ENTSO-E

The Transmission Grid Investment and Supply Chain Assessment Report 2026

A forward-looking assessment of planned transmission infrastructure investment across ENTSO-E member TSOs for the period 2026 – 2035, with analysis of supply chain implications and policy recommendations.

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Mission Statement

ENTSO-E – the European Network of Transmission System Operators for Electricity – brings together 40 electricity transmission system operators (TSOs) from 36 countries. ENTSO-E members are responsible for the secure and coordinated operation of Europe's electricity system. Together, they operate a system of around 500,000 km of power lines **– the largest interconnected electrical grid in the world –** and serve about 520 million citizens.

Electricity is not merely a market commodity; it is an essential service, and TSOs are fully regulated public service entities whose work is essential to powering Europe. The grid is the backbone of the electricity system and extends across the continent, beyond the borders of the EU. By working together, TSOs guarantee a functioning infrastructure that makes electricity trading possible, contributes to decarbonisation goals and ensures a reliable and efficient power supply for all members of society.

These shared public service responsibilities need close cooperation beyond national borders, which led to the creation of ENTSO-E. Today, the association serves two main complementary purposes:

1. Cooperation of European TSOs

The foundations of this cooperation date back to the 1950s, with the creation of electrical -synchronous areas and interconnections that laid the groundwork for today's interconnected European power system. TSOs established associations to work together on their own mandates and missions; these associations came together to form what is now ENTSO-E. The European electricity system is one of the most stable and reliable grids in the world, supported by cooperation and coordination among TSOs within the European Union and in closely interconnected European countries. ENTSO-E strives to build consensus for decision-making amongst its member TSOs, as this forms the strongest foundation for cooperation.

2. Fulfilling EU legal mandates

With the adoption of the Third Energy Package in 2009, ENTSO-E's role was formally recognised by European institutions. ENTSO-E was granted legally mandated tasks to further develop the European interconnected grid and to facilitate the integration of European electricity markets. These mandates cover a large spectrum of tasks, including system operation, system development, market integration, information technologies, R&D and innovation.

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Executive Summary

Europe's transmission grid is entering a period of significant transformation, with growing demands for faster expansion and the deployment of technologies that are, in some cases, still not yet mature. At the same time, supply chains have not yet adapted to support the exceptional scale and the need for speedy deployment of the grids.

This evidence emerges directly from the data that 27 European transmission system operators (TSOs) submitted to ENTSO-E's Investment Pipeline Survey 2026: seven major asset categories, 10 years of planned additions, and a demand profile that is simultaneously driven by the energy transition, a binding regulatory phase-out of SF_6, and a wave of end-of-life asset replacement across a fleet largely installed in the 1980s and 1990s.

This report is ENTSO-E's response to these developments. Prepared under Action 13 of the EU Grid Action Plan, which identified improved visibility of transmission investment pipelines as a prerequisite for addressing supply chain constraints at the European level, this report goes beyond a survey of future asset demand.

It analyses three interconnected dimensions of the deployment challenge that no single organisation can address alone:

- The readiness of the European supply chain to produce what is needed
- The legal and regulatory environment governing how TSOs procure it
- The availability of the skilled workforce required to plan, build, and operate the infrastructure once procured

Each dimension presents a challenge in its own right. Together, they determine whether Europe's grid investment ambition translates into infrastructure on the ground.

Three drivers, one decade

The 2026 – 2035 period covered by the Investment Pipeline Survey 2026 is not an arbitrary planning horizon. It is the decade in which three distinct, but simultaneous pressures converge on the same asset base, supply chain, and delivery capacity.

The energy transition requires substantial new high-voltage direct current (HVDC) corridors, underground and submarine cables, overhead line (OHL) uprating, and switching infrastructure to connect offshore wind, integrate solar generation, and build the cross-border interconnection capacity mandated under National Energy and Climate Plans (NECPs) across Europe while keeping the existing infrastructure in the best condition possible. This demand is structural and non-deferrable: it is the physical prerequisite for meeting 2030 and 2035 climate targets.

The SF_6 phase-out under Regulation (EU) 2024/573 creates a regulatory deadline that compels TSOs to procure SF_6-free alternatives for new switchgear installations, against a backdrop where those alternatives are still scaling in production maturity and manufacturing volume while some niche, but crucial applications remain in question. TSOs cannot defer this transition; they can only manage its pace within the regulatory constraints that apply to their specific installations and voltage levels.

Asset replacement cycles are generating a wave of renewal demand that is entirely independent of the energy transition but no less urgent, if not more critical, for the security of the grid and electricity supply. A significant share of the European transmission fleet, including power transformers, circuit breakers (CBs), gas-insulated switchgear (GIS), and other assets, has reached or is approaching end of life. This replacement demand does not compete with energy transition investment for policy priority, but it competes for the same factory capacity, the same installation crews, and the same procurement windows.

The convergence of these three drivers in the same decade, on the same supply chain and delivery capacity, is the central challenge this report addresses. No single one of them would be straightforward to manage in isolation. Taken together, these three drivers create substantial demand concentrated within the same decade, placing pressure on the European grid sector's supply chain and delivery capacity.

Principal findings

The data yields six findings of immediate significance for policymakers, manufacturers, and TSOs. The first five are drawn from the Investment Pipeline Survey. The sixth reflects the parallel skilled workforce survey conducted across the same TSO community.

1 // The SF_6 phase-out is generating a major technology transition signal.

Planned additions of SF_6-free GIS total 4,238 bays by 2035, representing 1,593 % growth on a near-zero starting base – one of the highest growth rates of any category in the survey. At the same time, TSOs plan 10,819 SF_6 CB additions and 2,884 SF_6 GIS bays through 2035, confirming that the transition is gradual rather than immediate and that both product streams must remain available and serviceable concurrently through at least 2030. This also highlights the importance of discussions about asset obsolescence and the need for spare parts in the decades to come. The survey also implies that the SF_6-free supply chain is not yet scaled to meet the demand profile. In several voltage categories, mature and type-tested SF_6-free products are still awaited, and some niche application needs remain unmet.

2 // HVDC cables – underground and submarine combined – are the most constrained supply chain.

Underground DC cable additions of 22,303 km (2,633 % on an 847 km baseline) and submarine DC cable additions of 11,687 km (595 %) together represent approximately 34,000 km of new HVDC cable by 2035 – a volume that will test access to specialised HVDC manufacturing capacity, **with leading European suppliers reported to be booked through 2030**. Underground demand is heavily concentrated in Germany, whose needs account for 85 % of the total. Submarine demand is more geographically distributed. The constraint is multi-layered: raw materials, factory capacity, cable-laying vessels, port infrastructure, and installation crew availability all require simultaneous expansion, each with its own lead time of three to five years or more.

3 // Grid optimisation and reinforcement is accelerating and the supply chain implications are underappreciated.

TSOs plan 64,107 km of high-temperature low-sag (HTLS) conductor additions (278 % of the 2025 baseline) and dynamic line rating (DLR) without sensors: +32,270 km (207 % of baseline); DLR with sensors: +5,901 km (219 % of baseline) by 2035. These technologies are used not only on new transmission lines but are especially focused on allowing existing infrastructure to carry significantly more current without the need for new towers or rights-of-way, making them the fastest route to additional grid capacity in constrained corridors. The demand concentration is significant: German TSOs account for approximately 69 % of HTLS conductor demand. HTLS conductor and DLR technology supply chains may face raw material constraints that sit outside the seven asset categories this survey covers directly but are very much relevant as well.

4 // HVDC converter stations represent a step-change in the equipment market that procurement timelines have not yet caught up with.

A total of 119 bipolar converter station additions are planned by 2035 (313 % of the 2025 baseline), each a bespoke long-lead engineering project with converter transformer lead times of four to five years. Projects that are to be commissioned by 2028 – 2030 must already be mature and have been procured; otherwise, they face a significant risk of delay due to asset lead times. HVDC converter stations are among the assets with the longest lead times, with many having waiting times of over seven years. The global manufacturing base for HVDC converter equipment is limited to a small number of contractors; the combination of concentrated demand and limited supply creates conditions that standard competitive procurement processes may not accommodate.

5 // A technology transition in reactive power compensation is already underway, and the legacy supply chain should not be assumed to persist.

Large STATCOM additions (>150 MVA) will grow 482 % by 2035, driven by the retirement of synchronous generation and the need for voltage stability in high-inverter grids. Legacy shunt capacitor banks and small STATCOMs show addition rates of only 17 % and 19 % of their baselines, respectively, indicating a shift in the composition of new reactive compensation investment. TSOs that continue to plan maintenance and replacement based on an available legacy supply chain for these technologies should verify this assumption against current manufacturer roadmaps, given the apparent risk of asset obsolescence.

6 // Skilled workforce can be a binding constraint on delivery, and the TSO community is asking for sector-level coordination.

A parallel survey of 12 TSOs found that nine of 12 submissions regard skilled workforce availability as a key challenge, either within their own organisation or in their subcontractor base. White-collar engineering and IT profiles are the most acutely affected. Project implementation – the building of substations, OHLs, and cable routes – is the most heavily subcontracted activity across the community, meaning that workforce risk is concentrated at the precise stage of delivery where the investment pipeline is largest. All 12 responses expressed unanimous support for collective action: increased sector visibility, collaboration with manufacturers and universities, international programmes, and cross-border certification reform. TSOs are explicitly open to a joint ENTSO-E-level exercise.

The procurement window is narrowing

Across virtually every category in the Investment Pipeline 2026 survey, planned additions peak between 2028 and 2032. This synchronisation of peaks is not coincidental: it reflects the convergence of the three structural drivers described above. What this means in practice is that the European supply chain will face simultaneous demand pressure across multiple product lines from multiple buyers in the same four-to-five-year window – at a scale and across a breadth of categories that has not occurred before.

TSOs that procure ahead of that peak are better placed to secure manufacturing slots while the supply base still has spare capacity and suppliers are still competing for orders. Early procurement does not guarantee more favourable pricing or terms, but it keeps more options open. TSOs that procure into the peak – or that allow procurement to be delayed by permitting uncertainty, budget cycles, or administrative constraints – will face longer lead times, higher prices, and reduced competitive choice. The difference is not marginal. For power transformers, delivery in 2028 required an order to be placed in 2025. For HVDC cable, factory slots for 2030 commissioning are being allocated now. Those who procure SF_6-free GIS early may find more competitive market conditions than those who wait until the peak in 2031. However, multiple TSOs are still very cautious about this relatively novel technology and are waiting for more information and maturity.

This is the central operational conclusion of the report: the time to act is before the peak, not during it. For ENTSO-E, for the European Commission, for Member State authorities, and for TSOs themselves, that means treating procurement timing as a strategic question, not an administrative one.

What this report can and cannot tell you

The figures in this report are lower bounds. Thirteen TSOs (out of 40 total) did not respond; their demand is absent from every aggregate total. The supply chain risk is therefore larger than the numbers show, not smaller. Additionally, in several categories the binding constraint may not be the finished asset but a critical subcomponent – grain-oriented electrical steel, mineral oil and bushings for transformers, optical fibres and power electronics for cables and converters, as well as other critical subcomponents. The survey focused on the overall assets; therefore, many necessary subcomponents fall outside its scope.

Based on the discussions that ENTSO-E Task Force Supply Chain & Public Procurement organised with asset manufacturers and manufacturers of asset subcomponents throughout 2025 and 2026, we can conclude that the entire grid supply chain is quite fragile.

Near-term data (2026 – 2028) reflects largely committed programmes, while long-horizon data (2032 – 2035) reflects planning intentions subject to revision. This report should be read as a directional signal and an early warning, not as a production schedule. Its value lies in the pattern, the simultaneity, and the scale – all of which are robust even after adjustment for the limitations of the methodology.

Data quality

This report reflects data that has been subject to thorough quality review.

Growth rates in this report are cumulative planned additions for 2026 – 2035 expressed as a percentage of the 2025 baseline reported by the participating TSOs. Where the installed base is small, these rates are very high and sensitive to small differences in the baseline. This applies in particular to SF_6-free GIS (266-bay baseline), underground DC cable (847 km), large STATCOMs (11 units) and SSSCs (6 units). In these categories, the high rates mainly reflect technologies now moving into large-scale deployment rather than the expansion of an established fleet. They should be read as indicating the direction and scale of change, not as precise multipliers.

In three voltage bands, planned additions were reported with no corresponding 2025 baseline: underground DC cable at 72.5 – 145 kV (2,702 km, around 12 % of planned underground DC additions), submarine DC cable at 72.5 – 145 kV (478 km), and STATCOMs above 150 MVA at 72.5 – 145 kV (one unit). These may be genuinely first-of-a-kind deployments or gaps in baseline reporting; the aggregate data do not distinguish between the two. The additions are included in the totals and therefore raise the reported growth rates. Excluding them, the growth rate for underground DC cable would be around 2,300 % rather than 2,633 %, and for submarine DC cable around 570 % rather than 595 %.

