IIGCC

Grids: Primer

Understanding key climate related risks and opportunities

August 2025

Part of the Engage Series

Contents

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Executive summary

Grids — electricity networks that transport power from generators to consumers — are becoming a major bottleneck to reaching net zero. Renewable generation and electrification are arguably the most important decarbonisation levers and both hinge on expanded and modernised grids. The consequences of this bottleneck are already visible: existing renewable generation is being curtailed, and the connection of new capacity is being delayed. In 2024, renewable capacity in advanced development stages waiting for grid connection reached 1,650 gigawatts (GW) globally — almost a quarter of the additional capacity required to meet the 2030 COP28 tripling renewables goal.

A key issue is underinvestment. While investment in renewable generation has more than doubled since 2015, grid spending has risen just 24%. To stay on track for net zero, the International Energy Agency (IEA) estimates that annual grid investment must double by 2030. But the answer is more than just additional capital — outdated permitting and planning policies must be reformed, and acute supply chain and labour shortages addressed.

Grid operators — which are often part of integrated electric utilities — must address this net zero imperative whilst also balancing energy security, affordability, and resilience objectives. In emerging markets over 700 million people still lack reliable power access. Meeting these multiple objectives requires system solutions: often the most cost-effective solutions to network challenges rest with enhancing demand-side or supply-side flexibility.

Policymakers, especially in Europe, are increasingly recognising the scale of the challenge. Initiatives such as the EU's Grid Action Plan aim to double annual grid investment by 2030, streamline permitting and accelerate infrastructure upgrades. National regulators are beginning to adopt net-zero mandates and reform incentive structures to catalyse investment. Yet implementation remains uneven, and regulatory frameworks often fail to reward cost-effective grid-enhancing technologies (GETs).

There is a role for investors in addressing these challenges. As capital providers, they can help the industry meet its funding needs. Through engagement of portfolio companies across sectors and policy advocacy, they can also contribute to solving some of the complex issues at hand.

About this Primer

Grids: Primer is the first resource of IIGCC's Engage Series to be published. The series provides practical resources to support investors as they consider how best to engage, in their own individual contexts, with major stakeholders on key themes and sectors.

This document provides useful context for investors seeking to engage with grid stakeholders. It outlines the critical role these stakeholders can play in achieving net zero, the technical and policy challenges they face and the competing objectives they must balance. Six key barriers to accelerating grid deployment and modernisation are identified. While much of the analysis is based on European examples, reflecting the engagement focus of IIGCC members, the issues highlighted are expected to be increasingly relevant as other regions advance their decarbonisation journeys.

Grids: Primer is accompanied by *Grids: Tool for engagement*, which provides specific questions investors looking to accelerate progress around grid deployment and modernisation may wish to ask policymakers and regulators.

1. Why investors should care about grids

1.1 Grids and the economy

Grids are the backbone of modern economies. From healthcare to digital services, the electricity they transport enables almost all economic and social activities. Yet arguably their role remains underappreciated. The expectation of uninterrupted electricity is such that only its absence triggers a prominent discussion of their role. The Iberian blackout in April 2025 highlights the acute social and economic impacts of power system failures.

In emerging markets, expanding and upgrading grid infrastructure is seen as essential to unlock development. For many countries limited, or unreliable electricity, remains a major barrier to both improving living standards and economic growth. More than 700 million people still lack access to electricity, with more than 80% of that number being in Africa.[1]

Grids are likely to become even more vital in the future. Rising electrification and the need to integrate low-cost renewable generation mean they will need to expand. Maintaining energy security requires a system that meets an ever-greater demand load with an increasingly variable supply. Network costs can account for around a third of electricity costs, depending on the region, so this expansion must be cost effective to maintain economic competitiveness.

1.2 Investors and net zero

Climate change poses significant financial risks and opportunities for institutional investors. Consistent with their fiduciary duties to manage these, many are working to align their investment portfolios with net zero. The most used framework to set net zero targets and develop strategies is the Net Zero Investment Framework (NZIF).

Stewardship

Stewardship through policy advocacy and corporate engagement is a key lever within NZIF to drive real economy change. Working both individually and through initiatives such as Climate Action 100+ and IIGCC's Net Zero Engagement Initiative (NZEI), many investors are engaging with electric utilities. These conversations have historically focused on decarbonising power generation, but many also operate grids. There is growing recognition that grid constraints represent a barrier to both their transition and that of the economy more broadly.

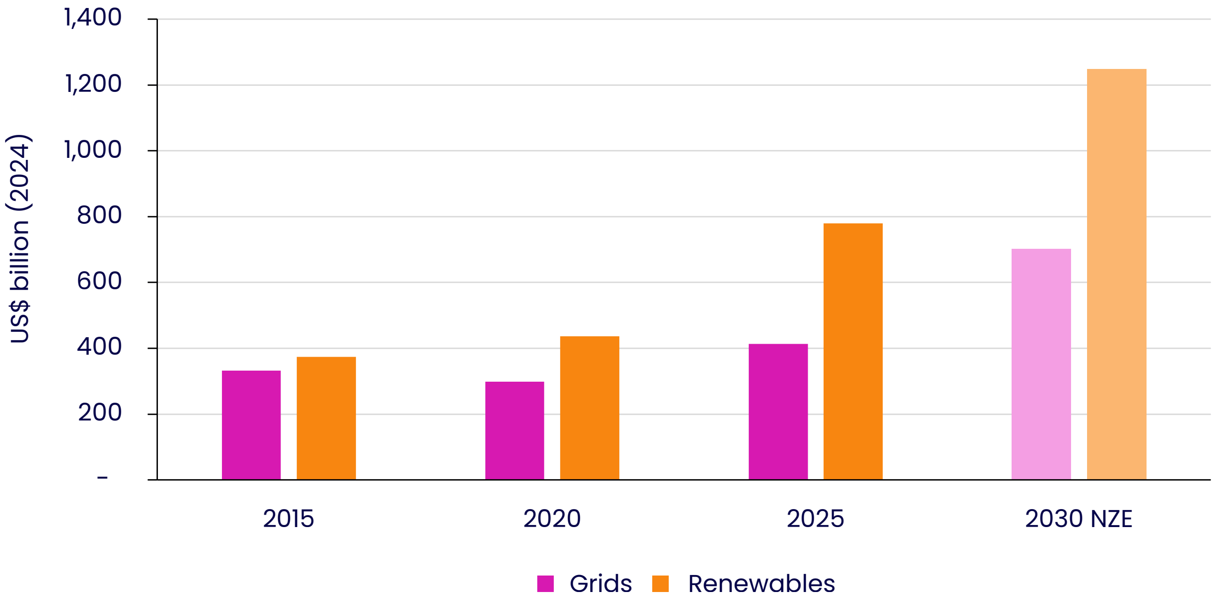
As grids are heavily regulated natural monopolies, investor stewardship can involve **both** corporate engagement with utilities/grid operators and systems engagement with policymakers and regulators. Investor engagement could support the development and implementation of policies that encourage greater grid investment.

1.3 The investment required

Scaling up investment in climate solutions[i] is one of NZIF's two portfolio level objectives. According to the IEA's Net Zero Emissions by 2050 (NZE) scenario, grids account for almost 15% of the incremental $2.5 trillion annual investment in all climate solutions required by 2030 (compared to current levels). Grid investment needs to increase by around 75% from 2025 levels to more than $700 billion,[2] making it a transition priority and a potential opportunity for investors.

The size of the grid funding gap becomes clear when comparing investment in grids and renewable energy. In 2015, grids and renewables received around $350 billion of investment each. Since then, investment in renewables has more than doubled whilst grid investment is only up 24%. There is a big regional difference for grid investment, which grew by 69% in advanced economies over the past 10 years, whereas emerging markets and developing economies saw an 8% decrease.

Figure 1: Annual global investment in grids and renewables, 2015 to 2030



Source: IEA.[3] Note: Investment is presented in real 2024 US dollars, adjusted for inflation using country-level GDP deflators and 2024 exchange rates. 2030 NZE data have been adjusted by IIGCC, as they were originally published in real 2023 US dollars.

According to the IEA, for every dollar spent on new generation (all sources) capacity in 2016 about $0.60 was invested in grids; today, that number has declined to less than $0.40. This is despite declining costs for renewables and increasing costs for transformers and cables. Plugging this funding gap will require support by investors; from both dedicated infrastructure investors and owners of electric utilities.[4] This report does not cover grid financing but, subject to member interest, IIGCC expects to produce further work on this in due course.

i Defined as 'activities, goods or services that, according to credible pathways, need to increase substantially to enable the global economy to reach net zero'.

2. Grids 101

2.1 The role of grids in decarbonisation

Electrification is expected to be the biggest driver of delivering net zero. In the IEA's NZE, deep decarbonisation of the transport, heating and industrial sectors results in electricity's share of global final energy consumption rising from 20% in 2022 to almost 30% in 2030 and more than 50% in 2050.[5] Combined with economic development, population growth and data centre expansion, this is expected to drive an acceleration in demand for electricity. In the last decade, global electricity generation grew by 2.5% per year on average. In 2024, it rose by 4.3% (outpacing expectations) and is forecast to continue to grow at close to 4% out to 2027.[6] In the NZE Scenario, it is expected to grow 3.5% per year between 2022 to 2050 (a 2.5x increase in total).

