Review
01

EN

Making the EU electricity grid fit for net-zero emissions

CURIA RATIONUM

EUROPEAN
COURT
OF AUDITORS

2025

Contents

Executive summary

I We often take it for granted that electricity will be available at the flick of a switch, but behind the scenes a delicate balance must be struck because electricity has to be used or stored the instant it is generated. Whether in busy cities or more remote locations, the EU electricity grid must constantly and consistently transmit and distribute power to homes and businesses, connecting 266 million households and companies with over 11.3 million km of lines – enough to encircle the Earth 282 times.

II As decisions on climate neutrality shape the future, it is crucial to ensure that the grid is fit for net-zero emissions. The grid has to power consumption and reliably integrate energy from renewable sources to drive decarbonisation and security of supply, while keeping electricity affordable. This review outlines the state of play and the main trends of the EU's electricity grids and related policies. While there is still time for decisive action, the document also presents challenges and opportunities for more efficient solutions in the context of the energy transition.

III This is not an audit report; it is a review that is mainly based on publicly available information or material specifically collected for this purpose. To provide a comprehensive overview of the situation, we conducted information visits to two member states, and had exchanges with the Commission, national regulatory authorities and other key stakeholders. We reviewed grid development plans and analysed the grid operators' financial capacity data.

IV Large-scale grid investments must be made in a bid to reach net zero by 2050. According to the Commission's estimates, €1 994 billion to €2 294 billion is required to meet the needs until 2050 and simply maintaining the current level of planned investments will not be enough. It is recognised that urgent scaling-up efforts are needed to accelerate the pace of investments. Success hinges on overcoming key challenges, including coordinating grid planning across the EU, streamlining permitting processes and tackling equipment and labour shortages.

V Investment needs can be reduced by making the grid, as well as the electricity system as a whole, more flexible. Europe's ambition for net zero and greater energy independence presents a timely opportunity to promote efficient solutions such as demand response, electricity storage, and advanced grid technologies, which help minimise the need for large-scale infrastructure expansions. Consumers who generate as well as consume energy can also play an important role in the new, more flexible energy system.

VI Regulatory frameworks are crucial for ensuring that sufficient grid investments are available, as they determine how much operators earn and how they are remunerated. Funding arrangements are particularly important in a situation where some operators face increased credit risk and struggle to access the necessary upfront investments. The long-term impact of grid investments on the electricity bill is unclear and difficult to predict. While network tariffs could increase in the short run, the Commission estimates that the price of generating electricity will remain relatively stable in the long term due to the increasing use of cheaper renewable energy.

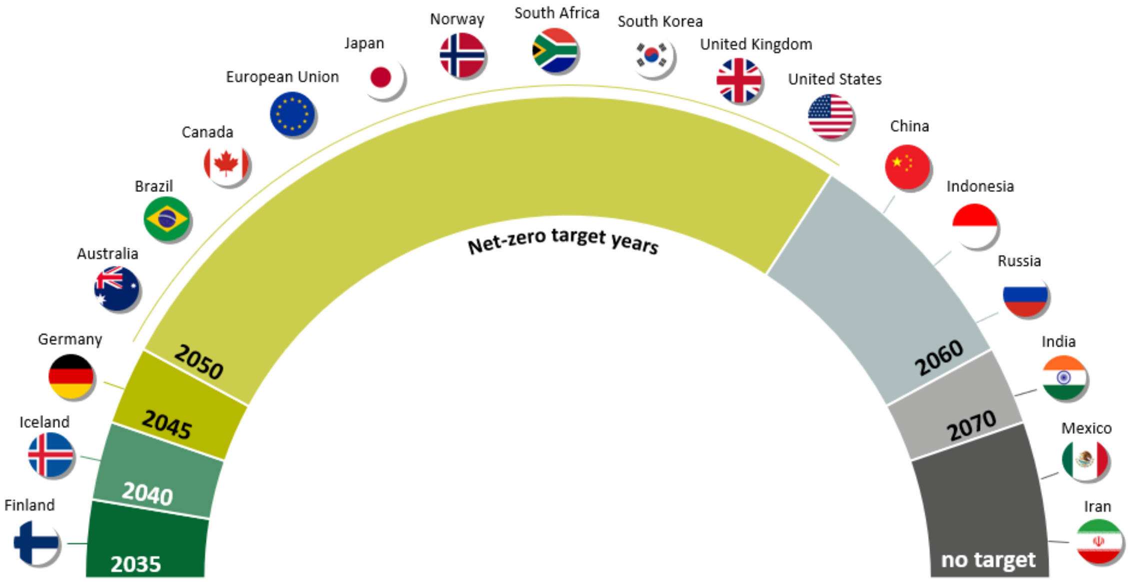
VII The European Union has a key role in making the grid fit for net zero. In particular by improving overall governance and planning, and creating the necessary legislative environment. At the same time, member states and grid operators are responsible for developing the grids and addressing the related practical, regulatory and financial challenges.