Table 1: Summary of headline figures (2026 – 2035, aggregate across all 27 TSOs)

Asset / Metric	2025 Baseline	→ 2030 (cumul.)	→ 2035 (cumul.)
Power transformers (units)	5,649	+1,393	+2,820
GIS without SF_6 – SF_6-free (bays)	266	+1,728	+4,238
OHL ACSR – circuit km	250,958	+49,914	+79,967
OHL HTLS – conductor km	23,031	+30,962	+64,107
Underground DC cable – conductor km	847	+8,222	+22,303
Submarine DC cable – conductor km	1,965	+5,664	+11,687
HVDC bipolar converter stations	38	+60	+119

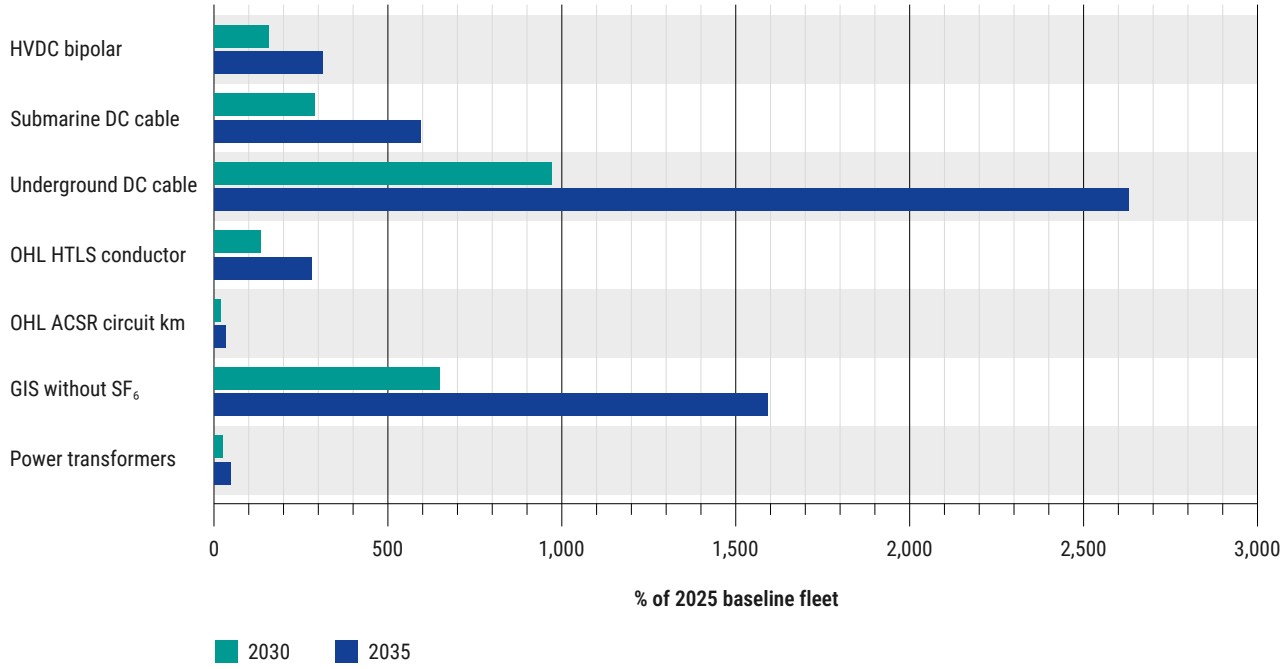
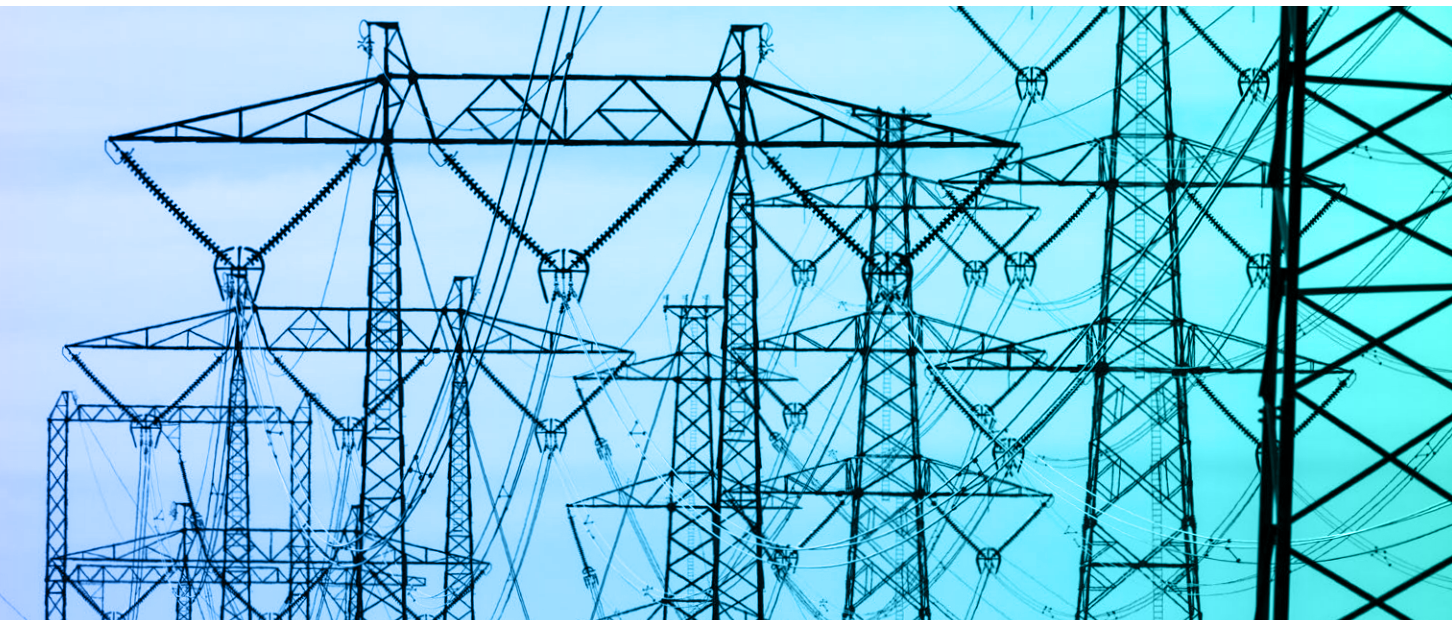


Figure 1: Planned Additions as % of 2025 Baseline Fleet



1 Regulatory and Policy Context

The SDC Investment Pipeline Survey complements the framework of ENTSO-E's statutory obligations under Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity (recast). Under that Regulation, ENTSO-E adopts a non-binding Union-wide ten-year network development plan (TYNDP) every two years (Article 30 (1)(b)), which builds on national investment plans and identifies investment gaps, notably with respect to cross-border capacity (Article 48 (1)).

ENTSO-E also carries out the European resource adequacy assessment (Article 23) and seasonal adequacy assessments (Article 30 (1)(m)). The survey supports this work by providing a bottom-up, TSO-reported view of asset-level investment intentions.

1.1 Relevant regulatory drivers

Investment demands identified in this survey are shaped by a convergence of European legislative requirements:

- **Regulation (EU) 2022/869 (TEN-E Regulation):** Establishes the framework for Projects of Common Interest (PCIs) and Projects of Mutual Interest (PMIs) and creates specific permitting and financing provisions for priority electricity infrastructure. PCIs and PMIs are an important framework through which many of the major cross-border HVDC and cable projects identified in this survey may be developed. The survey also covers national investments, including large domestic HVDC corridors, which may fall outside this framework.
- **Regulation (EU) 2024/573 on fluorinated greenhouse gases (recast):** introduces phased restrictions on the putting into operation of electrical switchgear that relies on fluorinated greenhouse gases for insulation or breaking, with dates and conditions varying by voltage level, short-circuit current and global warming potential (GWP). For transmission-level equipment, restrictions apply from 1 January 2028 to switchgear from 52 kV up to 145 kV with a short-circuit current up to 50 kA, and from 1 January 2032 to switchgear above 145 kV or above 50 kA, in both cases where the gas has a GWP of 1 or more. Derogations apply, including where tenders receive no compliant offers, for orders placed before 11 March 2024, and for certain extensions of existing installations. This regulation is the primary driver of the demand for GIS without SF_6 and CB without SF_6 identified in Section 3 of this report.
- **Directive 2014/25/EU on procurement by entities operating in the water, energy, transport, and postal services sectors (Utilities Directive):** Governs the procurement of equipment and services by TSOs. The supply chain constraints identified in this report, particularly for SF_6-free switchgear, HVDC cable, and power transformers, have direct implications for TSOs' ability to conduct competitive procurement processes. The Directive is likely to be repealed and replaced by the Public Procurement Act.
- **Regulation (EU) 2024/1735 (Net-Zero Industry Act, NZIA):** Establishes targets for European manufacturing capacity in strategic net-zero technologies, including grid infrastructure. The demand signals in this survey provide direct evidential support for NZIA capacity targets in power cables, transformers, and power electronics.
- **Critical Raw Materials Act (Regulation (EU) 2024/1252):** Establishes lists of strategic and critical raw materials relevant to several asset categories in this survey. These include copper (used, for example, in cables and transformer windings), bauxite / aluminium (used in OHL conductors, including both aluminium conductor steel reinforced (ACSR) and HTLS), rare earth elements and specialised insulation materials (used in HVDC cables).

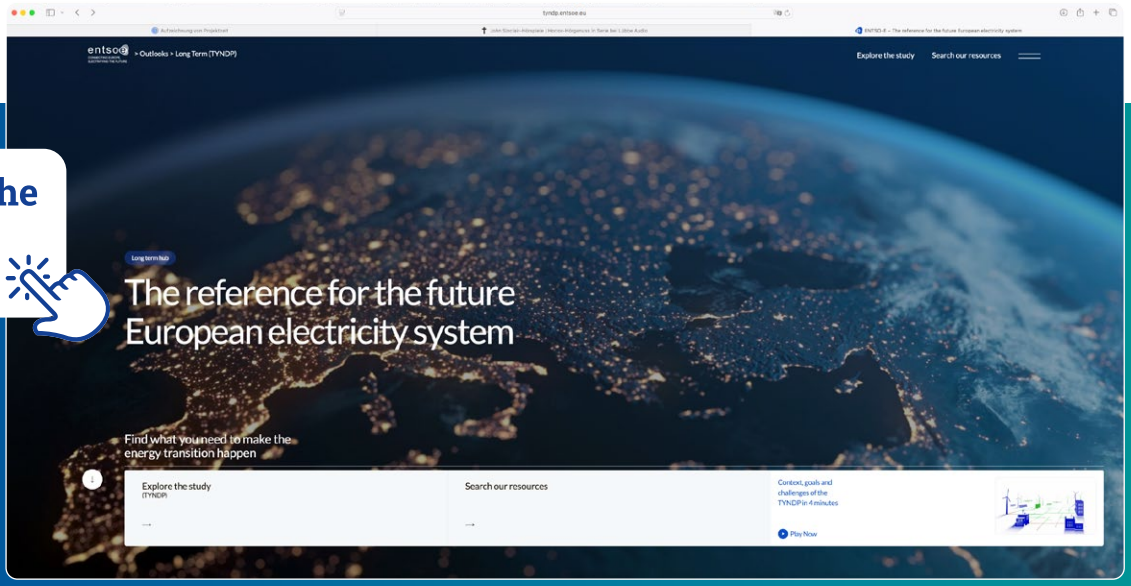
- **Proposal for an Industrial Accelerator Act (COM (2026) 100):** Tabled by the Commission on 4 March 2026 to accelerate industrial capacity and decarbonisation in strategic sectors, including through measures relating to public procurement and the introduction of "Made in EU" and low-carbon requirements. The proposal also amends Regulation (EU) 2024/1735 (NZIA). Depending on its final scope for grid technologies, the Act could introduce origin and sustainability requirements in TSO procurement of the equipment categories covered by this survey. This would come at a time when the supply constraints identified in this report are most acute. The proposal is currently being examined by the European Parliament and the Council.
- **Proposal for a Public Procurement Act (COM(2026) 590):** Adopted by the Commission on 9 September 2026, it would repeal the public sector, utilities, and concessions Directives and fold procurement provisions scattered across sectoral acts into a single, directly applicable Regulation. It introduces a "Buy European" framework for the first time, together with a specific framework for economic security and supply chain resilience. The proposal would directly reshape the rules under which TSOs contract for the equipment and services identified in this report, including award criteria and the treatment of non-EU suppliers.
- **Electrification Action Plan:** Presented on 17 July 2026 with an indicative electrification target of 46 % by 2040, measured as electricity's share in final energy consumption, with accelerating grid deployment among its focus areas. It was accompanied by a legislative proposal on network charges amending the Electricity Regulation. The Plan strengthens the demand-side case for the investment volumes reported here. As its targets translate into national planning, it may raise these volumes further.
- **European Grids Package:** Published by the Commission on 10 December 2025, the package has two legislative proposals at its core:
  - Proposal for a revised TEN-E Regulation (COM (2025) 1006): Would repeal and replace Regulation (EU) 2022/869 and amend the ACER, Electricity, and Gas and Hydrogen Regulations. It would introduce a new governance for EU-level network planning, making the Commission responsible for ensuring that cross-border grid planning is aligned with EU energy and climate goals.
  - Proposal for a Permitting Directive: Would amend the Renewable Energy, Electricity, and Gas and Hydrogen Directives to accelerate permit-granting. The package also includes Commission guidance on efficient grid connections.

1.2 Relationship to the TYNDP

This report, which draws on the ENTSO-E System Development Committee Investment Pipeline Survey 2026, provides asset-level investment input to the TYNDP 2026 Infrastructure Gaps Report. The data on specific assets and planned investments presented here complement the information on the TYNDP project portfolio and provide a cross-check against it. While two sources differ in scope, they complement each other: the TYNDP portfolio includes projects of pan-European relevance from both TSO and third-party promoters and covers a longer time horizon. This report captures overall planned investments in grid assets (both internal and cross-border) of 27 TSOs.