Grids will clearly need to expand to meet this demand. Yet, the lag in investment has seen increased network congestion in many countries, resulting in curtailment of existing renewable generation. Lack of investment is also delaying the connection of new renewable projects. In 2024, the generation capacity of advanced projects awaiting connection grew 10% to 1,650 gigawatts (GW) — almost a quarter of the additional capacity required to meet the COP28 tripling renewables goal by 2030.[7]

The IEA has estimated the emissions impact of delaying this investment. In its Grid Delay Case, failing to deliver grid infrastructure in a timely manner (and holding all else equal) doubled global coal and natural gas use demand by 2050 relative to its Announced Pledges Scenario (APS), which reflects national climate targets. The difference is even more pronounced in the European Union (EU). Globally, cumulative CO2 emissions from the power sector to 2050 would be 58 gigatonnes higher in the Grid Delay Case than in APS.[8]

But the significance of grid infrastructure to decarbonisation reaches beyond the power sector, of course. For example, adequate public charging is needed to extend electric vehicle (EV) ownership and usage. The substitution of fossil fuels for both industrial and residential heat requires additional network capacity.

Solutions to this bottleneck extend beyond additional capital and network deployment. Often, managing the utilisation of existing grids — through more efficient operation, such as increased flexibility and higher energy efficiency — needs to be adopted. A system approach requires considering demand-side responses and other forms of flexibility, such as interconnection or storage. These approaches often deliver lower overall system costs but require coordination with multiple stakeholders.

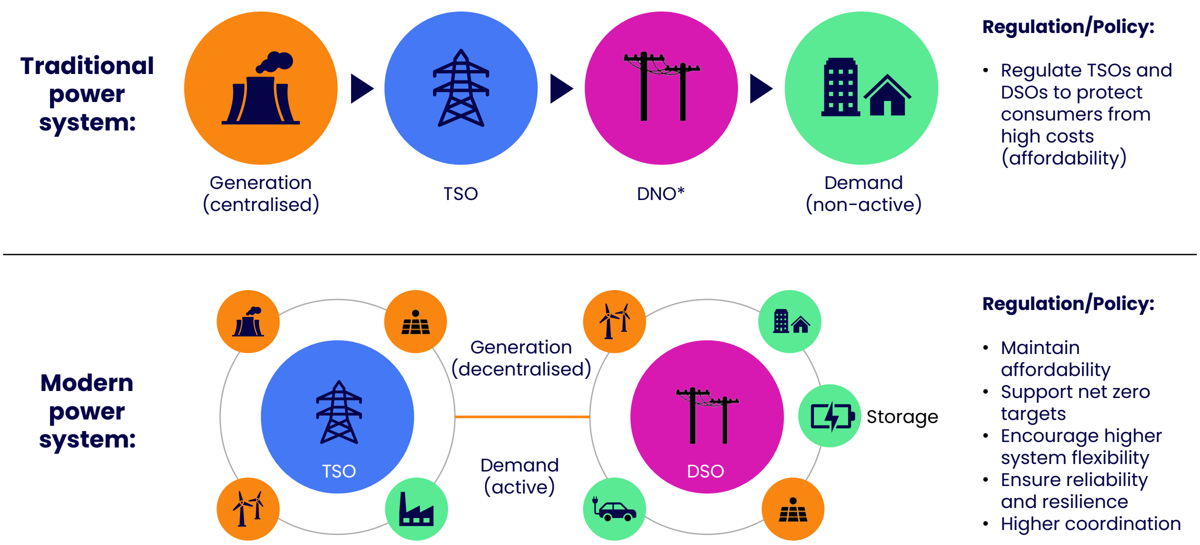
2.2 How key grid components are evolving

Grids consist of power lines, substations, and control systems designed to move and balance electricity between generators and demand. Typically, they comprise two main elements:

1. **Transmission:** power is transported over long distances at high voltage (>132 kV in the UK) to minimise losses.[ii] Transmission networks typically connect centralised generation, large-scale renewable projects, major industrial consumers, and the transmission systems of neighbouring regions and countries (interconnectors).
2. **Distribution:** power is stepped down to medium and low voltages (<132 kV in the UK) using transformers and delivered through local distribution networks to homes, businesses, and smaller industrial users, enabling safe end-use consumption.

Decarbonisation is prompting a significant transformation in their role. Historically designed for relatively predictable, one-way power flow from large, centralised power plants, grids now must accommodate variable renewable energy (VRE) sources like wind and solar, which are often decentralised. Eurelectric estimates that 70% of future renewable generation and storage in the EU will be connected to the distribution grid.[9]

Figure 2: The grid evolution



Source: Adapted from Eurelectric.[10] Note: TSO: Transmission System Operator, DSO: Distribution System Operator. Historically, DSOs were known as Distribution Network Operators (DNOs), reflecting their original role as passive owners and maintainers of physical infrastructure. As the grid evolves, DNOs are transitioning into DSOs, taking on more active responsibilities in managing distributed energy and system flexibility.

VRE generation reduces predictability and introduces new diurnal (daily solar-driven) and seasonal cycles (winter wind-driven). This makes flexibility essential via supply — side options such as interconnectors and batteries, as well as demand-side response from households, commercial, and industrial consumers.

This increased complexity requires grids to evolve from a passive element of the power system to a much more active and central role. They are becoming increasingly digitalised, with advanced monitoring and automation enabling smarter network management. The increasing interdependence between transmission and distribution networks requires closer coordination and planning, while new grid-enhancing technologies (GETs) are being deployed to boost capacity and resilience.

ii Transmitting power at higher voltage reduces losses because it allows the same power to be delivered with lower current. Power loss due to resistance is proportional to the square of current (Ploss =I2R), lower current means significantly less energy lost as heat.

2.3 The multi-stakeholder landscape

The development of electricity networks is shaped by a diverse set of stakeholders operating at local, national, and regional levels (such as the EU in Europe). These include grid operators, energy regulators, policymakers, power generators, and local authorities. Their roles and responsibilities vary across jurisdictions depending on regulatory frameworks, market structures and their ownership.

In many developed countries, grid operators are part of integrated utilities that manage multiple parts of the electricity value chain. For example, Enel operates across generation, distribution, and retail in Europe, while National Grid is active in both transmission and distribution in the UK. Investors seeking to engage with this sector must grapple with this complexity and these different ownership structures.

Transmission networks

In many European countries, the transmission network is controlled by a single entity. For example, RTE in France, Terna in Italy and REE in Spain control almost all the country's transmission network. However, there are four Transmission System Operators (TSOs) in Germany (TenneT, Amprion, 50Hertz, TransnetBW) and three in the UK (National Grid, SSEN, Scottish Power). The ownership of TSOs varies: RTE and TenneT are fully state-owned; Terna and REE are publicly listed with significant state ownership; and National Grid and SSE are fully publicly listed with negligible or no state ownership. TenneT, who is also the TSO in the Netherlands, is owned by the Dutch government, is currently seeking to sell its German subsidiary to attract more private capital.[11]