Introduction

Powering EU climate action through electrification

01 In 2015, the world entered into a binding agreement to combat climate change and limit global warming to well below 2 °C. This requires a significant reduction in global greenhouse gas emissions and a total transformation of the energy systems that are responsible for a significant part of these emissions. As part of this global effort, the EU has committed to achieving net-zero emissions by 2050 (***Figure 1***).

Figure 1 – A comparative look at EU climate action



Source: ECA, based on data from the IEA (2024), Global Energy and Climate Model, IEA, Paris, chapter 1.1.2 announced pledges scenario, Licence CC BY 4.0.

02 According to the International Energy Agency (IEA), we are now in a critical decade for climate action efforts. Advanced economies are advised to decarbonise their electricity sectors by 2035, with electricity expected to play an increasingly significant role in the overall energy system. Electricity demand is predicted to more than double from 2022 to 2050 (***Figure 2***), driven by strong growth in:

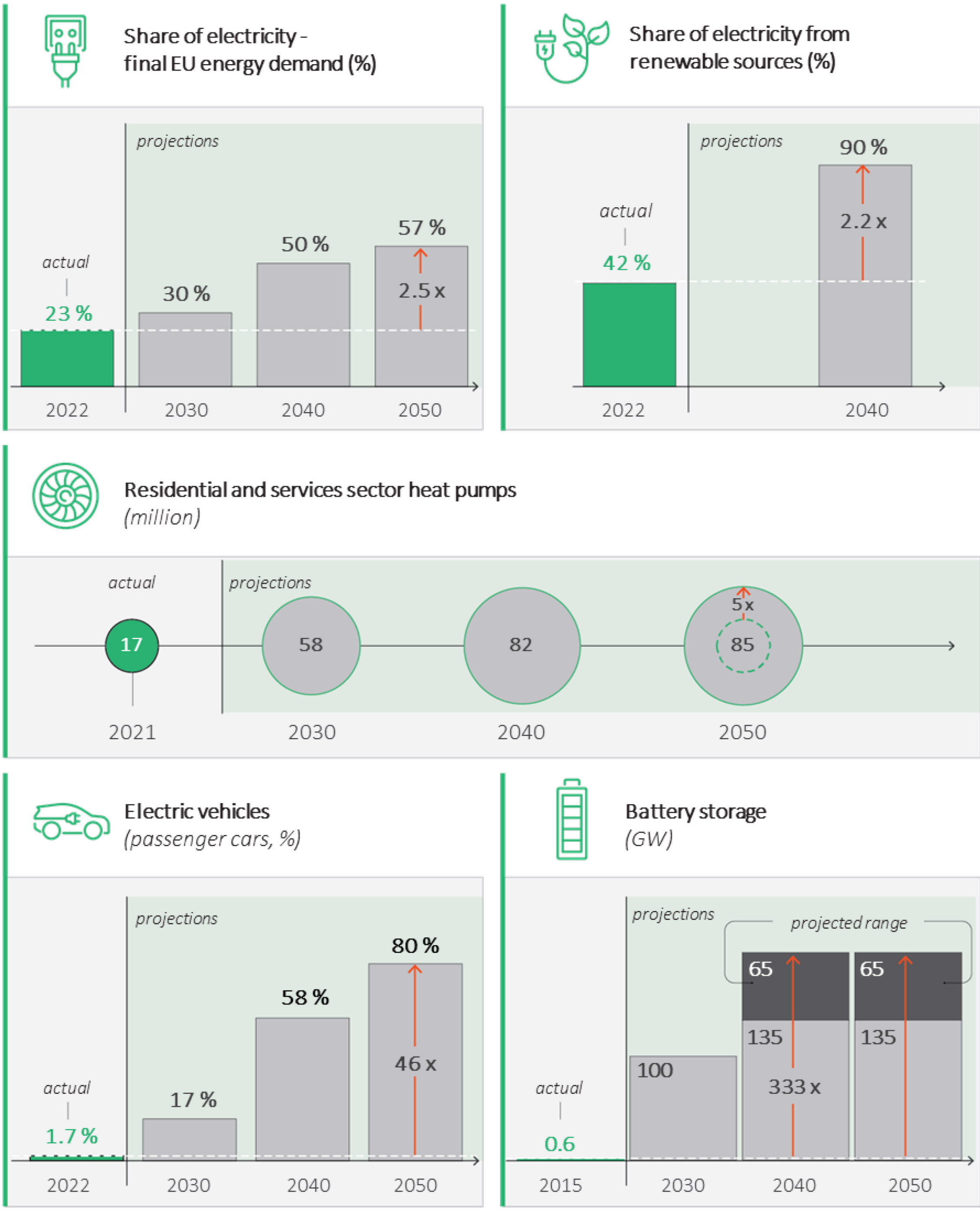
— transport (e.g. electric vehicles),

— heating (e.g. electric heat pumps), and

— industry (greater electrification of processes).

Renewables are at the heart of the energy transition: by 2023 they already accounted for 30 % of global electricity generation. One major EU achievement was producing around 42 % of electricity from renewables in 2022.

Figure 2 – Electricity trends in the EU



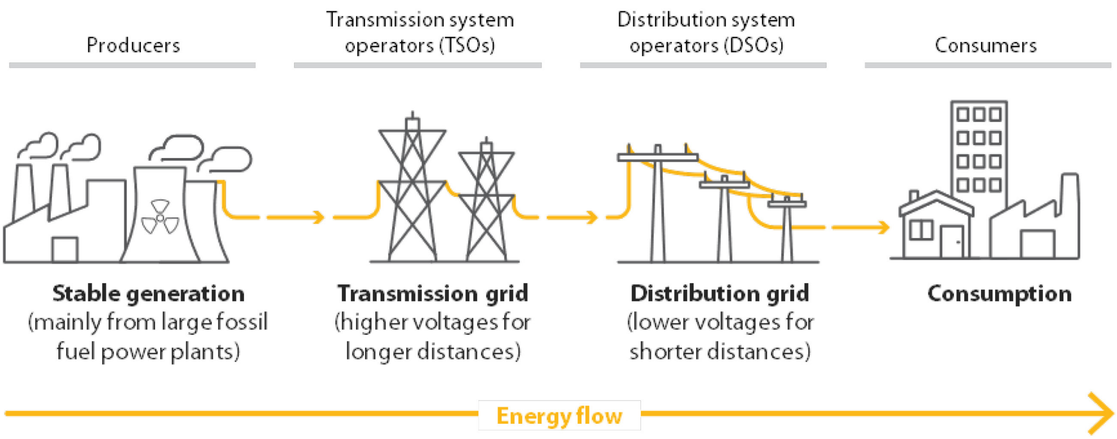
Source: ECA, based on Eurostat for actual figures; Commission for remaining data: COM(2024) 63 and SWD(2024) 63 (Securing our future), Heat pumps in the EU (2022), and SWD (2021) 307 (Progress on competitiveness of clean energy technologies).