This report is not one of the TYNDP deliverables that ENTSO-E is required to adopt under Regulation (EU) 2019/943. It is an analytical publication that draws on and contributes to the TYNDP process, and it does not form part of, amend or replace any TYNDP deliverable.

Link to the TYNDP Website



2 Survey Scope and Methodology

2.1 Scope

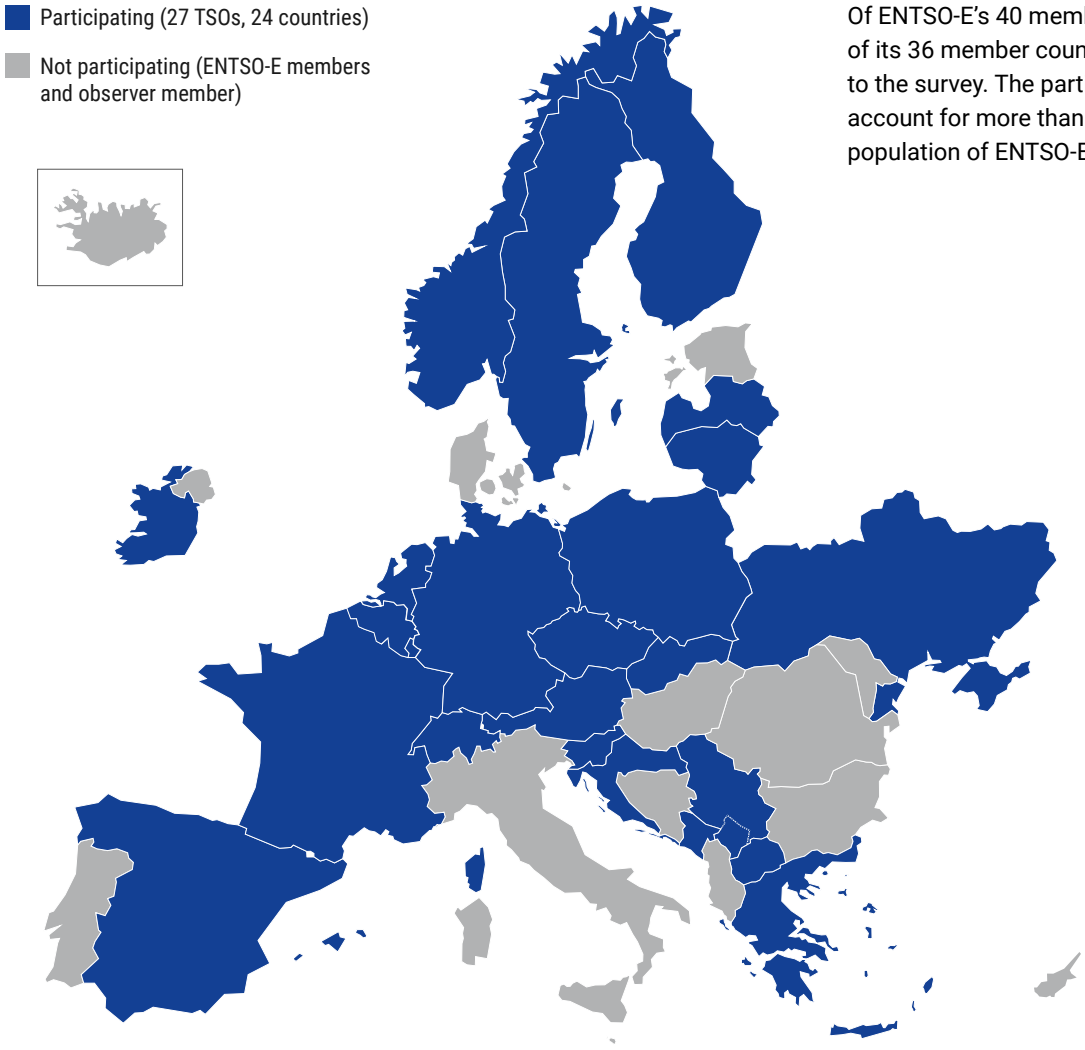
The survey collected data on planned additions to the transmission asset fleet at the following voltage levels: 36 – 72.5 kV, 72.5 – 145 kV, 145 – 245 kV, and 245 – 420 kV for AC assets, and 245 – 420 kV and 420 – 550 kV for HVDC assets.

Seven asset categories were covered: Power Transformers and Shunt Reactors; Switching Devices; OHLs; Underground Cables; Submarine Cables; STATCOM, Static VAR Systems (SVSs), Capacitor Banks and Static Synchronous Series Compensators (SSSCs); and HVDC Converters.

Data was requested for annual planned additions (not cumulative totals) for each year from 2026 to 2035, alongside the baseline fleet size. The baseline is the fleet in operation at the end of 2025. Planned additions are gross figures: they include all assets planned to be put into operation in each year, whether they expand the network or replace existing assets.

However, the survey did not collect decommissioning data. Additions expressed as a percentage of the baseline therefore indicate the volume of new equipment to the current fleet, not the overall asset base.

2.2 Participation



Of ENTSO-E's 40 member TSOs, 27 from 24 of its 36 member countries responded to the survey. The participating countries account for more than three-quarters of the population of ENTSO-E member countries.

Map: Investment Pipeline Survey 2026 – Participation by Region

3 Switching Devices

Asset type	2025 Baseline	Additions to 2030	Additions to 2035
All asset types (units and bays)	52.4 k	+14.2 k	+25.5 k

3.1 Policy context: Regulation (EU) 2024/573 on fluorinated greenhouse gases

Switching devices represent the category most directly affected by European legislative requirements in the survey period. Regulation (EU) 2024/573 introduces a phased prohibition of putting into operation SF_6-insulated switchgear, with prohibitions on new SF_6-based asset installations in certain GIS and air-insulated substation (AIS) categories from 2028 onwards. The survey data reveals the scale of the transition challenge for the years to come: a 22,027-bay installed base of SF_6 GIS equipment will require replacement or retrofitting after their asset lifetime, while new SF_6-free alternatives are not yet sufficiently mature and/or manufactured at the volumes the survey implies will be required.

3.2 SF_6 circuit breakers – sustained near-term demand

More than 10,819 SF_6 CB additions are planned by 2035 (40% of the 26,767-unit baseline). The addition profile is front-loaded, with 7,588 units planned by 2030. This reflects the fact that a significant proportion of installed SF_6 CBs will reach the end of their life cycle soon, and TSOs will bring a large number of SF_6-based assets into operation over the next few years. Western European TSOs (excluding Germany) account for approximately 55% of additions; German TSOs account for approximately 14%; and Nordic and Baltic TSOs account for 8%.

Annual planned additions (2026 – 2035): 1,230; 1,323; 1,385; 1,458; 2,192; 1,194; 598; 551; 452; 436 units.

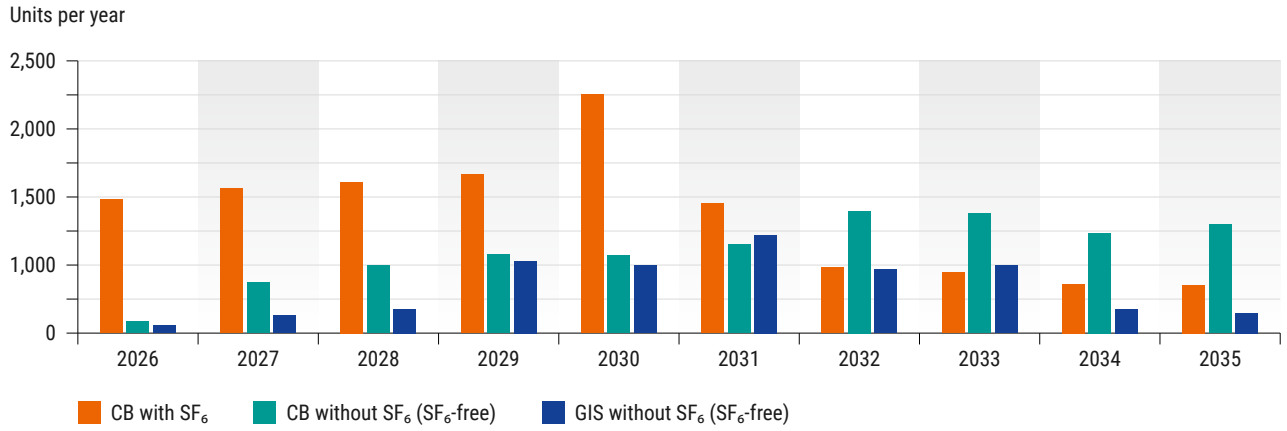


Figure 2: Annual switching device additions 2026 – 2035

Supply chain note

The 2030 peak of 2,192 annual SF_6 CB additions coincides with the peak demand years for SF_6-free alternatives (see Section 3.5). The ban on the use of SF_6/putting into operation assets with SF_6 has likely motivated TSOs to speed up the process of asset renewal before the ban comes into force. This also means that assets brought into use in 2030 should remain operational for at least the next 30 years, raising questions about the availability of spare parts and asset obsolescence.

Manufacturers are expected to sustain both product lines concurrently through at least 2032. Procurement timelines for 245 – 420 kV CBs are typically 18 – 24 months, meaning orders for the 2030 peak must be placed by 2028.

Finally, some niche (e.g. disconnecting circuit breaker) and high short-circuit current applications (e.g. 80 kA) are not yet mature or developed enough to meet grid operators' needs.

3.3 SF_6-free circuit breakers – accelerating ramp-up

More than 7,558 air-insulated SF_6-free CBs are planned by 2035 (223 % growth on the 3,383-unit baseline). The profile accelerates strongly in the second half of the decade: 2,615 units by 2030, rising to 7,558 by 2035. Western European TSOs account for approximately 68 % of planned SF_6-free CB additions; Nordic and Baltic TSOs account for 9 %; and German TSOs for 13 %.

3.4 GIS with SF_6 – deliberately constrained new investment

Only 2,884 new GIS SF_6 bays are planned by 2035 against a 22,027-bay installed base (13 %). This low ratio reflects TSOs' deliberate limitation of new SF_6 GIS investment in anticipation of the regulatory prohibitions in Regulation (EU) 2024/573. The significant installed base of SF_6 GIS equipment will, however, require replacement over a time frame extending well beyond the 2035 horizon of this survey due to expected asset lifetime, creating a long-duration replacement demand that is not fully captured in the current data. The same observations and concerns regarding asset obsolescence and the availability of spare parts also apply to this asset category, as they do to AIS SF_6 CBs.

3.5 GIS without SF_6 – the defining technology transition of the survey period

More than 4,238 SF_6-free GIS bays are planned by 2035, representing 1,593 % growth on a 266-bay starting base. This is one of the categories with the highest growth rate in the survey, and it signals a clear technology transition. Activity peaks in 2031 (903 bays), driven by regulatory milestones in Regulation (EU) 2024/573.

Annual planned additions (2026 – 2035):
65; 161; 217; 664; 621; 903; 585; 617; 220; 185 bays.

Western European TSOs account for approximately 80 % of planned SF_6-free GIS additions; German TSOs for 11 %; Nordic and Baltic TSOs for 5 %; and Central European TSOs for 3 %.

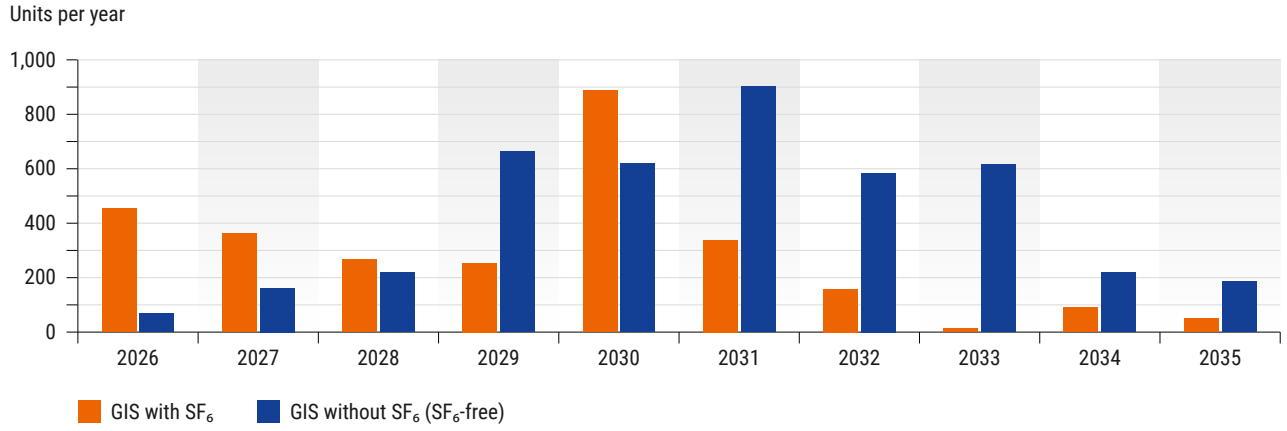


Figure 3: GIS annual and cumulative additions

Policy implication: market competitiveness

The concentration of SF_6-free GIS demand in the late 2020s and early 2030s, combined with a limited number of qualified manufacturers, makes it increasingly challenging to maintain effective market competition when procuring these assets.