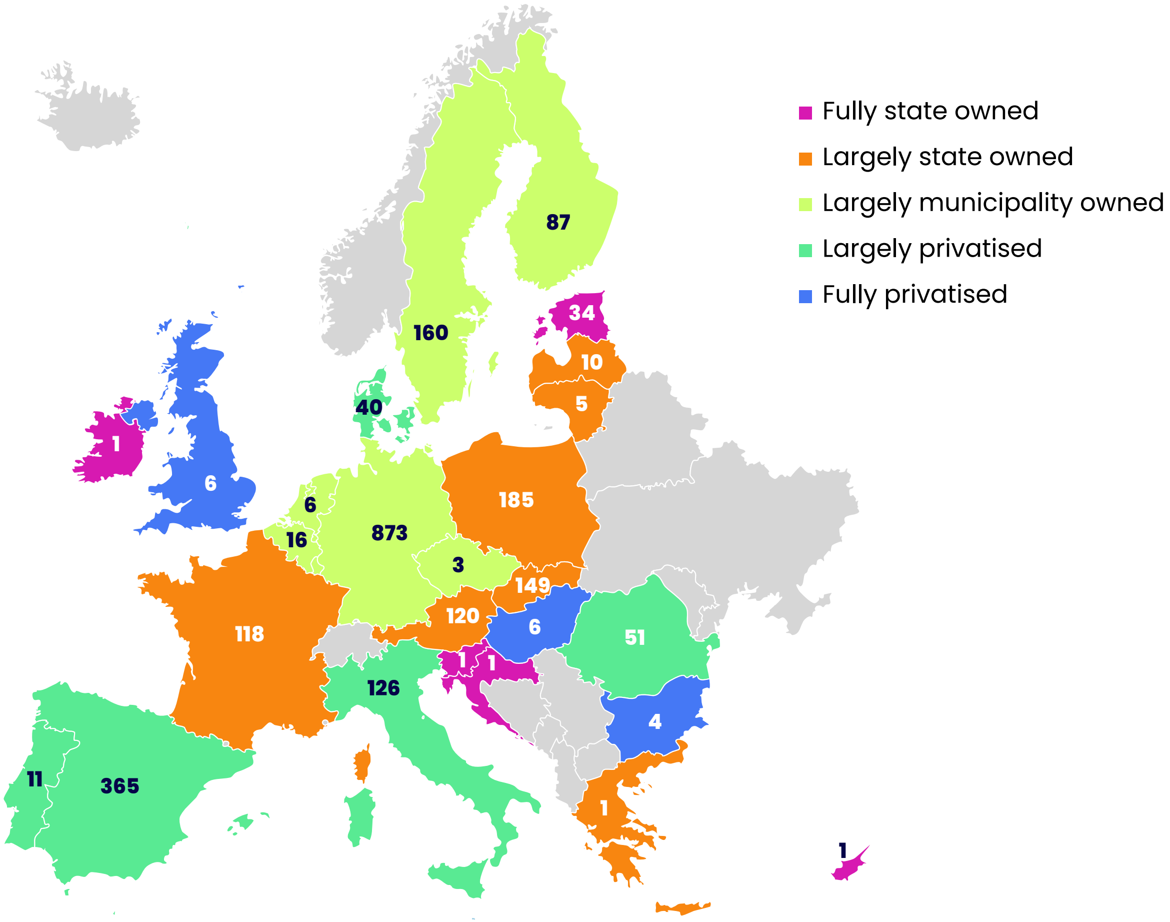
Distribution networks

Distribution is generally more fragmented. Germany has hundreds of smaller, municipality-owned distribution system operators (DSOs), each with a small share of the overall market. Despite the presence of more than 100 DSOs, markets such as France, Spain, and Italy are relatively concentrated. Enedis (95%) in France, Endesa and Iberdrola (90%) in Spain, and Enel subsidiary e-distribuzione (85%) in Italy control most of the distribution network (see Table 1). As shown in Figure 3 below, ownership of DSOs also varies significantly, ranging from fully state-owned to fully privatised (listed and unlisted). This variation in ownership structure affects how effectively investors can engage with these entities.

Table 1: Grid operators in in Europe's five biggest power markets

Country	Main TSO(s)	Main DSO(s)
France	▪ RTE (EDF subsidiary)	▪ Enedis (EDF subsidiary, ~95% coverage)
Germany	▪ 50Hertz ▪ Amprion ▪ TenneT ▪ TransnetBW	▪ E.DIS (E.ON group) ▪ Westnetz (E.ON group) ▪ Avacon (E.ON group) ▪ Bayernwerk (E.ON group) ▪ Netze BW (EnBW group)
Italy	▪ Terna S.p.A.	▪ e-distribuzione (Enel group, ~85% coverage) ▪ Areti (Rome) ▪ Unareti (Milan)
Spain	▪ Red Eléctrica de España (REE)	▪ i-DE (Iberdrola group) ▪ e-distribución (Endesa group) ▪ UFD (Naturgy group)
UK	▪ National Grid Electricity Transmission ▪ Scottish Power Transmission ▪ SSEN Transmission	▪ UK Power Networks ▪ SSEN Distribution ▪ Electricity North West ▪ Northern Power Grid ▪ National Grid Electricity Distribution

Figure 3: EU and UK DSOs, number and ownership structure



Source: Adapted from Bruegel[12]

National regulators

Regulation and policy play a central role in electricity distribution. Energy markets are typically regulated by National Regulatory Authorities (NRAs) with mandates to ensure fair competition, affordability and reliability. As networks are typically natural monopolies, this cannot be achieved by market mechanisms alone. Most countries use a Regulated Asset Base (RAB) model — the value of network assets owned by the T/DSO – to determine permitted returns. This return will reflect Weighted Average Cost of Capital (WACC) or a predefined Rate of Return (RoR) and may inform revenue or price caps which T/DSOs can charge for transmission services (see Table 2 for details).

As the regulatory structure directly influences grid operators' cash flows, investment planning, and exposure to policy risk, understanding it is crucial. While RAB-based frameworks offer predictability, the rate-setting methodology, incentives, and efficiency targets vary across jurisdictions. The table below summarises the key NRAs, regulatory models, and responsible ministries in Europe's five largest power markets.

Table 2: Regulators and policymakers in Europe's five biggest power markets

France	**NRA:** CRE - Uses a RAB-based revenue cap model with ex-ante setting of tariff evolution and investment incentives; introduces performance incentives for DSOs to deploy smart-grid capabilities. **Policymaker:** Ministry of Ecological Transition - Defines France's energy pathways.
Germany	**NRA:** BNetzA – Applies a revenue cap model across TSOs/DSOs, with detailed asset valuation via a RAB, WACC framework, and efficiency benchmarking. **Policymaker:** BMWK – Defines national energy and climate strategy, including Energiewende support mechanisms.
Italy	**NRA:** ARERA – Operates under the ROSS model, linking allowed return to RAB and monitoring actual investments to adjust returns; sets quality-of-service incentive tariffs. **Policymaker:** MiTE – Steers Italy's energy and environmental policy and grid modernisation plans.
Spain	**NRA:** CNMC – Follows a revenue-cap/RAB approach with periodic WACC and RAB value reviews; incentivises smart metering and network digitalisation. **Policymaker:** MITECO – Develops climate and energy policy and coordinates grid expansion within EU frameworks.
UK	**NRA:** Ofgem - Utilises the RIIO-2 framework (2021–2026) with revenue caps, incentive mechanisms for reliability, decarbonisation, and innovation, and defined Return on Regulated Equity (RoRE) ranges. Other stakeholders: DESNZ - Sets overarching energy/climate policy and net-zero targets (e.g. Clean Power 2030). NESO - Supports the energy system by bringing together planning, connections and six other priority activities.

Source: CEER[13]

As discussed in Section 3 and 4.1, the regulatory landscape continues to evolve in response to decarbonisation and changing policy goals. Regulators are introducing new mechanisms to accelerate investment, enhance innovation, or reward flexibility.

Other policy stakeholders

In Europe, entities such as ENTSO-E (the European Network of Transmission System Operators for Electricity), ACER (the Agency for the Cooperation of Energy Regulators), and CEER (the Council of European Energy Regulators) play a key role in system coordination, regulatory alignment (i.e. harmonising market rules and standards across countries), and infrastructure planning at the regional level. ENTSO-E publishes the Ten-Year Network Development Plan (TYNDP),[14] which provides a pan-European perspective on transmission needs and cross-border projects.

Local authorities, municipalities, and communities are increasingly involved in distribution-level investments, infrastructure siting, and permitting — factors that can significantly influence project delivery timelines.

3. European Union policy overview

3.1 Pre-existing policy environment

The EU has seen a surge of grid-related policy developments in recent years, reflecting the urgency of aligning infrastructure with its climate, energy security and economic competitiveness goals. The bloc has legally binding targets to reach net zero by 2050, cut emissions by 55% by 2030 from 1990 levels, and has proposed a 90% reduction by 2040. Power sector decarbonisation and increased electrification across the economy are key to meeting these goals.

To support this, the EU has set several energy sub-targets. The revised Renewable Energy Directive (RED III), adopted in 2023, raises the EU's binding renewable energy target to at least 42.5% of gross final energy consumption by 2030, up from 24.5% in 2023. While RED focuses on renewable generation, it directly affects grids: higher shares of variable, decentralised sources like solar PV and wind require an expanded and flexible grid. RED III includes provisions to accelerate permitting for renewables, through the designation of 'go-to' areas, which will need timely grid upgrades.[15]

At the national level, several countries have set even more ambitious power sector decarbonisation timelines. For example, Germany, Denmark and the Netherlands aim for full decarbonisation by 2035 (while the UK targets a net-zero electricity system by 2030). These timelines increase pressure on NRAs, TSOs, DSOs to scale up and modernise grids.

Recognising the need for greater network integration, the EU has set a 2030 interconnection target of at least 15%. This means each country should have infrastructure to import/export electricity equal to 15% of its generation capacity. By early 2025, 14 countries had met the target, five exceeded 10%, and eight remained below.[16]

The EU's Grid Action Plan, launched in late 2023, aims to support these goals by accelerating grid investments and addressing transmission and distribution bottlenecks. These include delays in connecting renewables, limited cross-border capacity, and congestion in high-renewables areas. The plan calls for doubling annual grid investment by 2030 and streamlining permitting for critical projects.[17]

These reforms build on the 2022 revision of the Trans-European Networks for Energy (TEN-E) regulation. The updated framework prioritizes Projects of Common Interest (PCIs) that enhance cross-border energy flows, integrate renewables, and improve energy security.[18] Funding for these projects through the Connecting Europe Facility (CEF) has also been expanded, providing financial backing for key initiatives such as offshore wind grid hubs in the North and Baltic Seas.[19]

3.2 Initiatives under the second von der Leyen Commission

The European Commission, under President Ursula von der Leyen's second term beginning in December 2024, has made grid development and system flexibility central to achieving the EU's decarbonisation and energy security goals.

The flagship Clean Industrial Deal (CID), published on 26 February 2025, positions decarbonisation as a growth driver for European industry and emphasises access to affordable, clean energy.[20] It aims to accelerate the shift to domestically generated, efficiently used, clean energy through a more integrated EU energy market. Key goals include raising the EU's electrification rate[iii] from 21.3% to 32% by 2030 and installing 100 GW of renewable electricity annually through 2030 — about one-sixth of the EU's total installed renewable capacity in 2023 (630 GW). While not legally binding, these targets carry weight due to the CID's political prominence.