The EU's policy is shaping the electricity system of the future

03 The EU's policy for electricity is one part of a broader energy policy with the aim of creating a competitive, secure, and sustainable internal electricity market that supports both the EU's climate goals and economic growth.

04 The electricity market was traditionally dominated by vertically integrated monopolies, where electricity flowed one way from large power plants to consumers through centrally managed electricity systems (***Figure 3***).

Figure 3 – Traditional electricity system



Source: ECA.

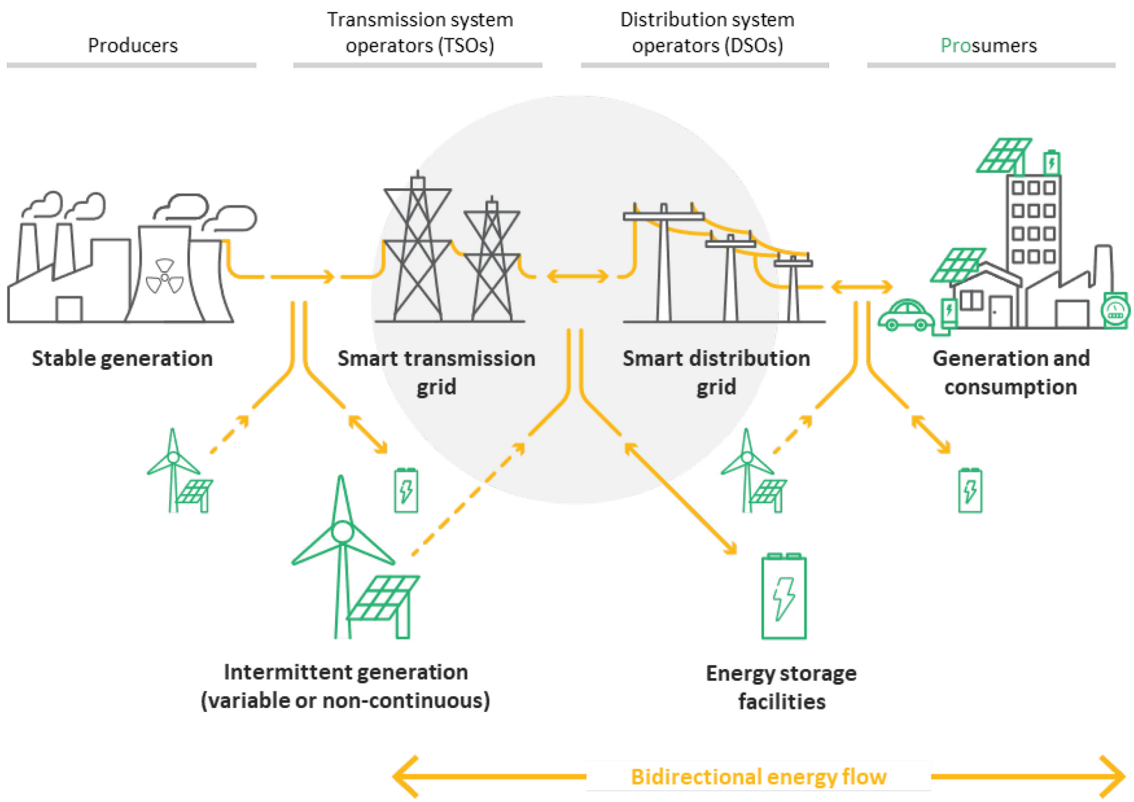
05 With the introduction of the first, second and third EU energy legislative packages, the monopolistic electricity markets were opened up to competition. This shift benefited consumers and, with improved grid interconnections between member states, facilitated the cross-border electricity trade and improved security of supply. Today, only the grids remain a monopoly and are regulated by national regulatory authorities (NRAs). ***Annex I*** presents the evolution of the EU electricity policy and the relevant legislative acts.