Policy implication: Discussions on PFAS, possible ban and impact on grid sector

Further regulatory uncertainty surrounds the EU's proposed restriction on PFAS under REACH. Leading SF_6-free alternatives, such as fluoronitrile-based gas switchgear and vacuum-based switchgear, comprise various subcomponents that fall within the PFAS family and could be subject to future restrictions (such as nozzles, lubricants, gases, etc.). TSOs procuring SF_6-free equipment in the near term should seek assurances from manufacturers and policymakers regarding the composition, availability, and obsolescence of components, and monitor the REACH restriction dossier.

4 Power Transformers and Shunt Reactors

Asset type	2025 Baseline	Additions to 2030	Additions to 2035
All asset types	6.9 k	+2.2 k	+4.1 k

4.1 Power transformers

More than 2,820 power transformers are planned by 2035, representing 50 % of the 5,649-unit 2025 baseline. Demand is geographically distributed across all participating regions: Western European TSOs (excluding Germany) account for approximately 45 % of planned additions; German TSOs for 30 %; Nordic and Baltic TSOs for 9 %; Central European TSOs for 8 %; and Southern and Mediterranean TSOs for 6 %.

The annual addition profile is relatively stable across the decade, ranging from 164 to 382 units per year with a peak in 2030. This stability reflects the structural nature of the demand: power transformer replacement cycles are usually driven by asset age and condition rather than discrete project decisions, and a significant portion of the European fleet installed in the 1980s and 1990s is reaching its asset life during this period.

Annual planned additions (2026 – 2035):
164; 237; 326; 284; 382; 329; 288; 256; 285; 269 units.

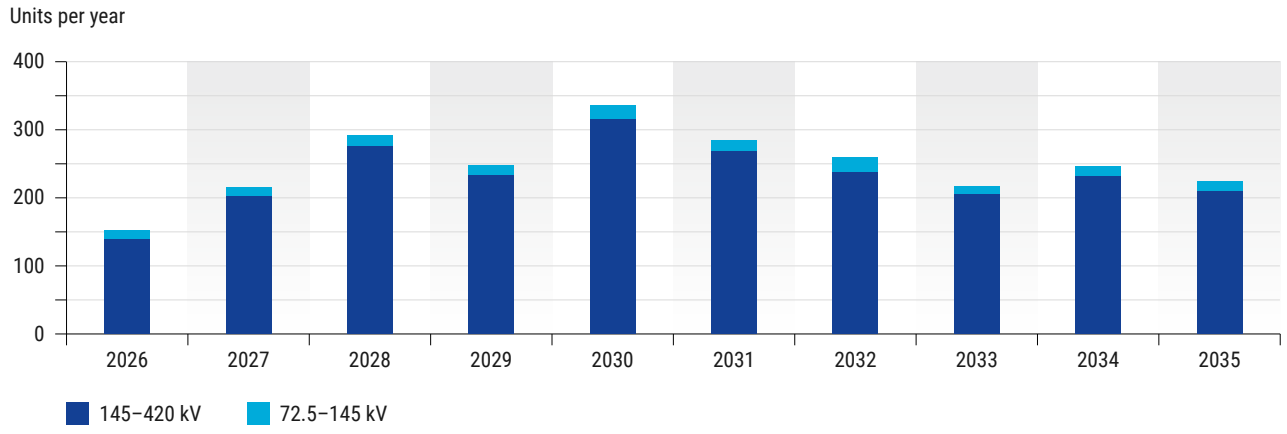


Figure 4a: Power Transformers: Annual Planned Additions by Voltage Band (units)

Supply chain note

The lead time for procuring power transformers at the 245 – 420 kV level is typically at least 36 months. At this voltage level, TSOs report planned additions of 113 – 243 units per year. Thus, this category requires early and sustained procurement planning.

It is also important to highlight the significant differences in complexity and value between normal transmission power transformers, oil-immersed shunt reactors, and phase-shifting power transformers (PSTs), as PSTs are significantly more complex and require more raw materials, making them significantly more expensive to procure. These differences may also affect supplier availability, manufacturing capacity, and procurement lead times.

Transformer manufacturing also relies heavily on a complex supply chain of critical subcomponents, such as tap changers, grain-oriented electrical steel, copper, aluminium, bushings, and mineral oil, all of which may be exposed to geopolitical tensions and global material supply pressures. These constraints may further increase lead times and costs and limit manufacturers' ability to respond to growing demand. TSOs have a limited view of manufacturing capacities because manufacturers do not publicly share this information. This further limits the response capabilities and preparedness of TSOs.

4.2 Phase-shifting transformers

More than 111 PSTs are planned by 2035, growing 108 % from a 103-unit baseline. PSTs are used for cross-border power flow management and to optimise the internal transmission grid. They are closely associated with increasing interconnector use in the Central European meshed grid. Each unit is highly customised, with lead times of more than four years.

Demand is concentrated in Central and Western Europe. PSTs are essential for managing power flow within the European grid. However, they are also among the largest and most expensive onshore grid assets. Each unit consists of several hundred tonnes of critical materials, with a total weight of up to a thousand tonnes.

4.3 Shunt reactors – oil-immersed

More than 1,017 mineral oil-immersed shunt reactor additions are planned by 2035 (138 % of the 735-unit baseline). Growth is directly linked to the expansion of the grid, for example, offshore wind connections as well as onshore renewable power generation and reactive power infeed from distribution networks, which must be absorbed.

The peak year is 2030 (228 units), reflecting the commissioning profile of major cable infrastructure projects. Western European TSOs account for approximately 47 % of planned additions; German TSOs for 21 %; and Southern and Mediterranean TSOs for 18 %.

4.4 Shunt reactors – air core/dry type

More than 155 air-core shunt reactor additions are planned by 2035 (35% of the 447-unit baseline). This category shows modest growth, reflecting the replacement of assets nearing the end of their life as well as increased grid compensation needs.

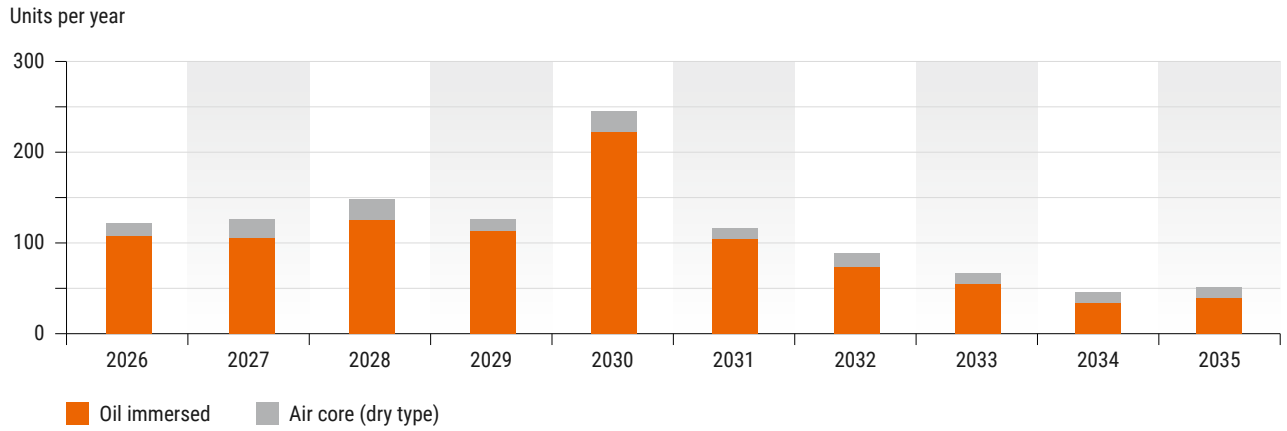


Figure 4b: Shunt Reactors: Annual Planned Additions by Type (units)

5 Overhead Lines[1]

Asset type	Unit	2025 Baseline	Additions to 2035	% of baseline
AC OHL (ACSR)	circuit km	250,958	+79,967	32 %
AC OHL (HTLS)	conductor km	23,031	+64,107	278 %
DLR without sensors	circuit km	15,593	+32,270	207 %
DLR with sensors[2]	circuit km	2,694	+5,901	219 %

5.1 AC OHL ACSR (circuit km)

More than 79,967 circuit km of ACSR OHL are planned by 2035, against a 250,958 km baseline (32 %). The geographic distribution reflects the scale of different national grid development programmes: Western European TSOs (excluding Germany) account for approximately 37 % of planned additions; Southern and Mediterranean TSOs for 20 %; Nordic and Baltic TSOs for 17 %; Eastern European TSOs for 5 %; and German TSOs for 5 %.

Annual planned additions (2026 – 2035): 4,907; 6,099; 9,666; 9,617; 19,625; 6,990; 7,549; 5,221; 3,179; 7,114 circuit km.

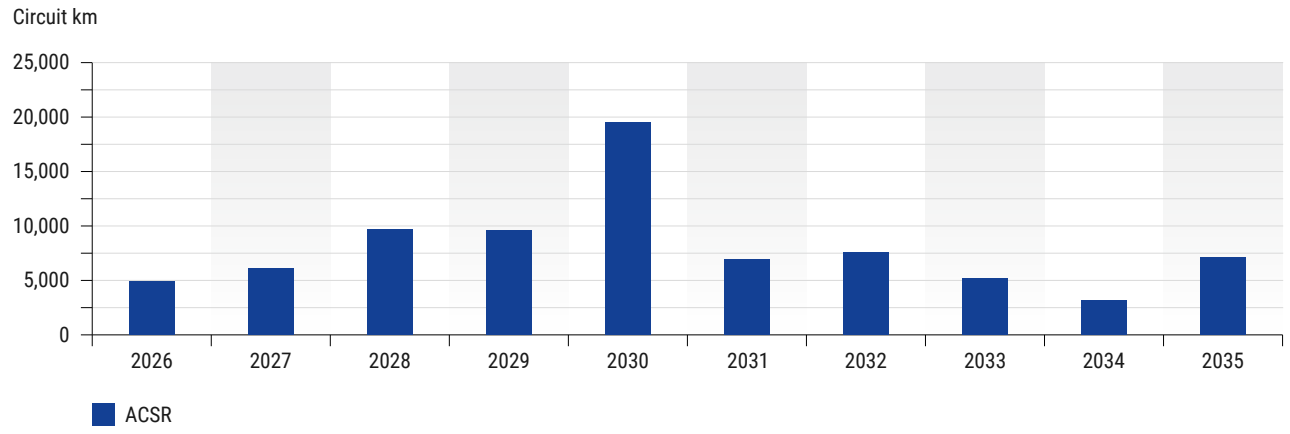


Figure 5: AC OHL ACSR additions

1 OHL additions are reported in different units, depending on how the technology is deployed. ACSR OHLs and DLR are expressed in circuit km, representing the length of the electrical circuit, with a double-circuit line on shared towers counting as two separate circuits. HTLS conductor uprating is expressed in conductor km, representing the physical length of conductor material replaced, because reconductoring replaces individual conductor bundles within an existing circuit rather than full circuit spans.

2 DLR is primarily deployed on existing infrastructure, these figures are largely independent of, and should not be added to or compared with, the planned ACSR and HTLS additions.

5.2 AC OHL HTLS in conductor km (grid optimisation)

More than 64,107 km of HTLS conductor are planned by 2035 (278 % growth on the 23,031 km baseline). One of the key benefits of the HTLS is that it allows existing pylons to carry 50 – 100 % more current without the need for new support structures, making it one of the preferred grid optimisation tools for TSOs facing planning constraints. Approximately, German TSOs account for 69 % of HTLS conductor demand; Western European TSOs for 17 %; Southern and Mediterranean TSOs for 8 %; and Central European TSOs for 6 %.

Annual planned additions (2026 – 2035): 4,647; 4,979; 7,070; 6,357; 7,909; 7,432; 7,455; 12,005; 1,824; 4,429 conductor km.

Policy implication

HTLS conductor uprating reduces permitting requirements compared to new OHL construction, as it does not require new support towers or rights-of-way. The strong HTLS conductor demand signal suggests that regulatory frameworks supporting fast-track permitting for reconductoring may be more effective at unlocking grid capacity in the near term than frameworks focused solely on new construction. This has implications for national permitting law reforms underway in several Member States pursuant to Directive (EU) 2023/2413 (revised Renewable Energy Directive).

5.3 Dynamic Line Rating

DLR without sensors

More than 32,270 circuit km are planned by 2035 (207 % on a 15,593 km baseline). Central European TSOs account for 83 % of planned DLR without sensor deployment. This metric reflects the deployment of ambient temperature DLR, as it is a very cost-effective form of grid optimisation that requires minimal hardware.

DLR with sensors

A total of 5,901 circuit km is planned by 2035 (219 % on a 2,694 km baseline). Southern and Eastern Mediterranean TSOs account for the largest share, with significant contributions from Central European TSOs. The smaller volume relative to DLR without sensors reflects the additional cost and planning requirements of sensor-based deployment. DLR figures refer to the circuit km of overhead lines planned to be equipped with dynamic line rating. As DLR is primarily deployed on existing infrastructure, these figures are largely independent of, and should not be added to or compared with, the planned ACSR and HTLS additions.

6 Underground Cables

Asset type	Unit	2025 Baseline	Additions to 2030	Additions to 2035	% of baseline
Underground cable AC a steady replacement demand	conductor km	33,150	+16,949	+30,665	93 %
Underground cable DC a surge driven by HVDC corridor programmes	conductor km	847	+8,222	+22,303	2,633 %

6.1 Underground AC conductor km

More than 30,665 km of AC underground cable are planned by 2035 (93 % of the 33,150 km baseline). The addition profile is stable at 2,500 – 3,900 km per year, indicating sustained replacement and expansion programmes rather than discrete project-driven spikes.