To support implementation, the Commission released the Affordable Energy Action Plan alongside the CID in February 2025.[21] The action plan sets out the specific steps to achieve the CID's clean energy objectives and places strong emphasis on the need for EU countries to swiftly and fully implement existing EU electricity legislation. As of June 2025, most Member States have transposed some elements of the revised Electricity Market Design into national law, including connection queue reforms.

However, implementation remains uneven, especially in areas like distribution grid digitalisation, capacity transparency, and permitting. The action plan identifies grids and interconnectors as critical enablers of the energy transition and industrial decarbonisation. The Commission commits to accelerating grid expansion, modernisation, and cross-border links through a European Grid Package, to be proposed by Q1 2026.

In June 2025, the Commission issued guidance on anticipatory grid investments, highlighting the need for €1.2 trillion in transmission and distribution upgrades by 2040.[22] It calls on NRAs to define anticipatory investments, apply upfront cost-approval and return rules, and consider two-step approvals to speed up delivery. Member States are urged to set connection deadlines with penalties and use tools such as public funding or guarantees to limit tariff impacts. These recommendations are expected to inform the upcoming European Grid Package.

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iii The electrification rate is the share of final energy use met by electricity. Increasing it can shift more energy demand — across transport, heating, and industry — toward electricity, encouraging higher renewable energy deployment.

3.3 Upcoming policies

The upcoming European Grids Package will build on the 2023 Grid Action Plan. It will include both legislative and non-legislative measures to:

- Simplify the TEN-E Regulation
- Ensure cross-border integrated planning and delivery of projects, especially on interconnectors
- Streamline permitting
- Enhance distribution grid planning
- Boost digitalisation and innovation
- Increase visibility of manufacturing supply needs

The Commission has indicated the package will follow a top-down planning approach, integrating regional and EU interests and develop effective cost sharing mechanism (e.g. for cross-border projects), for an optimised energy system.

A key component is the Grids Manufacturing Package, launched by the European Investment Bank (EIB) under the Clean Industrial Deal. It offers at least €1.5 billion in counter-guarantees to banks and intermediaries, enabling them to underwrite performance and advance-payment bonds for EU-based grid component manufacturers. These guarantees reduce lender risk, giving manufacturers the confidence to scale up production in support of accelerated grid deployment.[23]

In addition to the Grids Package, several other upcoming policy initiatives may also impact renewables and grid development. These are summarised in the table below:

Table 3: Upcoming EU policy initiatives affecting grids

Policy	Description	Expected
European Climate Law	This Regulation will be revised to include an intermediate climate target for 2040, which will impact the EU's future renewable energy targets and grid developments post-2030.	Q3, 2025
Electrification Action Plan	This Action Plan aims to support the electrification of EU industry and incentivize their use of clean energy.	Q4, 2025
Clean Energy Investment Strategy for Europe	This strategy will aim to unlock private investment into e.g. grids and cross-border energy infrastructure.	TBC, 2025
Assess legal framework on European Grids	This assessment will determine what actions can be taken to support the upgrading and expansion of grids.	Q4, 2025
European Grids Package	The package will contain legislative proposals and non-legislative measures to accelerate the expansion, modernisation and digitalisation of grids.	Q1, 2026

4. The key issues

Based on an extensive literature review, investor dialogue, inputs from industry experts and grid operators, this section summarises the key challenges holding back the deployment and modernisation of grids.

4.1 Attracting investment through regulatory reforms

To stay on track with net zero pathways, grid investment needs to significantly accelerate. However, most NRAs still lack a clear mandate to support decarbonisation targets. In 2023, the UK government amended the Energy Bill to give Ofgem a statutory net-zero duty.[24] A net-zero mandate for other NRAs could encourage anticipatory grid investments, which proactively oversize network capacity, allowing easier future renewables' integration. Eurelectric estimates that doubling the capacity of a grid project may only increase costs by 10-20%.[25]

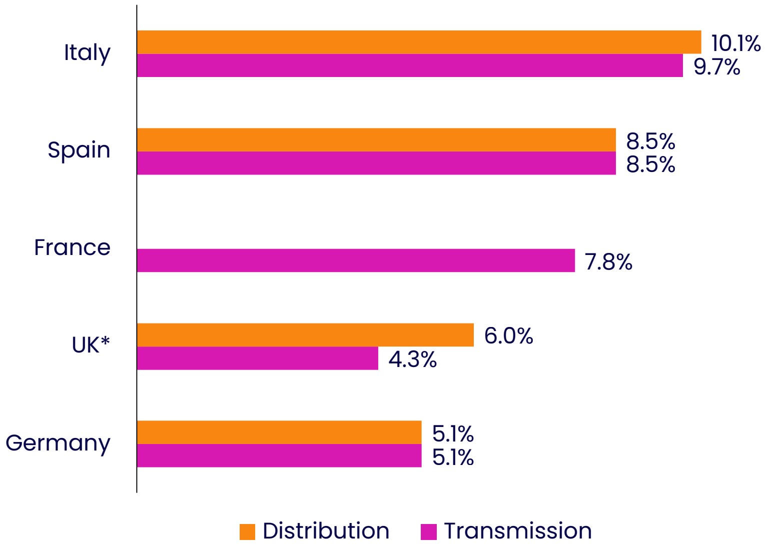
Traditional cost-based regulation often incentivised capital-intensive investment (capex), effectively rewarding spending over efficiency. As highlighted by ACER and CEER, this discourages the use of operational or digital solutions that could deliver equal or better outcomes at lower cost. For example, grid-enhancing technologies (GETs) — such as dynamic line rating — are often undervalued because they are operational costs that do not significantly increase the RAB and hence permitted returns.[26]

Modern incentive-based models — such as the UK's RIIO and Italy's ROSS — tie returns to total expenditure (TOTEX), encouraging grid operators to optimise both capital and operational costs. By linking remuneration to outcomes such as decarbonisation, flexibility, or resilience, TOTEX-based regulation helps correct the capex bias, supports the deployment of cost-effective solutions like GETs, and enables more affordable, efficient and reliable grid development aligned with the energy transition.

Regulators can also play a role in attracting private capital by ensuring the rates of return (RoR) defined by NRAs are competitive with other markets and comparable risk-adjusted investment opportunities. Across Europe pre-tax RoR on equity typically range from 5–10% in most markets as shown in Figure 4 below. However, any increase in permitted returns must take account of the importance of energy affordability.

Grid operators often have stretched balance sheets that mean they are unable to (cheaply) raise the additional capital needed to fund the incremental investment. Guarantees from governments or multilateral development banks (MDBs) could help them access capital while maintaining their 'investment grade' financial ratings and ensuring affordability for end-users.

Figure 4: Network pre-tax return on equity rates (2024) in Europe's big five markets



Source: CEER.[27] Note: UK rates are from 2023 and excludes Northern Ireland. In France, distribution assets are not remunerated via a WACC.

In the EU, the Connecting Europe Facility for Energy (CEF-E) has allocated €5.84 billion for 2021–2027 to support strategic cross-border infrastructure, including electricity, hydrogen, and smart grids.[28] Support is provided through grants, guarantees, and project bonds, often blended with private or EIB financing to crowd in additional capital. The EU Innovation Fund, expected to generate approximately €40 billion from EU ETS revenues by 2030, could indirectly support grid-related investments such as energy storage. However, stakeholders have called for simpler access procedures and larger funding envelopes.

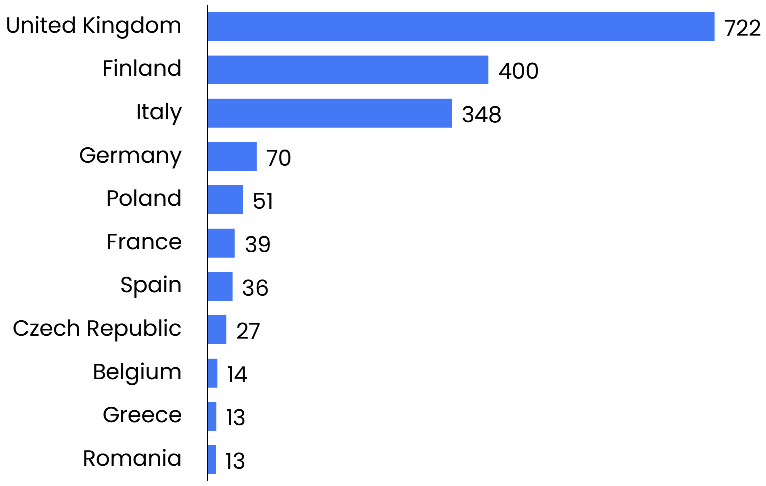
Beyond supporting the deployment and modernisation of domestic grids, regulatory frameworks need to support an increase in interconnection. In Europe many interconnectors are classified as PCIs and benefit from enhanced regulatory support.