06 As the EU increasingly recognised the importance of combating climate change, electricity policy began to prioritise decarbonisation and the integration of renewable energy. The adoption of the 2020 climate and energy package marked the first significant step. Building on this, the clean energy package further emphasised the transition from fossil fuels to a carbon-neutral economy, a trajectory that was reinforced with the European Green Deal and the Fit for 55 package.

07 The energy crisis, triggered in late 2021 by post-pandemic recovery and gas supply issues, was intensified by the 2022 Russian invasion of Ukraine. It underscored the need to achieve the EU's ambition of reducing its dependence on external energy sources, while ensuring affordable and secure electricity. This was addressed through temporary measures, followed by the REPowerEU plan and the electricity market design reform, which was focused on consumer protection[1]. The 2023 EU Action Plan for Grids specifically targets electricity grids to improve grid development, transparency and funding.

08 EU policy is shaping the electricity system with a dual approach. On the one hand, it fosters decentralisation by supporting local electricity generation (e.g. rooftop solar panels, wind turbines), local consumption (e.g. households), and using batteries to store electricity locally. On the other, it also promotes centralisation by driving large-scale renewable projects like offshore wind farms and solar parks, to which high voltage transmission infrastructure and advanced digital and control systems are connected (*Figure 4*).

Figure 4 – Towards the electricity system of the future



Source: ECA.

1 Directive (EU) 2024/1711 and Regulation (EU) 2024/1747 on the EU's electricity market design.

09 This dual approach changes the way in which electricity grids, particularly distribution grids, are managed. Distribution grids increasingly integrate numerous small- and medium-scale renewables-based generators and integrate flexibility resources (e.g. storage systems). They are also affected by the increase in consumption from electric vehicles and heat pumps. By 2030, 70 % of renewables are expected to be connected at distribution level, rising to 80 % by 2040. This change presents unique challenges for distribution system operators (DSOs).