Western European TSOs account for approximately 72 % of planned AC underground cable additions.

Annual planned additions (2026 – 2035): 2,572; 3,449; 3,844; 3,237; 3,847; 3,009; 2,672; 2,819; 2,530; 2,686 conductor km.

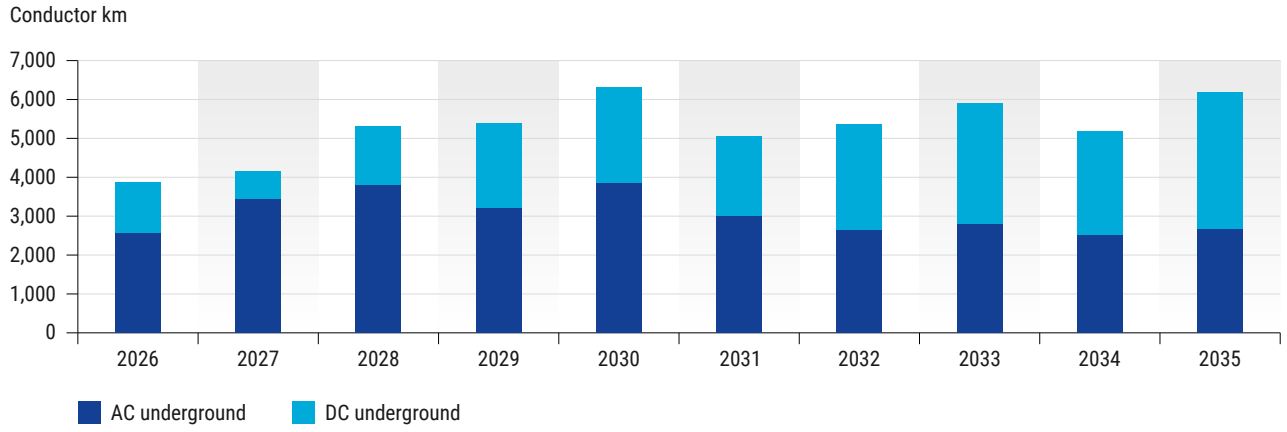


Figure 6: Underground cables

6.2 Underground DC conductor km – the defining infrastructure challenge

More than 22,303 km of HVDC underground cable are planned by 2035, representing 2,633 % growth on an 847 km baseline. The survey indicates a step-change in the scale of European underground HVDC deployment relative to the participating TSOs' reported baseline. The demand is driven by large-scale national HVDC corridor projects: TSOs in Germany collectively account for 85 % of total European underground DC cable demand. TSOs in other Member States account for the remaining 15 %, primarily for cross-border interconnectors.

These projects are concrete and advanced, with many benefiting from regulatory approval[3] and inclusion in the TYNDP. In Germany alone, SuedLink, SuedOstLink, A-Nord, and other north-south DC corridors account for the majority of the reported volume. The concentration of up to 3,530 km of expected delivery in 2035 would place considerable pressure on the supply chain.

Europacable estimates[4] that European HV and extra high voltage (EHV) underground-cable production capacity currently exceeds projected average demand and is set to more than double by 2030. However, these figures combine AC and DC cables and do not demonstrate the availability of suitable HVDC manufacturing slots when several major projects require delivery simultaneously. Indeed, the IEA[5] reports that leading European HVDC suppliers are booked through 2030 and that some procurement lead times exceed five years. The survey therefore points to project bunching, access to specialised manufacturing capacity, and delivery scheduling as material risks to the pipeline, alongside permitting, financing, and other project-delivery constraints.

Annual planned additions (2026 – 2035): 1,320; 730; 1,510; 2,179; 2,483; 2,071; 2,708; 3,118; 2,654; 3,530 conductor km.

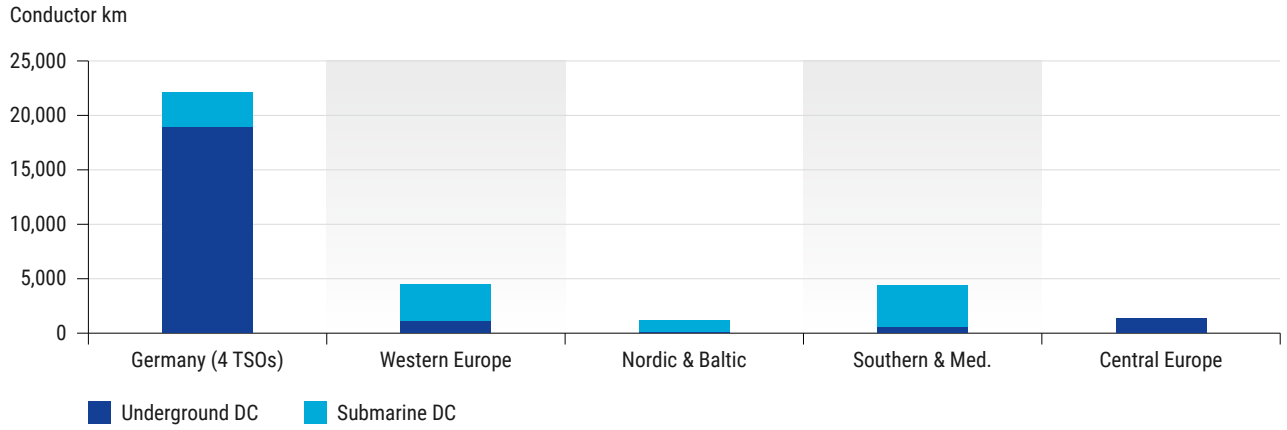


Figure 7: DC cable demand by region

3 Bundesnetzagentur, Energy transition clears crucial hurdle – significant progress in electricity grid expansion in 2025, 2 January 2026

4 Europacable, Securing Cables for Electricity Transmission and Distribution: Europacable Proposal on the Industrial Accelerator Act, 15 May 2026

5 International Energy Agency, Building the Future Transmission Grid, 2025, pp. 31 – 32

7 Submarine and Offshore Cables

Asset type	Unit	2025 Baseline	Additions to 2030	Additions to 2035	% of baseline
Submarine/offshore cable AC island connections and short sea crossings	conductor km	4,777	+2,915	+5,338	112 %
Submarine/offshore cable DC offshore wind and cross-border HVDC	conductor km	1,965	+5,664	+11,687	595 %

7.1 Submarine AC conductor km

More than 5,338 km of AC submarine cable are planned by 2035 (112% of the 4,777 km baseline). AC submarine cable is limited to relatively short crossings due to charging current constraints. Applications include island interconnections and short cross-border sea crossings.

Demand is spread across TSOs in Western Europe, the Nordic region, and the Mediterranean.

Annual planned additions (2026 – 2035): 684; 317; 480; 3; 1,431; 143; 577; 1,019; 414; 270 conductor km.

7.2 Submarine DC conductor km – offshore wind and cross-border interconnection

More than 11,687 km of DC submarine cable are planned by 2035 (595% on the 1,965 km baseline). Demand is driven by two distinct project types: offshore wind collection and export cables (primarily Western and Northern European TSOs) and cross-border HVDC interconnectors (Southern European and Mediterranean TSOs).

Regional breakdown of planned additions to 2035: Southern and Mediterranean TSOs 33% (3,874 km, e.g. IPTO's Aegean island interconnections and Red Eléctrica's Mediterranean links); Western European TSOs 30% (3,477 km, e.g. RTE's offshore wind export cables and Elia Group's North Sea connections); German TSOs 28% (3,276 km, e.g. 50Hertz's Baltic offshore wind spurs and Amprion's North Sea links); and Nordic and Baltic TSOs 9% (1,060 km, e.g. Statnett's Norwegian interconnectors and Litgrid's Baltic links).

Annual planned additions (2026 – 2035): 26; 332; 736; 3,243; 1,327; 370; 809; 653; 1,936; 2,255 conductor km.

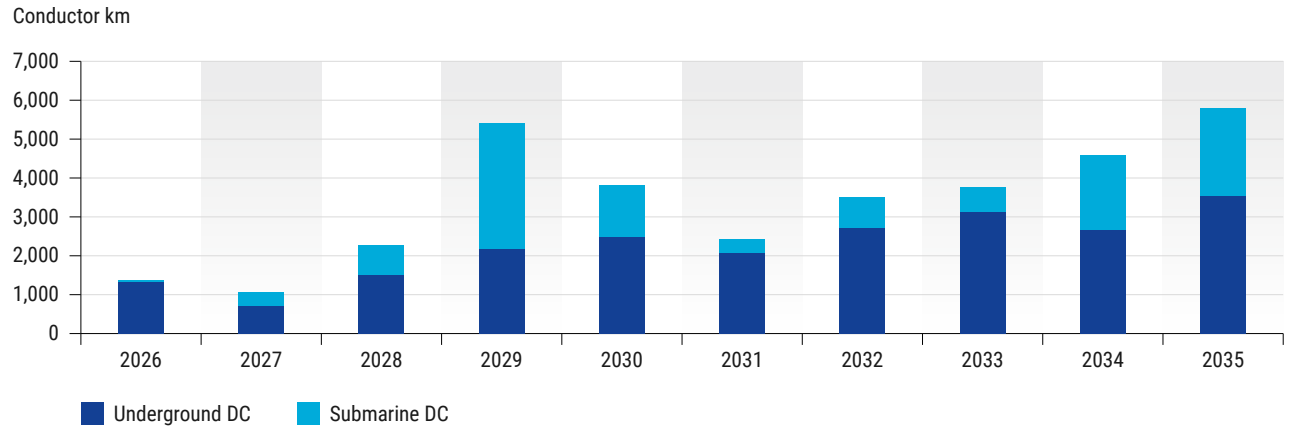


Figure 8: HVDC cable annual additions

The addition profile is irregular and heavily project-driven, with 2029 showing a pronounced peak of 3,243 km. Approximately 52% of total planned additions fall in the second half of the decade (2031 – 2035).

Policy implication

The survey identifies approximately 34,000 km of cumulative DC cable demand by 2035, comprising 22,303 km of underground DC cables and 11,687 km of submarine DC cables. This cumulative figure cannot be compared directly with published annual manufacturing-capacity estimates, particularly because recent Europacable figures combine AC and DC production.

Nevertheless, the concentration of demand in particular delivery years could create pressure on specialised HVDC production slots, project sequencing, and installation capacity. This risk is especially relevant for submarine projects, given the limited availability of suitable cable-laying vessels and skilled operators.

8 STATCOM, SVS, Capacitor Banks, and SSSC

Asset type	2025 Baseline	Additions to 2030	Additions to 2035
All reactive compensation types	623	+104	+196

8.1 STATCOM greater than 150 MVA – voltage stability for high-renewable systems

More than 53 large STATCOM units are planned by 2035 (482 % growth on an 11-unit baseline). German TSOs account for approximately 72 % of planned additions; Nordic and Baltic TSOs for 19 %; Western European TSOs for 6 %; and Central European TSOs for 4 %[6]. Large STATCOMs provide dynamic reactive power compensation essential for voltage stability as synchronous generators retire, and inverter-based renewable generation increases its share of system dispatch. The demand for large STATCOMs is expected to grow further beyond 2035 as grid-scale synchronous compensation from conventional generation declines.

Annual planned additions (2026 – 2035): 8; 2; 4; 4; 7; 3; 12; 2; 5; 6 units.

8.2 Technology transition: from passive to dynamic reactive compensation

The survey reveals a clear and accelerating technology transition in reactive power compensation. Three legacy categories are in terminal investment decline:

- Compensation without Static VAR Systems: Only 22 additions by 2035 (61 % of baseline).
- STATCOM 150 MVA or below: Only 11 additions by 2035 (19 % of the 58-unit baseline). This category is being superseded by larger, more powerful units.
- Shunt capacitor banks: Only 89 additions by 2035 (17 % of the 512-unit baseline). Capacitor banks remain relevant for sustained reactive power demand, while STATCOMs and synchronous condensers provide complementary dynamic voltage support; the appropriate mix depends on system needs. Compensation without Static VAR Systems: Only 22 additions by 2035 (61 % of baseline).

Conversely, two categories are growing:

- STATCOM greater than 150 MVA: +53 units (482 % growth) – becoming the standard dynamic compensation solution.
- SSSC: +21 units (350 % growth) – early-stage adoption for congestion management on heavily loaded AC corridors and as an alternative to PSTs.

6 Percentages may not add up to 100 % due to rounding.

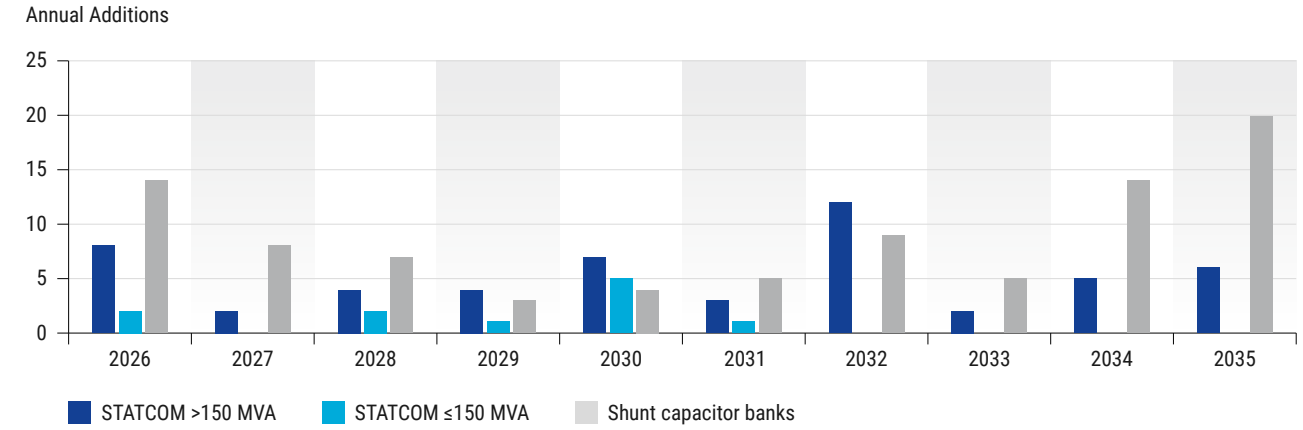


Figure 9: FACTS reactive compensation technology shift

Supply chain note

Large STATCOM manufacturing lead times are at least 36 months. Framework agreements or call-off contracts should be considered by TSOs with 2028–2031 commissioning requirements, given that the 2032 peak of 12 annual large STATCOM units creates concentrated demand pressure on a limited manufacturing base.

