imports in total imports at the firms' level (Lefebvre & Wibaux, 2024).

Stress tests

Stress tests are simulations designed to determine the ability of a supply chain to withstand disruptions and recover. Although the real resilience level can be assessed only after shocks have occurred, well-designed stress tests can be used as diagnostic tools for examining weak points in the supply chain, showing both public authorities and businesses vulnerabilities in their procurement strategies (Ivanov, 2025). In this sense, stress tests may help address the energy safety verification paradox by providing a credible proxy of how supply chains may behave under adverse conditions, which would be unobservable in normal market conditions.

As mentioned in part II on the regulatory toolbox, the CRMA provides for EU-level stress tests, but no mechanism is envisaged to stress-test contracting entities and contractors' supply chains. Therefore, we propose a system to incentivise economic operators to perform stress tests.

Although the literature on stress tests for supply chain resilience remains limited, valuable insights can be drawn from other sectors, most notably the banking and financial sector[19], where stress is an established instrument for assessing robustness (Konietschke et al., 2022). Similarly, in a recent study, Varela-Irimia and Dumont (2024) developed a supply chain stress test on critical inputs and provided evidence on its positive impact on firms' sourcing decisions.

Indeed, by analogy with the banking sector, stress tests could be conducted through scenario analysis. The competent authority should be responsible for issuing clear methodological guidance. Such scenarios should reflect realistic geopolitical, economic and environmental shocks. Most typical shocks considered in the literature (Dolgui et al, 2025) are on supply, production, logistics, cash-flow, and ripple effect risks. A meaningful example could include a continuation or escalation of trade frictions affecting critical materials on which the EU depends.

4.2 Who Should Measure Resilience and How

A preliminary issue concerns the identification of the authority responsible for assessing whether supply chains are resilient. In general, each buyer is interested in acquiring from resilient suppliers. However, delegating these duties to individual contracting entities would be unfeasible: it would generate a duplication of efforts, require additional specialised skills, and produce uneven assessments, potentially leading to inconsistent outcomes and opening for abuses.

[18] After identifying high-risk areas, the GRI index calculates the share of materials sourced from these countries and to set realistic benchmarks aimed at reducing overall exposure within the supply chain.

[19] In the banking sector, stress tests are a fundamental tool used by national and European authorities to assess banks' financial vulnerabilities, especially after the 2008 crises. In the European framework, from 2013 the ECB is required to carry out stress tests on significant banks at least once a year (Art.100, Capital Requirements Directive).

In this framework, one possibility could be to establish an independent third-party authority able to measure resilience through the indicators outlined above. The objective would be to have a single body capable of:

- ensuring consistency of requirements across MS;
- avoiding cost duplication and time-consuming administrative procedures.

However, establishing a new agency entails high regulatory costs, including the need for specialised staff, monitoring tools and operational resources. For this reason, alternative solutions to assess resilience in public contracts could be explored. For instance, relying on already existing and accredited Certification Authorities, such as those involved in the ISO certifications[20] developed by the International Organization of Standardization and issued by accredited bodies. These certifications are one-shot systems, meaning that a firm can only obtain a pass or fail outcome. Therefore, authorities might be unable to discriminate positively towards better-performing firms, which is what would happen under a ranking system.

For the sake of simplicity, a feasible option may be to combine the results of the above-mentioned measurements outlined into an aggregated resilience indicator able to capture multiple dimensions.

Once all these indicators are completed and verified, the competent authority would disclose the results. This could be done in a more granular form than standard-setting certifications, for example, one analogous to the credit-rating framework used in the financial sector[21], where ratings range from AAA (Prime) to CCC (Extremely Speculative), enabling a differentiated evaluation of financial stability.

A similar system could be used to assess supply chain resilience by aggregating firms' performance across the proposed indicators and translating the results into a resilience rating scale. Such a system would allow a more granular differentiation among suppliers, capturing varying degrees of resilience and providing contracting authorities with a more informative metric to use in procurement procedures.

4.3 Implementation of Resilience Indicators in Procurement Procedures

To incentivise resilience investments along the contractor's supply chain, contract notices may either require or reward resilient upstream supply chains. Therefore, under this model, the resilience score issued by the competent authority could be integrated in public procurement procedures as a selection criterion or an award criterion, or through a combination of both.

[20] Certification schemes such as ISO 22301 on Business Continuity Management or ISO 28000 on Security and Resilience already set out standards on continuity and risk management that indirectly support resilience objectives.

[21] In the EU, credit ratings are assigned by external and independent agencies, supervised by the European Securities and Markets Authority (ESMA) under the Credit Rating Agencies Regulation, based on an assessment of the security and credibility of banks' assets.

For example, contracting authorities could establish a minimum threshold that suppliers must reach to access the public tender while also assigning increasing award points based on the aggregation of the indicators' results.

The choice between selection and award criteria depends on different factors (Dini et al., 2006). Minimum requirements are most appropriate when the contracting authority can clearly define ex-ante the level of resilience expected. Conversely, when resilience is subject to structural constraints, a scoring mechanism may be more suitable, as it ensures flexibility while still allowing authorities to positively discriminate in favour of firms improving their supply chain management. Therefore, the most suitable option may be to set a relatively low resilience threshold while using a scoring mechanism to reward firms. This combined approach could both incentivise firms to improve their resilience and guarantee inclusiveness in the procurement process.

5. Conclusions and Recommendations

Supply chain resilience in the electricity market is a fundamental challenge that requires coordinated action by Member States. Although several instruments have been introduced in recent years, the regulatory toolbox remains fragmented and insufficient to address key vulnerabilities and bottlenecks.

In this context, public procurement represents a strategic lever to incentivise resilience among all the relevant actors of the supply chain. The main takeaways are summarised as follows:

- Division into lots and multi-sourcing could be incentivised to increase diversification and resilience. The revised Directives may make this more explicit.
- Minimum Buy European requirements could be considered cautiously and in line with international obligations. Such measures should be narrowly targeted to technologies in which the EU has high growth potential and where the current supply is highly concentrated in a single third country.
- Existing centralised and joint procurement procedures could be strengthened/expanded and used more often, particularly for homogeneous goods, and supported by greater EU harmonisation.
- Innovation is key to developing new technologies that reduce dependency on foreign inputs such as CRMs. Especially if combined with centralised or collaborative procedures, PPI can achieve the scale necessary for innovation.
- Strengthening competences of public buyers is crucial.
- To incentivise resilience through public procurement, resilience indicators of suppliers could be included in selection or award criteria.
- Resilience indicators could be issued by a measurement and certification body to avoid placing excessive burden on contracting authorities.
- Among the relevant indicators, greater emphasis could be placed on stress tests as predictors of supply chains' capacity to withstand disruptive events.

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