Establishing common frameworks for cross-border financing — such as Europe's cross-border cost allocation (CBCA)[29] — ensures benefits are shared fairly between countries catalysing investment. A similar approach could accelerate the deployment of offshore hybrid assets (OHAs) — next-generation infrastructure that combines offshore wind with interconnection between multiple countries. Unlike traditional setups where offshore wind farms connect to a single national grid, OHAs bundle generation and cross-border transmission in a single project, enabling more efficient use of infrastructure and better integration of offshore renewables into the European grid.

4.2 Shortening connection queues and reducing curtailment

The global lengthening of connection queues for renewable generation is also an issue in Europe. According to BFF, over 1,700 GW of renewable projects are stuck in connection queues, almost double Europe's total installed renewable capacity —although many of these are in early stages or unlikely to be built.[30] As Figure 5 shows below, there is a large variation in queue size by country.

Figure 5: Grid connection queues (GW) for renewable and hybrid projects in Europe



Source: BFF[31]

These queues are often the result of speculative renewable projects, a first-come, first-served approach and limited visibility on the grid's available capacity at specific locations. Ofgem's recent connection reforms in the UK aim to address this by prioritising strategic projects and mandating that applicants meet specific milestones to progress in queues.[32] Furthermore, grid operators are providing information about the network's available capacity to project developers using grid hosting capacity maps — with attempts being made by the EU to harmonise these.[iv]

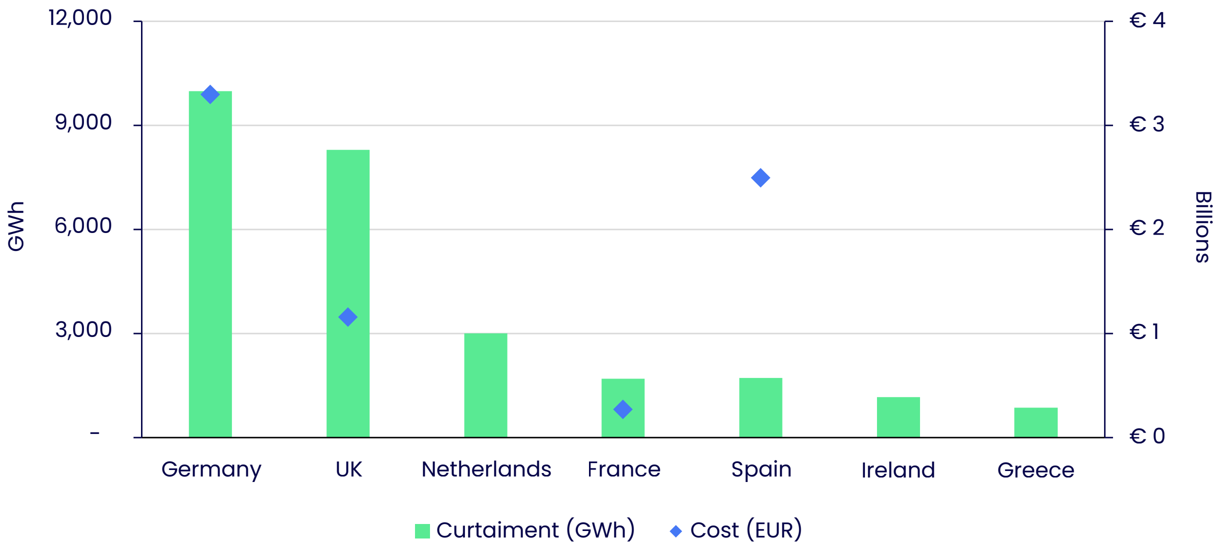
Grid congestion — when transmission capacity is insufficient to carry all electricity from where it is generated to where the demand is — often forces operators to curtail (not use) renewable generation. Aside from driving up overall generation emission intensity, wasting this energy also raises costs as renewable generators still have to be compensated. Carbon Tracker estimates wind congestion costs across the Scotland-England boundary could surpass £3.5 billion in 2030, resulting in a near £200 increase in annual electricity bills for British households.[33] Recent curtailment data in Europe is shown in Figure 6.

There are several approaches for congestion management. For example, renewable energy zones (REZs) were introduced in Texas, Australia, South Africa and India to identify regions suitable for developing new transmission connections. Additional options include the colocation of renewables and storage (to smooth output and reduce export peaks), shared connections (where multiple generators use the same grid access point), and alternative connection contracts (non-firm grid access).[34]

iv The EU Grid Action Plan assigned two tasks to ENTSO-E and the EU DSO Entity under Action 6. Firstly, to agree on harmonised definitions for available grid hosting capacity for system operators, to enable the search for available capacity by grid users. Secondly, to establish a pan-EU overview of available grid hosting capacities by mid-2025 to give visibility to project developers.

Locational Marginal Pricing (LMP) sets prices at different grid locations based on the cost of delivering the next unit of electricity, factoring in generation costs, transmission losses, and congestion. By reflecting local grid conditions, LMP aims to promote efficient dispatch and provide clear investment signals for new generation, storage, or network upgrades where they are most needed. However, it exposes consumers and investors to locational risks and price volatility. As of June 2025, discussions for its adoption in the UK are still ongoing.

Figure 6: Total renewable curtailment volume and costs, 2023-2024



Source: BFF.[34] Note: Costs refer to curtailment payments, re-dispatch and/or counter-trading costs depending on the country. Curtailment data is limited and collected using various methodologies, which may not allow a direct comparison

Improved network planning is crucial to addressing curtailment, congestion and connection queues. Currently grid operators forecast demand using integrated scenarios to identify the energy resources needed to meet system needs. It is important that scenarios consider emissions mandates, span over appropriate time horizons and include the demand-side flexibility potential of transport, heating, and industrial sectors.

Coordination between generation, transmission, and distribution, as well as local, national, and cross-border plans can better align perspectives. While EU TSOs typically publish their network development plans (NDPs) every two years as mandated by EU Regulation 2019/943, for DSOs NDPs are less standardised. ACER has identified that the state of network planning in Europe is fragmented, with different planning approaches at different levels. At the EU-level ENTSO-E publishes joint electricity and gas scenarios aligned to EU policies, assessing how much cross-border capacity is needed with cost-benefit analysis (CBA) for candidate PCIs. However, at the national (transmission) and local (distribution) level there are no harmonised approaches for scenario development and inconsistent transparency on the system's needs assessment and project CBA, holding back grid deployment.[35]

4.3 Incentivising flexibility for system benefits

Power systems need to continuously match supply to demand (i.e. energy balancing). Energy system flexibility is the ability to adjust supply and/or demand to achieve that energy balance. Improving flexibility is seen as crucial to enabling the power system to meet the challenges of the transition. Grid capacity is sized to accommodate diurnal and seasonal peaks in demand while variation in renewable generation is typically synchronous in a specific area and time. By smoothing out these variations in demand and supply over time, flexibility can accelerate the transition and reduce overall system cost, including the need for expensive grid infrastructure expansion. There are two main forms of flexibility:

1. **Supply-side flexibility:** Historically, flexibility has primarily come from the supply side, through the ability to ramp generation up or down — most notably using gas turbines. Today, this also includes long-term energy duration storage (LDES) such as pumped hydro and batteries which can absorb excess electricity and discharge it when needed, and interconnectors which enable electricity to be imported or exported across borders.
2. **Demand-side flexibility:** Flexibility can also come from adjusting energy demand to better align with supply. Demand-side flexibility spans residential, industrial, commercial, and transport sectors, each with varying characteristics and capabilities to respond. While individual actions have limited impact, aggregating many responses can significantly benefit the system. Coordination by aggregators or energy suppliers is essential, as they incentivise participation and manage portfolios of demand-side response (DSR) technologies. As participation grows, effective data management becomes increasingly important.

Box 1: Vehicle to grid (V2G) flexibility

Vehicle-to-Grid (V2G) enables electric vehicles (EVs) to discharge stored energy back into the grid, helping to balance supply and demand.

In December 2024, EDF UK partnered with Pod Point, an EV charging provider, to deliver flexibility services to UK Power Networks (a DSO). EDF will aggregate and optimise the energy usage of its customer's EV chargers to form a virtual power plant (VPP). This VPP can discharge EV batteries, in response to flexibility requests from UK Power Networks, supporting grid stability. In return, UK Power Networks compensates EDF for this flexibility.