9 HVDC Converters

Asset type	2025 Baseline	Additions to 2030	Additions to 2035
HVDC converter stations (bipolar + monopole)	52	+67	+138

9.1 Bipolar converters

More than 119 bipolar HVDC converter stations are planned by 2035 (313 % on a 38-station baseline). German TSOs collectively account for approximately 67 % of planned bipolar additions, reflecting the converter stations for national HVDC corridor programmes. Western European TSOs account for 13 %; Central European TSOs for 7 %; Southern and Mediterranean TSOs for 8 %; and Nordic and Baltic TSOs for 4 %.

Annual planned additions (2026 – 2035): 3; 7; 11; 14; 25; 19; 4; 19; 6; 11 converter stations.

Each bipolar converter station is a bespoke engineering project. There is no off-the-shelf product. Key long-lead equipment includes converter transformers (typically 48 – 60 months from order to delivery), thyristor or insulated gate bipolar transistor (IGBT) valves (24 – 36 months), and high-voltage cable termination systems. The aggregate year-by-year totals in this report represent demand signals, not a production schedule; individual project timelines will vary substantially.

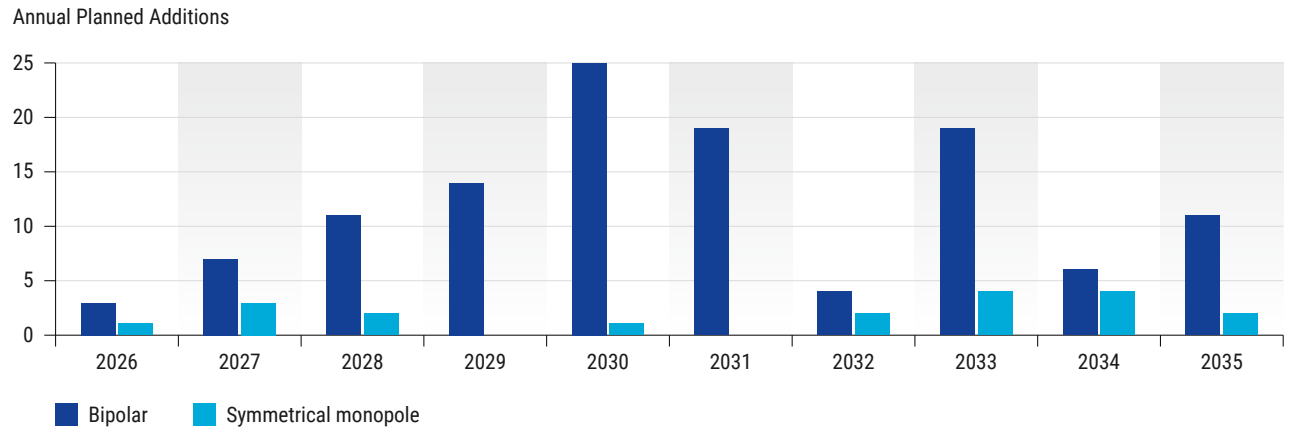


Figure 10: HVDC converter station annual additions

Policy implication: an oligopolistic market

The concentration of bipolar converter demand in a small number of very large projects, combined with limited global manufacturing capacity, creates a highly concentrated supplier market. Competition exists, but limited supplier capacity can drive up prices, extend delivery times, and limit innovation.

TSOs can address this using the procedures and flexibility available under Directive 2014/25/EU, such as the negotiated procedure with prior call for competition, competitive dialogue, and long-term framework agreements that give suppliers the visibility needed to invest in additional capacity. Preserving this flexibility, including framework agreement durations suited to long-lead equipment, will be important in the ongoing revision of the EU procurement framework.

9.2 Symmetrical monopole converters

More than 19 voltage source converter (VSC)-HVDC symmetrical monopole converter stations are planned by 2035 (136% growth on a 14-station baseline). This topology is the preferred configuration for offshore wind point-to-point links and is expected to grow rapidly as offshore wind scales beyond 2035. Current volumes are modest but growing, with additions spread across Western European and Southern European TSOs.

10 Skilled Workforce for Transmission Grid Infrastructure

The Investment Pipeline Survey 2026 was accompanied by a parallel survey on skilled workforce availability across the ENTSO-E TSO community. While the Investment Pipeline Survey maps the physical asset demand, workforce availability is a cross-cutting constraint that affects the ability to plan, build, commission, and maintain that infrastructure. This chapter presents the findings of that survey and draws out their implications for the investment outlook presented in this report.

10.1 Survey scope

The skilled workforce survey was conducted across the ENTSO-E TSO community, with 12 TSOs submitting responses. The survey covered current and projected workforce composition, the severity of skilled workforce shortages, the job categories most affected, the degree of reliance on subcontractors, the maturity of upskilling and talent-attraction programmes, identified bottlenecks, and views on collective action.

10.2 Severity of the challenge

The majority of responding TSOs regard skilled workforce availability as a material operational constraint. Of the 12 submissions received, five describe it as a key challenge for their own organisation, three describe it as a key challenge primarily affecting subcontractors, and one identifies it as a key challenge at both levels. Three TSOs report no critical concern at present. The challenge is therefore real but not uniform: a significant minority of TSOs report that the pressure is felt not in their own staffing but in the capacity of the subcontractors on which they depend for project delivery. The operational consequences reported reflect this distribution. Six responses cite project delays as a consequence already occurring. Three cite increased risk of employee overwork or exhaustion. Two cite work quality concerns. Four report no negative impact to date. The most commonly reported strategic response among TSOs that have already acted is insourcing of previously outsourced activities and the use of longer-term partnership contracts with subcontractors. This shift is not without cost: insourcing increases internal headcount demand precisely in the white-collar and technical categories already identified as most affected by skilled workforce shortages, potentially trading external subcontractor risk for a deeper internal recruitment burden.

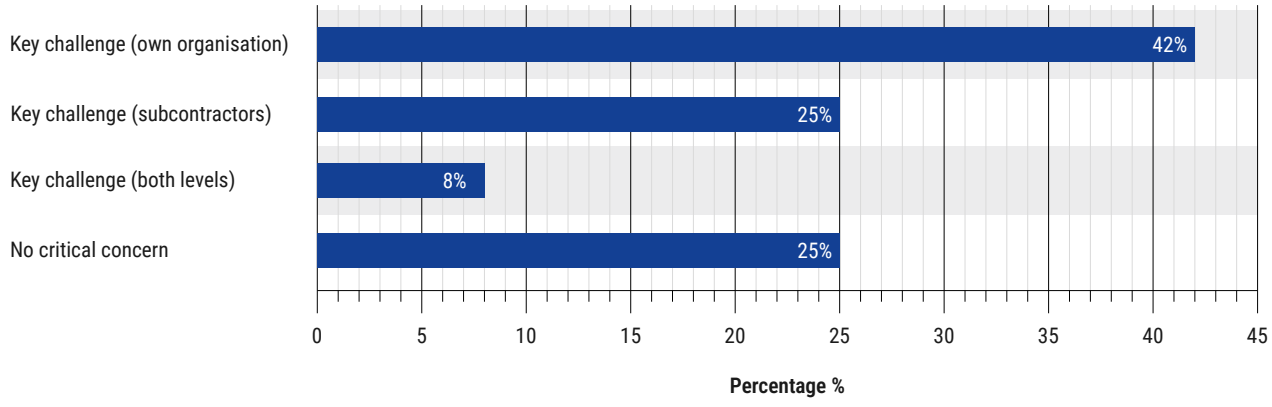


Figure: Severity of skilled workforce shortages among responding TSOs and their subcontractors

10.3 Job categories most affected

Respondents were asked to rank job specialisations from most to least affected by skilled workforce shortages. White-collar workers – engineers, analysts, project designers, and market specialists – were ranked as the most affected category by six of the 12 responses. IT and cybersecurity specialists were ranked first by three responses. Blue-collar workers – maintenance technicians, cable jointers, and construction crews – were ranked first by three responses.

This result is significant in the context of the investment pipeline. The categories facing the sharpest workforce pressure – engineering and IT – are precisely those required for project design, protection and control engineering, HVDC system engineering, and the digital infrastructure that underpins grid operation. The pressure on white-collar technical roles reflects competition with the broader engineering and digital labour market rather than a problem specific to the utility sector. Several respondents noted that experienced project managers, protection and control engineers, and OHL specialists – profiles with sector-specific competence – are particularly difficult to recruit and retain.

The average age of respondents' workforces is roughly 40 – 48 years. Combined with the planned growth in workforce size reported by several TSOs, this demographic profile may indicate a risk of succession pressure if a significant share of experienced technical staff retires during the same 2026 – 2035 window as the peak investment programme identified in this report.

10.4 Subcontractor reliance and associated risks

Ten of 12 responses identify project implementation – the building of substations, OHLs, and cable routes – as one of the three areas where their organisation relies most heavily on subcontractors. Project design is the second most cited area (seven of 12), followed by studies and feasibility analyses (six of 12), vegetation management (five of 12), and asset maintenance and diagnostics (four of 12).

This concentration of subcontractor dependence in project implementation and project design has a direct bearing on the investment pipeline. Subcontractors delivering these services operate in the same labour market as TSOs, and in several cases face more acute recruitment challenges: they are typically smaller organisations, offer less employment security, and compete at a disadvantage with TSOs for scarce engineering talent. Nine TSOs report having already taken concrete decisions in response, including insourcing previously outsourced activities and structuring longer-term framework contracts to give suppliers sufficient planning horizon to recruit and train staff. These are appropriate near-term adaptations, but they do not resolve the underlying structural gap.

Supply chain note

The overlap between subcontractor workforce risk and the supply chain constraints identified in Chapters 6 – 9 of this report merits attention. HVDC cable installation, for example, depends not only on cable manufacturing capacity but also on the availability of qualified installation crews, jointing technicians, and commissioning engineers – profiles in short supply across the industry. A production capacity expansion that is not matched by a parallel expansion in installation and commissioning workforce capacity will not translate into faster network delivery.

10.5 Programme maturity across the TSO community

The survey reveals a meaningful disparity in the maturity of workforce planning and development programmes across respondents. On upskilling and reskilling, six of 12 responses report systematic programmes in place, four report that development is underway or planned but no formal programme yet exists, and one reports only ad hoc training. On talent attraction, internship programmes, graduate schemes, university partnerships, and career fair participation, the majority of TSOs have at least one initiative in place, with graduate and internship programmes the most common format.

Workforce strategy maturity is the most uneven dimension. Of the 12 TSOs that responded to the workforce survey, eight have a formal workforce strategy or human resource plan in place, in several cases including succession planning and knowledge transfer provisions. Four describe their current approach as informal or ad hoc, without a documented medium-to-long-term plan. No respondents reported having no workforce planning at all; the distinction is between formalised and undocumented approaches. A third of respondents therefore lack a structured medium-to-long-term view of their workforce requirements, a gap that is difficult to reconcile with the scale and duration of the investment programmes described in this report.

10.6 Identified bottlenecks

Respondents were asked to identify the key bottlenecks preventing progress on skilled workforce availability. The most frequently cited bottleneck is lack of visibility of the sector as a career destination (seven of 12), followed by lack of incentives to attract and retain qualified workers (five of 12), gaps in the education and training pipeline (five of 12), and suboptimal workforce planning at the sector level (two of 12).

The visibility finding is consistent across TSOs regardless of whether they describe the situation as critical. The transmission sector competes poorly for graduate attention against technology, finance, and more visible engineering fields, despite offering strong employment security, clear mission relevance to the energy transition, and a technically demanding working environment. One respondent noted that by the time awareness-raising reaches university students, many career decisions have already been made, pointing to the need to engage earlier in the educational pipeline, including at the secondary school level.

10.7 Proposed actions and collaboration mandate

Respondents were asked to rank five proposed actions from most to least preferred, one of which was framed as a null option: "no need to change anything, as skilled workforce is not an issue in our case". Every one of the 12 respondents ranked this option last, including the three TSOs that elsewhere described the current situation as not critical. In other words, even TSOs without an acute workforce problem today do not regard the status quo as the right collective posture; all 12 preferred at least one form of active response over doing nothing.

Among the four active options, no single proposal dominated the rankings, and preference ordering varied across respondents. All four were consistently rated above the null option:

- Increasing the spotlight on the importance of the sector
- More extensive collaboration with equipment manufacturers, universities, and vocational training institutions
- International collaboration programmes across the TSO community and with other sector actors
- Targeted policy changes, including cross-border recognition of professional certifications

The unanimous rejection of "no action needed" is arguably a stronger signal than support for any individual measure: it indicates a sector-wide consensus that collective action is warranted, even among TSOs not currently reporting acute shortages.