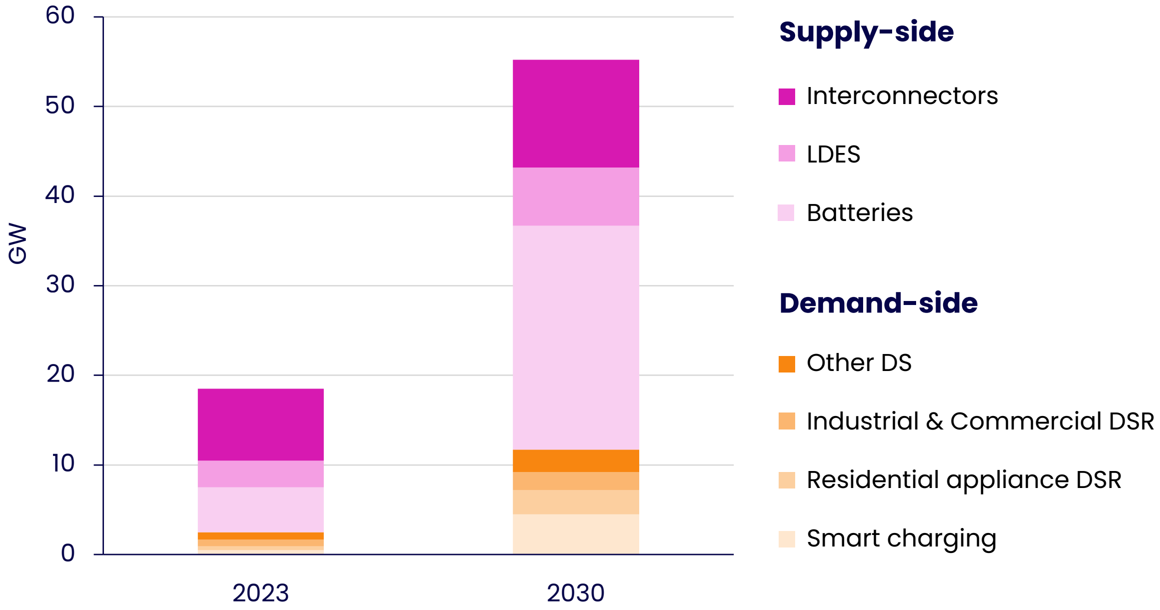
This UK initiative is part of EDF's broader V2G strategy. In 2021, the EVVE project focused on European V2G charging stations and was supported by the EU's Innovation Fund. Fraunhofer ISE and ISI estimate that V2G could save EU energy systems €22 billion a year by 2040.

Sources: SEI on EU energy system costs, SEI on EDF-led consortium, SEI on DSO flexibility contracts in UK

NESO estimates that total flexibility in the UK[v] needs to reach 55 GW by 2030, including 10–12 GW from DSR, 12 GW from interconnectors and 23-27 GW from batteries, as shown in Figure 7 below. This would represent more than a third of total generation capacity and almost half of total variable renewable capacity.[36]

v Supply side flexibility only includes batteries, long-term duration storage (LDES) such as pumped hydro and interconnectors

Figure 7: Flexibility in UK system, 2023 and 2030



Source: NESO[41]

A pre-requisite for a more flexible system is grid digitalisation which involves integrating information and communication technologies into the electricity network. This includes deploying sensors, smart meters, automation systems, and advanced data analytics to enable real-time monitoring, control and optimisation of electricity flows. This enhanced visibility is a key enabler of system flexibility, supporting the integration of variable renewables and decentralised energy resources. The European Commission estimates that €170 billion will be needed for digitalisation by 2030, accounting for over a quarter of the total investment in the EU Grids Action Plan.

Much of this will be spent on smart meters. By the end of 2024, over 195 million smart meters had been deployed across the EU27+3, covering around 63% of electricity consumers.[37] Smart meters are critical for enabling Time-of-Use (ToU) tariffs, which incentivise consumers to shift their energy use, supporting flexibility. However, in the UK, millions remain in 'dumb mode', limiting their ability to provide real-time data and insights. Digitalisation also faces structural barriers: poor interoperability between systems, fragmented data governance, and rising cybersecurity risks.[38]

One of the policy issues associated with DSF is ensuring it is inclusive for all consumers and protects vulnerable households. As low-income households, who can potentially benefit most from the potential bill savings, are likely to be slower adopters of both heat pumps and EV's, they are rarely the first in line for these services. Consequently, such households are likely to have less ability to shift demand and may be adversely impacted by ToU tariffs.[39]

4.4 Streamlining permitting whilst protecting communities and nature

The construction of new grid infrastructure — particularly large transmission lines — is often delayed at the permitting stage due to lengthy administrative procedures involving multiple stakeholders. In Europe, the average duration of the permitting stage ranges between five to six years, resulting in total project duration often exceeding a decade. Over a quarter of electricity PCIs are subject to delay due to permit granting.[40]

Countries are taking measures to reduce the red tape for strategic grid and renewable energy projects. For example, the UK's Clean Power 2030 Action Plan is overhauling planning rules to accelerate permitting for Nationally Significant Infrastructure Projects (NSIPs), including measures like streamlining environmental assessments or setting statutory time limits for decisions.[41] Many of the administrative issues are compounded by public opposition reflecting concerns about infrastructure visual aspects, noise and biodiversity impacts (see Box 2).

Box 2: Example of opposition from local stakeholders

In September 2024, more than 400 people protested against both Scottish Power's and National Grid's plans for new grid infrastructure in the East Anglia region. Scottish Power plans to bring cables onshore from two new Doggerland wind farms, in the North Sea and National Grid has proposed Sea Link – a 138-kilometre offshore electricity link between Suffolk and Kent. Although the cable is mostly subsea, the project includes substantial onshore infrastructure such as converter stations and new transmission lines, which have drawn local opposition.

Local stakeholders argued that the projects will disturb the natural habitat wildlife as and damage the local economy, which relies on agriculture and tourism. For example, in 2021, the High Court revoked planning permission for Swedish developer Vattenfall's Norfolk Vanguard wind farm following similar concerns. Permission was regranted in 2022, and the project was sold to RWE, which began offshore construction in 2025.

Source: FT

Early community engagement and, potentially, compensation can increase project acceptance. In Europe, grid operators are expected to implement the 'pact for engagement' launched alongside the EU Grid Action Plan, which calls for cooperation between authorities and alignment of permitting and stakeholder engagement. In Australia, the Energy Grid Alliance[42] aims to improve community engagement and advocate for best planning processes in transmission lines. Offering local communities price discounts for electricity consumption and ensuring local business involvement in the project can enhance acceptance. The UK's Electricity Bill Discount Scheme recommends community funds and direct benefits in the form of bill discounts.[43]

The deployment of grid infrastructure should seek to minimise its impacts on nature and biodiversity, which predominantly revolve around habitat loss and disruption. Well-designed, nature-positive projects can enhance reputation by demonstrating corporate biodiversity leadership, support overarching nature restoration targets, and reduce the risk of permitting delays. Furthermore, considering nature in a grid project's design can also enhance resilience to physical hazards such as storms and floods.

Box 3: Nature and biodiversity mitigation actions from TenneT

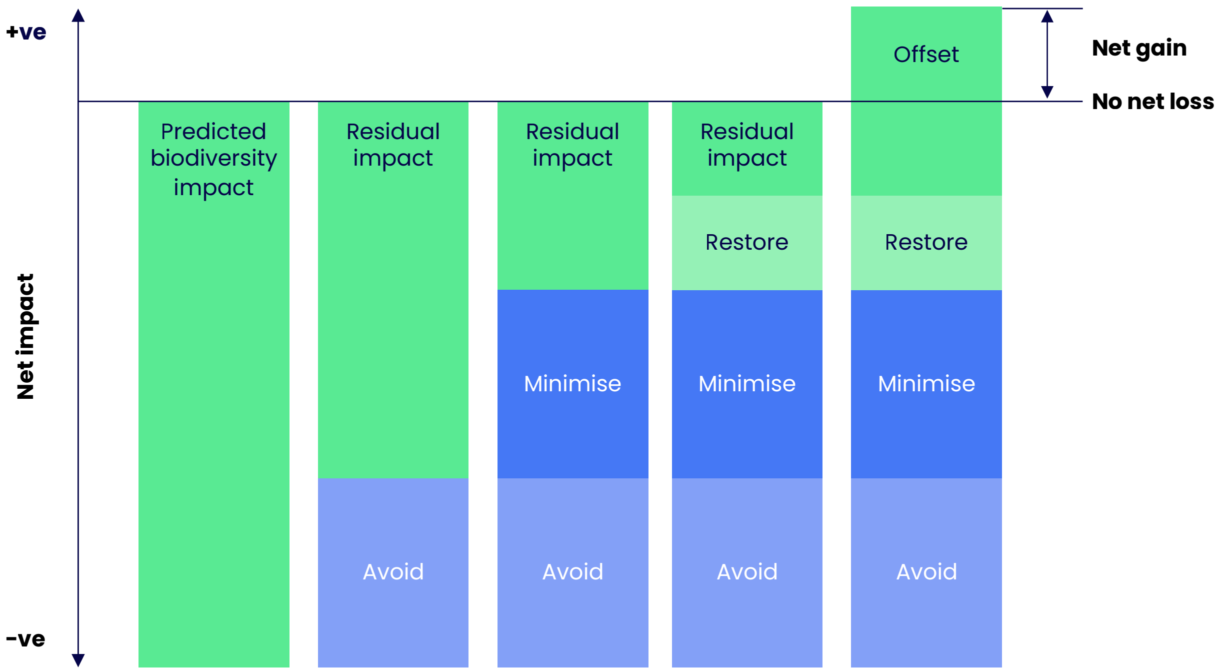
In its annual report, TenneT acknowledges that the construction and operation of its assets and land and sea can disturb natural habitats and affect biodiversity. The company has set a goal to reduce its net impact to nature to zero and has undertaken the following actions (among others):

- All investment plans contain a paragraph, describing the anticipated nature impact, mitigation measures and opportunities for positive impacts
- Use of a nature mitigation hierarchy (see below) to define priorities
- Identification of high-risk bird spots and implementation of bird-friendly barrier measures to avoid collisions
- Vegetation management such as flower lines
- Incorporation of fish enclosures on offshore assets

Source: TenneT

Eurelectric has developed a guidebook to help grid operators assess a project's nature impact throughout its lifecycle. Biodiversity integration is anchored in the mitigation hierarchy[44] — a sequential framework to avoid, minimise, restore, and offset negative impacts — with the aim of achieving a net biodiversity gain wherever possible.[45] Site selection offers the greatest opportunity to avoid negative impacts. Prioritising low-biodiversity-value areas such as brownfields, degraded lands, and redevelopment zones can significantly reduce habitat loss and minimise the need for costly restoration or offsetting.

Figure 8: Nature mitigation hierarchy for renewable energy and grid projects



Source: Eurelectric[50]

4.5 Managing grid operations and supply chain constraints

While the strategic challenges of the transition loom large, grid operators also face operational issues. These include managing their own emissions, ensuring access to skilled human capital, and deploying grid-enhancing technologies (GETs).

Grid operator emissions

Grids' primary significance to the transition is enabling the power system and to the economy more broadly to decarbonise; their operations do not release a lot of direct (i.e. Scope 1) emissions, particularly compared to power generation. Nonetheless, they still need to decarbonise. Their emissions can be grouped in three main categories:

1. **Sulphur hexafluoride (SF_6)** is an insulating gas used in electrical substation equipment such as switchgear and transformers. It is a potent and long lived GHG gas—24,000 times stronger than CO2. Whilst SF_6 contributes only around 1% of CO_2-equivalent modelled global warming, power systems account for over two thirds of total SF_6 and for some grid operators it can be 90% of their Scope 1 emissions.[46, 47, 48] Policymakers and grid operators are working to reduce these emissions, through the adoption of SF_6-free equipment (see Box 4).

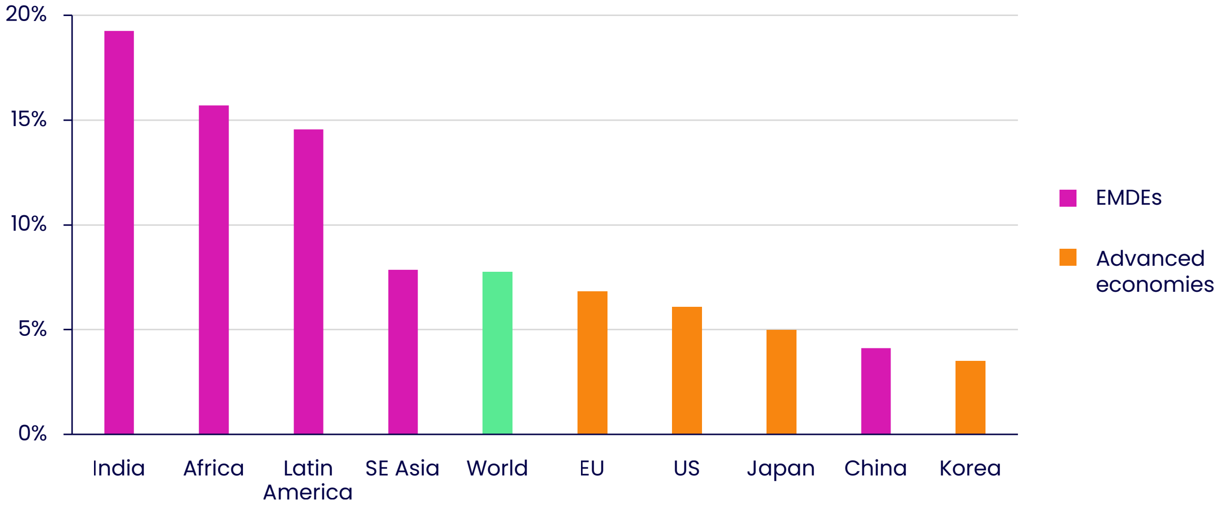
Box 4: EU SF_6 Regulation will come into force by January 2026

European regulation 2024/573 mandates the use of SF_6-free switching technology by January 2026. As part of a project that aims to enhance the sustainability and efficiency of Italy's electricity distribution networks in 2024, Siemens and Unareti (an Italian DSO), installed the first SF_6-free medium-voltage GIS switchboard. This switchboard uses 'Clean Air' technology, a natural gas insulation alternative ().

Source: SEI

2. **Network Losses.** Over 2,100 TWh of electricity was lost due to inefficient transmission globally in 2022 — around 8% of total generation, according to the IEA.[49] The extend of this varies significantly between regions, with losses in India and Africa exceeding 15% as shown in Figure 9. As generating this power typically releases emissions, the losses are reported by grid operators as Scope 2 emissions. If network operators could limit transmission losses to 5%, this would reduce the cost of the transition and cut global emissions by more than 400 $MtCO_2$ annually.
3. **Embedded emissions.** New grid infrastructure typically includes steel, copper, aluminium and concrete — all materials that are emissions intensive to make. These emissions are reported in Scope 3 category 1. Given the wider decarbonisation benefits, this should not dissuade operators from procuring what they need to drive grid investment, however, ultimately reaching net zero will require the use of low carbon materials.

Figure 9: Technical grid losses as a share of total generation by country/region, 2022 (IEA)



Source: IEA[50]

Grid Enhancing Technologies (GETs)

To improve system efficiency and make better use of existing grid infrastructure, operators are deploying GETs — hardware and software tools that improve the capacity, flexibility, reliability and resilience. Installing GETs could reduce the need for network buildout by approximately 35% by 2040 in Europe.[51] As outlined in section 4.1, GETs deployment relies on regulatory frameworks that incentivise operational efficiencies.

Key GETs for DSOs include dynamic line rating, dynamic voltage control, automatic network reconfiguration and high-temperature low sag conductors, as shown on Table 4. By the end of 2025, a common Technopedia Platform operated by the ENTSO-E and the EU DSO entity should materialise, providing an overview of existing GETs.

Table 4: Technologies supporting Grids for Speed

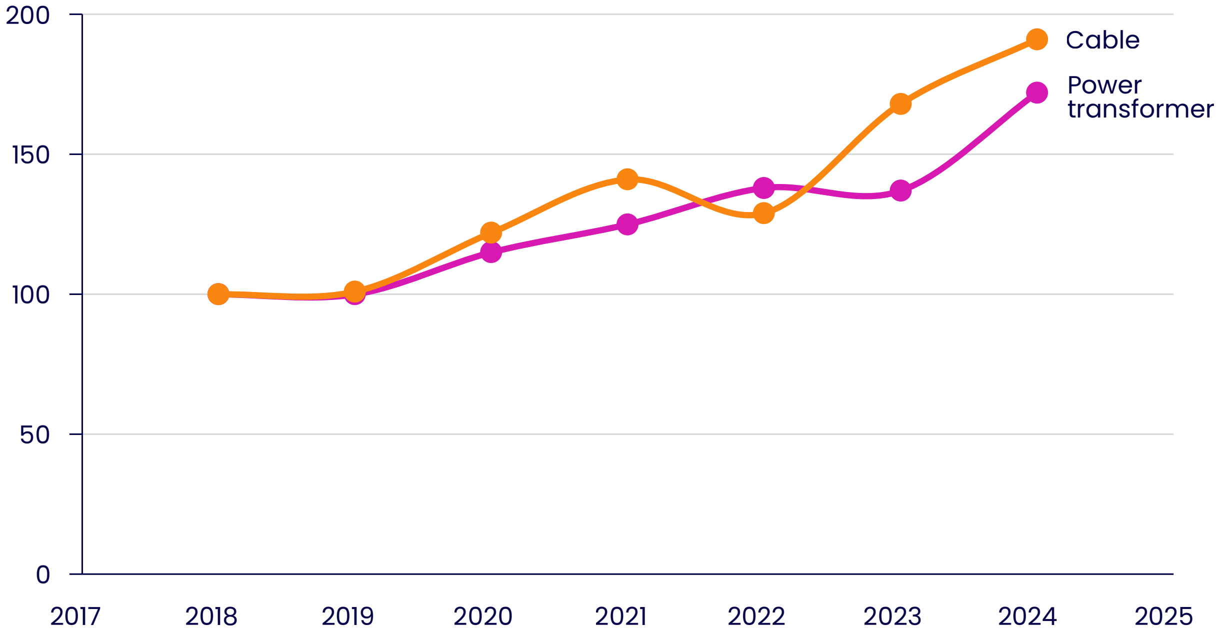
GET	Overview
On Load Tap Changer transformers (OLTCs)	Allow dynamic voltage control. For example, on sunny days, transformer will lower output voltage to maximise solar feed-in
Line Voltage Regulators (LVR)	Provide voltage stability by increasing voltage headroom on lines, maintaining optimal voltage levels under fluctuating loads
Dynamic Line Rating (DLR)	Allow lines to optimise their potential. For example, on cool days more power can flow through an overhead line
Automatic Network Reconfiguration	Enable efficient detection and isolation of faults, followed by fast adaptation of equipment to avoid or reduce power outages
High Temperature Low Sag (HTLS) Conductors	Enhance grid resilience by offering higher thermal capacity and reduced sag, while using existing tower structures
Flexible Alternating Current Transmission	Enhance DSOs' ability to control real and reactive power flow across the grid

Source: Eurelectric.[52]

Supply chains

Shortages of grid components also pose potential roadblocks for the energy transition. A shortage of transformers has been ongoing since 2021 amid supply chain disruption and rising demand, driving up prices and causing project delays. Between 2018 and 2024, cable and transformer prices have almost doubled, as shown below.