Policy implication

The unanimous rejection of the null option, combined with strong preference ordering towards international collaboration and targeted policy change, indicates clear TSO support for coordinated action. As a policy position, ENTSO-E has called for a Net-Zero Academy for Grids – a call first raised publicly at the May 2025 joint webinar "Electrifying Europe: Perspectives from the Industry and Grid Operators on Skilled Workforce as a Supply Chain Bottleneck", co-hosted by ENTSO-E, T&D Europe, DSO Entity, and Europacable. The joint webinar, attended by over 150 stakeholders, presented that 88 % of TSOs, representing 364 million people, already identified skilled workforce as a supply chain bottleneck, consistent with the findings of this survey a year later.

The European Commission's own contribution to that webinar situated the grid sector's skills gap within its broader "Union of Skills" agenda, reinforcing that a coordinated, EU-level training and qualification framework is not solely a sector-specific ask but aligned with the Commission's own strategic direction.

An eventual Net-Zero Academy for Grids would directly address two of the bottlenecks identified in this survey: the lack of visibility of the transmission sector as a career destination (Section 10.6) and the absence of standardised, portable qualifications that would support cross-border mobility of grid installation and maintenance crews.

11 Cross-Cutting Themes and Analysis

11.1 The 2028–2032 simultaneous investment peak

Across virtually every asset category in this survey, planned additions peak between 2028 and 2032. Power transformers peak in 2030; SF_6 CB additions peak in 2030; SF_6-free GIS peaks in 2031; HTLS conductor peaks in 2033; and underground DC cable demand grows steeply through 2032 – 2035. This synchronisation of peaks across categories is not coincidental.

It reflects the convergence of three structural drivers:

- Age-based replacement demand: European grid assets installed in the 1980s and 1990s are reaching end of life simultaneously across multiple asset classes.
- Regulatory forcing functions: Regulation (EU) 2024/573 creates a hard deadline for putting SF_6 switchgear into operation that synchronises with the asset replacement cycle.
- Energy transition milestones: HVDC corridors, offshore wind connections, and grid reinforcement programmes under national NECPs target 2030 as a key commissioning milestone.

The aggregate consequence is that the global electrical equipment supply chain will face simultaneous demand pressure from European TSOs across multiple product categories in the same four-to-five-year window. This concentration of demand represents a structural stress test for European and global manufacturing capacity.

11.2 The DC infrastructure

The combined underground DC and submarine DC demand of approximately 34,000 conductor km by 2035 represents the most acute single supply chain constraint in the survey. Meeting this demand profile without supply disruption or significant price inflation will depend on timely access to specialised HVDC manufacturing slots, which leading European suppliers report are booked through 2030 (see Section 6.2). The constraint is multi-layered: raw materials (copper, specialised cross-linked polyethylene (XLPE)), factory capacity, cable-laying vessel availability, port logistics, and installation crew capacity all require simultaneous expansion.

Critically, the lead time for expanding cable manufacturing capacity – through new production lines, new factories, or expanded workforce training – is itself three to five years.

This suggests that additional cable manufacturing capacity to serve demand in the early 2030s would depend on investment decisions taken in the next few years, subject to assumptions on factory utilisation, permitting, financing and technology qualification.

11.3 The dual-track switchgear transition

European TSOs plan to put both SF_6 and SF_6-free switching equipment into operation in parallel for several years: Regulation (EU) 2024/573 allows SF_6 switchgear to be put into operation until 2028 (52 – 145 kV, up to 50 kA) and 2032 (above 145 kV or above 50 kA), subject to derogations. These are not interchangeable: they require different manufacturing processes, testing infrastructure, and installation competencies. The survey shows that TSOs plan to add 1,000 – 2,200 SF_6 CBs per year through 2031 while ramping up SF_6-free CB additions from under 500 units per year today to over 1,000 units per year by 2032.

12 Data Quality and Known Limitations

12.1 Coverage gaps

Not all TSOs submitted data for all categories. Of the 27 TSOs, 15 submitted no HVDC converter data, 11 submitted no submarine cable data, and eight submitted no STATCOM data. The aggregate totals for these categories should be treated as lower bounds rather than complete figures. Coverage gaps are more prevalent in smaller TSOs, whose network characteristics may genuinely exclude certain asset types.

12.2 Structural limitations of the Investment Pipeline survey methodology

- The survey captures planned additions only. No decommissioning data was collected. Net procurement demand, calculated as additions minus retirements, would provide a more precise supply chain signal for several categories with large ageing fleets.
- The survey does not distinguish between committed projects (with regulatory approval and funding) and aspirational plans. Near-term additions (2026 – 2028) are likely to reflect confirmed programmes, while long-horizon additions (2032 – 2035) may be subject to significant revision. However, TSOs were explicitly asked to only provide information on mature projects.
- Data is aggregated to the voltage band level. Within a voltage band, project specifications vary significantly; this level of aggregation may be insufficient for manufacturer production planning for certain asset types.

13 Conclusions and Recommendations

The Investment Pipeline Survey 2026 identifies a substantial and simultaneous increase in planned transmission infrastructure deployment across Europe. The challenge is the concentration of demand across several long-lead asset categories during the same period, combined with major technology transitions, limited supplier choice in certain markets, and growing pressure on specialised engineering and installation capacity.

Three findings require particular attention.

- **First**, the expected concentration of commissioning activity between 2028 and 2032 creates a risk of competition for manufacturing slots, qualified suppliers, and skilled personnel across multiple asset categories. This risk is particularly significant for power transformers, HVDC cables and converters, large STATCOMs, and high-voltage switchgear.
- **Second**, the investment programme includes important changes in technology composition. TSOs must manage the transition from SF_6-containing to SF_6-free switchgear while maintaining existing equipment and procuring solutions for applications in which alternatives are still developing. At the same time, increased deployment of HVDC infrastructure, HTLS conductors, DLR, and dynamic reactive compensation is changing the capabilities required from manufacturers, contractors, and the TSO workforce.
- **Third**, the investment pipeline cannot be delivered through manufacturing expansion alone. Equipment production, component availability, project engineering, civil works, installation, testing, commissioning, and operational competence form an interdependent delivery chain. Capacity expansion at one stage will have limited effect if bottlenecks persist elsewhere.

The survey should therefore be understood as a strategic demand signal rather than as a forecast of annual orders or manufacturing output. Its findings point to the need for earlier coordination, better visibility on available supply chain manufacturing capacity, and more adaptable procurement and regulatory frameworks. The following recommendations are addressed to the principal actors responsible for translating the investment pipeline into operational infrastructure.

13.1 For the TSO community

Move from project-by-project procurement towards portfolio-level supply chain planning

Where national regulatory frameworks allow, TSOs should assess the combined supply chain requirements of their planned investment programmes rather than considering each project exclusively in isolation. Projects requiring similar equipment, components, or specialised personnel should be mapped together to identify cumulative demand, potential scheduling conflicts, and opportunities for earlier market engagement, common technical requirements, or framework agreements. This approach does not require all projects to be procured jointly; its purpose is to anticipate shared constraints and prevent individual projects from competing for the same limited manufacturing or installation capacity.

Portfolio-level planning could support earlier market engagement, more predictable tender schedules, framework agreements, qualification systems, and the appropriate use of options or call-off mechanisms. It could also reduce unnecessary bunching of procurement activity within individual TSOs.

This does not mean awarding contracts before investment needs are sufficiently mature. It means identifying common requirements and engaging the market early enough to understand technical readiness, capacity constraints, and realistic delivery schedules before these become critical project risks.

Increase the use of harmonised specifications and common technical requirements

Excessively prescriptive or divergent legacy specifications can reduce supplier participation, increase engineering costs, and limit manufacturers' ability to allocate production efficiently. TSOs should therefore continue developing common high-level requirements and, where appropriate, harmonised specifications for strategically important equipment.

The current collaboration[7] on HVDC specifications, cable testing, and prequalification offers a relevant model. Similar opportunities should be assessed for transformers, switchgear, reactive compensation, and other equipment categories, as repeated qualification or divergent requirements can cause unnecessary delays. This effort also relies heavily on cooperation with asset manufacturers, as they have the most up-to-date knowledge of the requirements that lead to unnecessary manufacturing delays.

Harmonisation should not remove TSOs' ability to reflect legitimate system-specific requirements. Its objective should be to establish a common technical core, with deviations limited to cases supported by network conditions, safety requirements, or other clearly identified operational needs.

Strengthen asset life cycle, refurbishment, and spare parts strategies

The investment pipeline should not be interpreted as requiring the automatic replacement of all ageing assets. Replacement decisions should also be based on asset condition, criticality, performance, system need, and the applicable regulatory framework.

At the same time, technology transitions and changing manufacturer portfolios increase the risk that spare parts, maintenance expertise, or compatible replacement components become unavailable before the end of an asset's expected operational life.

This is especially relevant for SF_6-containing equipment installed before the applicable prohibitions and for technologies experiencing lower levels of new investment.

TSOs should therefore strengthen long-term obsolescence monitoring, strategic spare-parts planning, and cooperation on refurbishment practices. The feasibility of voluntary sharing or swapping of critical equipment and spare parts between TSOs should also be explored, subject to applicable procurement, liability, security, and technical requirements.

7 ENTSO-E, EU DSO Entity, Europacable, and T&D Europe, **Roadmap towards Future-Proof Grids: EU Grid Action Plan Action 13**, June 2025

Integrate workforce capacity into investment and procurement planning

Workforce availability should be treated as part of the investment delivery chain rather than as a separate human resources issue. TSOs should identify the skills required at each stage of their investment programmes and assess whether these capabilities are expected to be available internally or through contractors.

Particular attention should be given to profiles that require long periods of training or system-specific experience, including protection and control engineers, HVDC specialists, project managers, cable jointers, commissioning engineers, and OHL specialists.

13.2 For Member States, regulators and European institutions

Use the investment pipeline to inform targeted industrial-policy measures

The survey provides evidence of the scale, timing, and technology composition of expected TSO demand. The European Commission and Member States should use this evidence, together with information on manufacturing investment and market capacity, to identify asset categories in which targeted industrial policy measures may be justified.

Relevant measures could include accelerated permitting for manufacturing facilities, support for innovation and industrial deployment, skills development, access to finance, and measures addressing critical-material or component dependencies.

For HVDC cables and converters, the principal concern emerging from the survey is access to suitable production, installation, and commissioning capacity during the years in which several large projects require delivery. Industrial-policy assessment should therefore consider the timing and technical composition of capacity, not only headline production volumes.

For SF_6-free switchgear, policy should support the timely availability and qualification of solutions across the voltage and application categories affected by Regulation (EU) 2024/573, including applications where mature alternatives remain limited.

Ensure that European manufacturing capacity is available to European grid projects

European origin requirements alone may not guarantee access to equipment manufactured in Europe. European TSOs compete with buyers in other regions for production slots from many of the same manufacturers.

As set out in ENTSO-E's paper *Procuring Europe's Energy Transition – Aligning Public Procurement with Strategic Grid Needs*,[8] the policy objective should therefore encompass both "Made in Europe" and "Sell in Europe". Where public support or other incentives are provided for European manufacturing expansion, policymakers should consider how those measures can contribute to the availability, timely delivery, and resilience of supply for European infrastructure projects, while respecting international commitments and maintaining effective competition.

Supply chains should be made resilient without delaying grid deployment, using transparent supplier-risk assessments and clear security criteria rather than broad origin-based restrictions, and preserving competition, procurement flexibility and timely delivery in a market with a limited supplier base and strong technology dependencies.

8 ENTSO-E, **Procuring Europe's Energy Transition: Aligning Public Procurement with Strategic Grid Needs**, January 2026

Adapt the procurement framework to long-lead and capacity-constrained markets

The upcoming reform of the EU public procurement framework should consider the specific characteristics and strategic and critical nature of transmission infrastructure procurement: long lead times, technically complex equipment, evolving requirements, concentrated supplier markets, and contracts extending over several years.

The revised framework should:

- Allow TSOs to apply context-specific and proportionate non-price criteria rather than uniform mandatory weightings
- Provide clearer and more workable routes for procuring innovative materials, technologies, and processes
- Strengthen legal certainty concerning functional specifications
- Allow appropriate flexibility in selecting and adapting tender procedures when market or technical circumstances change
- Clarify the boundary between substantial and non-substantial modifications of contracts and framework agreements
- Provide workable rules for adjusting long-term agreements when objectively justified changes in volumes, timing, or technical needs arise; and maintain framework agreement durations suited to the utilities sector, in line with the current eight-year limit under Directive 2014/25/EU, while allowing longer durations where objectively justified by long production lead times, supplier capacity investments, or asset life cycles
- Facilitate the sale, transfer, or swapping of publicly procured equipment and relevant call-off rights between TSOs in justified circumstances

These reforms should safeguard transparency, equal treatment, and competition. Flexibility should not be understood as a general exemption from procurement obligations, but as a means of ensuring that the applicable procedures remain workable in markets where rigid processes can lead to cancelled tenders, reduced participation, and infrastructure delays.

Improve procurement data and monitoring

The Commission should improve the completeness, comparability, and usability of procurement information available through TED, eForms, e-Certis, and related systems. Procurement data should make it possible to assess tender participation, award timelines, market concentration, and the incidence of unsuccessful or single-bid procedures in strategic infrastructure markets.