Figure 10: Power transformer and cable price index in real terms, 2018-2024



Source: IEA[55]

The IEA states that lead times have almost doubled since 2021. It now takes two to three years to procure cables and up to four years to secure large power transformers.[53] Avoiding supply chain bottlenecks for grid components requires coordinated efforts, providing firm and transparent grid project pipelines, and standardising grid equipment procurement.

Labour

Access to skilled labour is essential to deliver infrastructure projects and is already proving a challenge to grid operators. Global employment in the power grid sector was over 8 million in 2023. To deliver the network expansion envisaged in the IEA's NZE scenario, this needs to rise to 11 million by 2030 (3 million job gap).[54]

4.6 Maintaining reliability and enhancing resilience

Ensuring reliability and resilience are critical aspects of grid operation. This becomes an increasing challenge in the context of ageing infrastructure, growing variable renewable penetration, and changing climate.

Reliability refers to the grid's ability to consistently deliver electricity without interruptions. Many grid components in developed countries are over 25 years old, increasing the risk of failures. Grid operators often report reliability using metrics such as the System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI). These indicators are often central to grid operator performance and are frequently linked to their remuneration and incentive structures.

Inertia is also an important concept for power system reliability. Historically, the large rotating turbines used in thermal electricity generation meant that output continued for a short period even if generation stopped completely. In the event of power losses or system issues this is a valuable property not replicated by renewables. As renewable generation increases, grid operators are turning to technologies such as synchronous condensers (SCs) and grid-forming inverters to artificially create inertia. BNEF expects a record SC deployment in Europe in 2025, driven by the UK and Italy.[55]

Box 5: Iberian peninsula blackout in April 2025

On 28 April 2025, the power systems of Spain and Portugal — impacting tens of millions of people and approximately 27 GW of demand — experienced a total blackout following the sudden disconnection of around 2.2 GW of generation. The event began with a 355 MW generation trip in Spain, which triggered voltage instability and cascading generator disconnections, including wind and solar assets. This led to a sharp frequency drop, activating under-frequency load-shedding and isolating the Iberian grid as both AC and HVDC interconnectors with neighbouring countries were disconnected. The outage extended across mainland Spain, Portugal, and briefly into southern France.

ENTSO-E's Expert Panel — comprising TSOs, ACER, and NRAs — has launched an investigation to reconstruct the event and recommend preventive measures. Early findings point to a combination of sudden generation loss and insufficient dynamic voltage regulation. The incident has intensified scrutiny of grid resilience, prompting renewed calls across Spain and Europe for increased interconnection — currently below the EU's 15% 2030 target — and accelerated investment in grid-stabilisation and flexibility technologies.

Sources: Reuters, Reuters, ENTSO-E

Resilience refers to the grids capacity to withstand and recover from unexpected events such as extreme weather or cyberattacks. Climate change is increasing the frequency and severity of wildfires, floods and hurricanes and grid infrastructure must be resilient to these events. At the same time, higher digitalisation and advancements in AI necessitate higher grid resilience.

Policymakers are recognising the importance of resilience and have started supporting upgrades. In 2024, the U.S. Department of Energy announced nearly $2 billion in funding for grid resilience projects, though future funding may depend on evolving political priorities.[56]

Utilities are also seeking to enhance the resilience of their grids. In reviewing its exposure to physical climate risks, Enel identified storms, hurricanes and fires as direct risks and noted that heatwaves can lead to demand spikes that could cause overload. It has dedicated 12% (more than €3 billion) of its future grid investment to resilience, focusing on proactive adaptation and damage reduction solutions that would preserve service continuity and support rapid recovery.[57] Iberdrola is burying overhead networks in vulnerable areas and designing substations that can maintain service during floods and fires.[58]

5. Engaging on grids

Addressing the complex challenges needed to accelerate grid deployment identified above requires capital, an aligned policy environment and coordinated actions across various stakeholders. To support investor dialogue with both policymakers as well as grid operators, we group the key issues into six topics (Figure 11).

The six topics form the basis of the accompanying *Grids: Tool for engagement* — a resource designed to support this dialogue by providing specific questions that investors looking to accelerate progress may wish to put.

Figure 11: IIGCC Grids Investor Engagement Tool themes

Appendix – Additional resources

General

- Electricity infrastructure development to support a competitive and sustainable energy system: 2024 Monitoring Report (ACER)
- Electricity Grids and Secure Energy Transitions (IEA)
- Global Grids Index (Bloomberg)
- Upgrading Europe's electricity grid is about more than just money (Bruegel)
- Grids for Speed (Eurelectric, EY)

A. Regulatory Framework Reform

- Regulatory Frameworks for European Energy Networks 2024 (CEER)
- A roadmap for cost-reflective electricity network tariffs in the EU (smartEn)

B. Capacity and Planning

- ENTSO-E Transparency Platform
- RIP first come, first served (RAP)
- How Europe's grid operators are preparing for the energy transition (BFF, Ember, E3G, IEEFA)

C. Flexibility and Digitalisation

- Unlocking flexibility: No-regret actions to remove barriers to demand response (ACER)
- Nine clean flexibility tools (Ember)
- 2024 Market Monitor for Demand Side Flexibility (LCP Delta, smartEn)
- Demand side flexibility – unleashing untapped potential for clean power (ETC)
- Unlocking Smart Grid Opportunities in EMDEs (IEA)

D. Permitting and Communities

- Biodiversity Net Gain – new requirements for connections (National Grid)
- Community benefits for electricity transmission network infrastructure (UK Gov)

E. Operations and Supply Chains

- Decarbonising Distribution: carbon footprints & mitigation strategies for DSOs (Eurelectric)
- Statement on building resilient and diverse clean energy technology supply chain (UNEZA)
- Building the Future Transmission Grid (IEA)
- Technologies supporting grids for speed (Eurelectric)

F. Reliability and Resilience

- Iberian Peninsula Blackout (ENTSO-E)
- How to increase grid resilience through targeted investments (McKinsey)

References

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2 Net Zero Roadmap 2023 Update (IEA)
3 World Energy Investment 2025 (IEA)
4 National Grid Rights Issue (NG)
5 Net Zero Roadmap 2023 Update (IEA)
6 Electricity 2025 (IEA)
7 Renewables 2024 (IEA)
8 Electricity Grids and Secure Energy Transitions (IEA)
9 Grids for Speed (Eurelectric – EY)
10 Distribution Grids Handbook (Eurelectric)
11 TenneT Germany prepped for potential sale (SEI)
12 Upgrading Europe's electricity grid is about more than just money (Bruegel)
13 CEER Report on Regulatory Frameworks for European Energy Networks 2024 (CEER)
14 Ten-Year Network Development Plan (ENTSOE)
15 Renewable Energy Directive (European Commission)
16 EU Electricity Interconnection Target (European Commission)
17 EU Grid Action Plan (European Commission)
18 Trans-European Networks for Energy (European Commission)
19 Connecting Europe Facility – Energy (European Commission)
20 Clean Industrial Deal (European Commission)
21 Affordable Energy Action Plan (European Commission)
22 Guidance on anticipatory investments for developing forward-looking electricity networks (European Commission)
23 EU Clean Industrial Deal: Grids Manufacturing Package (EU Monitor)
24 Ofgem welcomes proposed legal mandate to prioritise the UK's 2050 net zero target (Ofgem)
25 Grids for Speed (Eurelectric – EY)
26 Combining Forward-Looking Expenditure Targets and Fixed OPEX-CAPEX Shares (Bovera et al.)
27 CEER Report on Regulatory Frameworks for European Energy Networks 2024 (CEER)
28 Connecting Europe Facility 2021-2027 (European Commission)
29 Cross-Border Cost Allocation
30 Installed electricity capacity from renewables in Europe (Ember)
31 How Europe's grid operators are preparing for the energy transition (BFF)
32 Clean energy projects prioritised for grid connections (UK GOV)
33 Gone with the wind (Carbon Tracker Initiative)
34 RIP first come, first served (RAP)
35 Electricity infrastructure development to support a competitive and sustainable energy system (ACER)
36 Clean Power 2030 (NESO)
37 Europe's smart electricity meters penetration approaching two-thirds (SEI)
38 Digitalization challenges and opportunities in the future energy system (TwinEU)
39 Flex-ability for all: Pursuing socially inclusive demand-side flexibility in Europe (RAP)
40 Electricity infrastructure development to support a competitive and sustainable energy system 2024 Monitoring Report (ACER)
41 Clean Power 2030 Action Plan: A new era of clean electricity (DESNZ)
42 Energy Grid Alliance
43 Electricity Bill Discount Scheme for transmission network infrastructure: policy position (DESNZ)
44 Science-Based Targets for Nature (SBTN)
45 Power Plant 2.0 – A guidebook to electrify in harmony with nature (Eurelectric)
46 SF6: The Little Gas That Could ... Make Global Warming Worse (Baker Institute)
47 Sulfur Hexafluoride (SF6) Basics
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