This would complement the forward-looking investment-pipeline data collected by ENTSO-E with evidence about actual market outcomes. Better data would also allow future policy measures to target demonstrated problems rather than relying on generalised assumptions about supplier availability or competition.

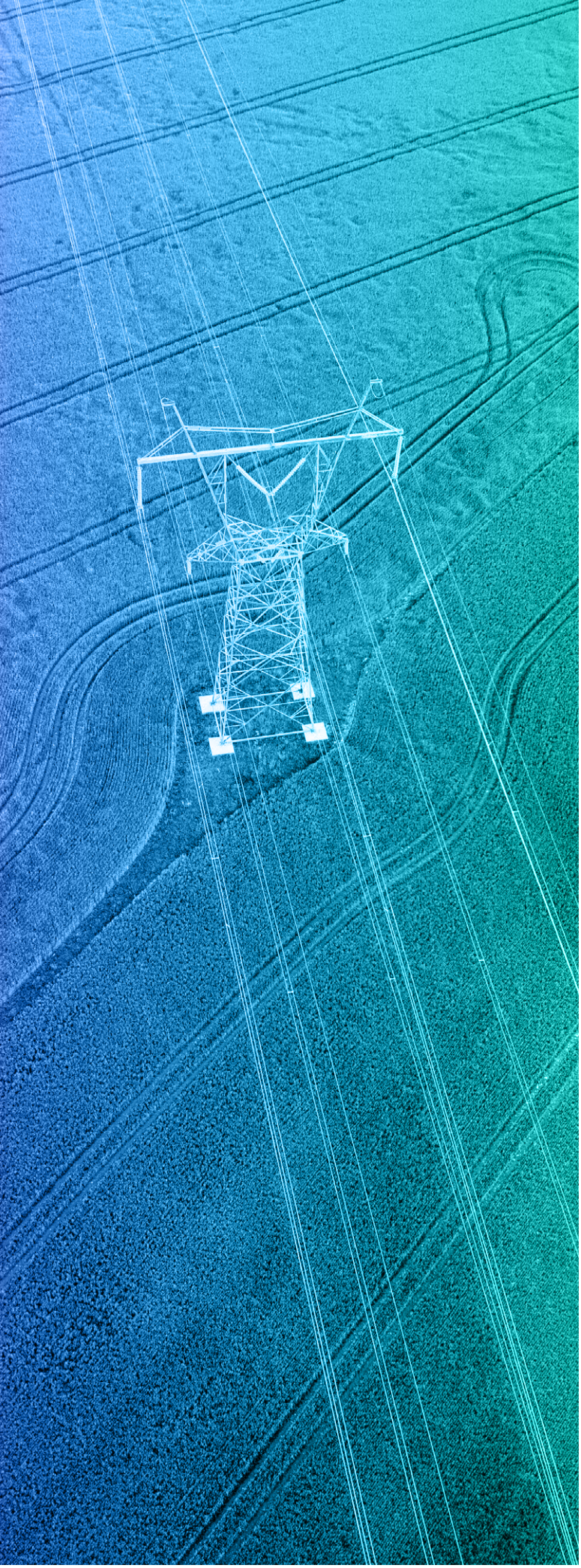
Administrative simplification should accompany improved monitoring. Information already available through trusted national or European registers should be reusable, limiting repetitive documentation and reducing barriers to participation, particularly for smaller and cross-border suppliers.

Align national regulatory frameworks with anticipatory procurement

TSOs may identify future equipment needs years before projects receive final regulatory approval or funding certainty. However, manufacturers generally require sufficiently credible commitments before investing in additional production lines, facilities, and workforce.

National regulatory frameworks should therefore allow appropriately controlled anticipatory expenditure, early procurement, and longer-term contracting where these measures are supported by system needs and reduce expected delivery risk or total project cost. Regulators should assess value over the full project and asset life cycle rather than focusing exclusively on the lowest acquisition price.

Mechanisms should include safeguards against over-procurement and stranded commitments but should recognise that waiting for complete project certainty may itself create higher costs and increase the risk that equipment is unavailable when required.



Accelerate permitting for grid optimisation and manufacturing investment

HTLS reconductoring and DLR can increase the capacity of existing corridors with more limited spatial impact than the construction of entirely new lines. Member States should establish proportionate and accelerated procedures for reconductoring, sensor deployment, and related substation adaptations when these measures do not create material additional environmental or land-use impacts.

Permitting reform should also cover new or expanded European manufacturing facilities for grid technologies and critical components. Announced industrial investment will contribute to grid delivery only if the relevant factories, production lines, test facilities, port infrastructure, and logistics capacity become operational in time to serve the investment peak.

Develop a coordinated European grid-skills initiative

The European Commission, Member States, TSOs, manufacturers, and training providers should develop a coordinated initiative for electricity-grid skills, building on the relevant EU skills initiatives and Net-Zero Industry Academies (**see the "Net-Zero Academy for Grids" proposal in Section 10.7**).

The initiative should focus on occupations where competence is specialised, training periods are long, or cross-border deployment is constrained. Priorities should include:

- Common competence profiles for selected grid occupations
- Mutual recognition or portability of relevant qualifications
- Expanded vocational and technical training capacity
- University and industry partnerships
- Conversion and reskilling programmes for adjacent sectors
- Increased visibility of grid careers at the secondary-school, vocational, and university levels

A European initiative should add scale and mobility to national programmes while leaving responsibility for recruitment, employment conditions, and detailed training delivery with the appropriate national and sectoral actors.

13.3 For manufacturing and supply chain stakeholders[9]

Provide greater visibility on capacity, lead times, and investment conditions

Within the limits of EU competition law, manufacturers and suppliers could provide indicative lead-time ranges, production-capacity developments, technical qualification constraints, and critical dependencies.

This dialogue could help distinguish between aggregate capacity announcements and capacity that is technically suitable and available for particular voltage levels, configurations, and delivery periods. It could also identify the degree of demand visibility or contractual commitment required for manufacturers to proceed with additional investment.

Tier 1 asset manufacturers could share long-term demand forecasts and production expectations with Tier 2 and Tier 3 suppliers. This is because a critical bottleneck could occur at the level of a subcomponent of a critical asset. Without sufficient long-term visibility, Tier 2 and Tier 3 manufacturers may struggle to justify the necessary investment in production or workforce capacity.

Align capacity expansion with the composition and timing of demand

Manufacturing strategies could take into account not only total expected volumes but also the concentration of demand in particular years and the changing composition of TSO requirements. Relevant examples include the parallel demand for SF_6-containing and SF_6-free switchgear during the transition period, the growth of high-voltage DC cable and converter projects and increasing demand for large dynamic reactive-compensation equipment.

Investment in final-asset production could be accompanied by corresponding attention to critical components, testing capacity, engineering resources, logistics, installation, and commissioning. Expansion of one part of the supply chain will not resolve delivery constraints when another stage remains capacity limited.

Support voluntary harmonisation, standardisation, efficient qualification and interoperability

Manufacturers could collaborate with TSOs, testing bodies, and standardisation organisations to identify areas where common requirements and the mutual acceptance of relevant test results could reduce duplication and accelerate project deployment, all while bearing in mind asset quality and high grid reliability. The goal could be to remove repeated processes that do not provide proportionate additional assurance, particularly when the same platform or component is supplied to several TSOs. Manufacturers could also identify opportunities for modularity, standard interfaces, and design families that can accommodate TSO-specific requirements without requiring a fully bespoke solution for every project.

Provide credible life cycle and obsolescence plans

For equipment affected by technology or regulatory transition, manufacturers could provide customers with credible information on expected product support, spare-parts availability, maintenance capability, and end-of-life services. For SF_6-free equipment, this should include transparency regarding insulating technologies, relevant material dependencies, and the implications of possible future chemicals regulation. For existing SF_6-containing equipment, it could include long-term maintenance, gas-handling, and spare-parts strategies for assets expected to remain in service for several decades.

9 All recommendations involving the exchange of information between market participants are subject to EU competition law, and any such exchange should be limited to what is necessary and, where appropriate, aggregated or anonymised.

Expand workforce capacity alongside production capacity

Manufacturers and contractors could align investment in factories and production lines with investment in engineering, installation, testing and commissioning skills. Joint training programmes with TSOs, universities and vocational institutions could be developed for profiles that are scarce across the entire sector.

Longer-term contracting and improved demand visibility can support such investment by giving suppliers a clearer basis on which to recruit and train additional personnel.

13.4 Final outlook

Europe's transmission investment challenge is not a series of isolated equipment shortages. It is a system-wide delivery challenge in which manufacturing capacity, critical components, technology qualification, procurement, permitting, financing, installation capability, and skilled personnel must align within the same time frame. Progress in one area will not compensate for persistent constraints elsewhere: additional factory capacity will not accelerate deployment without qualified products and installation teams, while faster permitting or procurement will have a limited effect if suitable production slots and technical expertise are unavailable.

The unique value of the Investment Pipeline Survey lies in making this combined challenge visible. By bringing together TSO-reported data across asset categories, voltage levels, regions, and years, the report provides a forward-looking view of the scale, composition, and timing of Europe's transmission equipment needs that cannot be obtained from individual project announcements alone. It reveals where demand is concentrated, where major technology transitions overlap, and, most importantly, where several asset classes will compete simultaneously for the same industrial, financial, and human resources. Although the figures should not be interpreted as a precise schedule of orders or commissioning, they provide a common evidence base against which investment decisions, procurement strategies, industrial-policy measures, and workforce initiatives can be tested.

This visibility could help inform action by all stakeholders. The report may offer manufacturers a clearer basis for assessing future market needs; it could help TSOs identify shared vulnerabilities and opportunities for coordination, and it could provide policymakers and regulators with evidence to target interventions where they can have the greatest effect. Repeated over time and combined with dialogue on manufacturing, installation, and workforce capacity, the survey can become an early-warning mechanism, tracking whether emerging constraints are easing, shifting between asset categories, or beginning to affect project delivery.

The survey results tend to show that the scale of Europe's grid ambitions is matched by an equally significant delivery challenge. This report contributes to addressing that challenge by providing a shared, forward-looking evidence base on the timing and composition of TSO demand. Used alongside project-level planning, market information, and continued stakeholder dialogue, it can support earlier identification of emerging constraints and better-informed decisions across the delivery chain. Its value could ultimately lie in helping stakeholders anticipate where coordination may be needed before individual constraints develop into wider bottlenecks.

List of Abbreviations

This list covers abbreviations and acronyms used in the report. Where an abbreviation refers to a specific regulation or ENTSO-E work product, a brief explanatory note is included.

Abbreviation	Full term	Notes
AC	Alternating Current	
ACSR	Aluminium Conductor Steel Reinforced	Standard overhead line conductor type
AIS	Air-Insulated Substation	
CB	Circuit Breaker	
DC	Direct Current	
DLR	Dynamic Line Rating	Technology enabling real-time adjustment of overhead line capacity based on ambient and/or conductor conditions
DSO	Distribution System Operator	
EHV	Extra High Voltage	Typically 245 kV and above
ENTSO-E	European Network of Transmission System Operators for Electricity	
EU	European Union	
FACTS	Flexible Alternating Current Transmission System	Family of power electronics-based devices used for reactive power and voltage control
GIS	Gas-Insulated Switchgear	
HTLS	High-Temperature Low-Sag	Conductor technology characterised by its ability to operate conductors at elevated temperatures while maintaining a safe sag range
HVDC	High-Voltage Direct Current	
IGBT	Insulated Gate Bipolar Transistor	Power semiconductor device used in HVDC converter valves
MVA	Megavolt-Ampere	Unit of apparent power in an electrical circuit; used for example in the power ratings of transformers and STATCOM
NECP	National Energy and Climate Plan	Strategic plans submitted by EU Member States under the Energy Union Governance Regulation (EU) 2018/1999
NZIA	Net-Zero Industry Act	Regulation (EU) 2024/1735 establishing targets for European manufacturing capacity in net-zero technologies, including grid infrastructure
OHL	Overhead Line	
PCI	Project of Common Interest	Category of priority cross-border energy infrastructure projects under the TEN-E Regulation (EU) 2022/869
PMI	Project of Mutual Interest	Category of priority energy infrastructure projects involving third countries under the TEN-E Regulation (EU) 2022/869
PST	Phase Shifting Transformer	Transformer used for controlling power flows on meshed AC networks
SF_6	Sulphur Hexafluoride	Greenhouse gas used as electrical insulation and as arc extinguisher in switchgear; subject to phase-out under Regulation (EU) 2024/573
SSSC	Static Synchronous Series Compensator	FACTS device used for series reactive power compensation on AC lines
STATCOM	Static Synchronous Compensator	Power electronics-based device for dynamic reactive power and voltage support
SVS	Static VAR System	Legacy reactive power compensation system; predecessor technology to STATCOM
TEN-E	Trans-European Networks – Energy	EU regulatory framework governing cross-border energy infrastructure; see Regulation (EU) 2022/869
TF	Task Force	
TSO	Transmission System Operator	
TYNDP	Ten-Year Network Development Plan	Biennial ENTSO-E publication providing a pan-European view of network investment needs; the Investment Pipeline Survey 2026 provides asset-level input to the TYNDP
VAR	Volt-Ampere Reactive	Unit of reactive power
VSC	Voltage Source Converter	Converter technology used in modern HVDC systems, enabling independent active and reactive power control
XLPE	Cross-Linked Polyethylene	Insulation material used in high voltage underground and submarine power cables

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