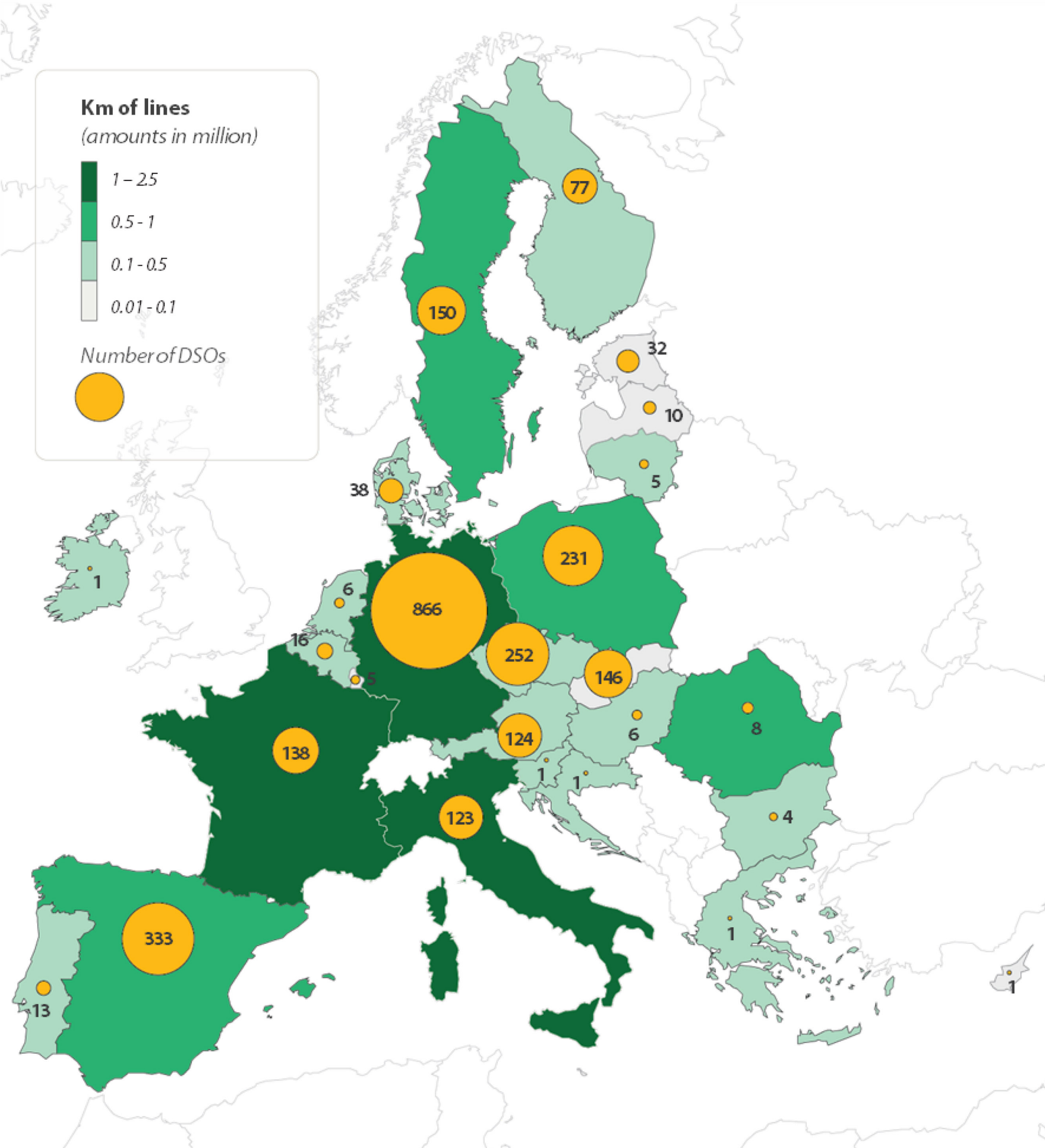
The EU's electricity grid

10 Electricity is a perishable resource – it must be consumed or stored the instant it is generated. This creates a constant challenge for grid operators to maintain a perfect balance between increasingly variable supply and demand, especially during peak hours, e.g. when cities wake up in the morning or when people return home in the evening. Whether in busy cities, remote villages, or on islands, the grid must ensure a reliable supply of electricity to homes and businesses everywhere.

11 The electricity grid is the largest, most complex and most widespread man-made infrastructure in the world, stretching across 11.3 million km in the EU alone[2] – enough to encircle the Earth 282 times (***Figure 5***). In the EU, it is managed by over 2 500 DSOs that oversee 96 % of the grid and 30 transmission system operators (TSOs), who serve 266 million customers (households and companies) and connect 27 countries and multiple EU regions. The EU's electricity grid is a critical part of the broader European grid, which forms the world's largest interconnected grid. More details on the EU grid can be found in ***Annex II***.

[2] Information provided by the NRAs to the ECA and the CEER, Regulatory Frameworks for European Energy Networks 2023, 2024.

Figure 5 – The largest EU infrastructure: electricity grids and operators (2024)



Source: ECA, based on EU DSO Entity, Map the Green Deal's drivers: Distribution grids across the EU (2024) and information provided by NRAs.

12 The EU electricity grid is the largest of its kind worldwide but, as in other advanced economies, it is ageing. The average lifespan of power lines ranges from

40 to 60 years[3], depending on whether they include underground cables or overhead lines, and approximately 40 % of distribution grids are more than 40 years old[4].

Roles and responsibilities

13 Multiple actors play distinct roles and have diverse responsibilities in the development of electricity grids. The Commission plays a key role in developing electricity grids by proposing and overseeing policies to: establish trans-European networks, promote cross-border grid interconnections, make grids smarter, and ensure network interoperability. It also focuses on enabling the internal energy market, energy security, and integrating renewable energy. To support these objectives, the Commission has developed market rules and guidelines for infrastructure investment, which are underpinned by a legal framework[5]. At EU level, different entities (e.g. ACER, ENTSO-E and EU DSO Entity), among other specific responsibilities, promote cooperation and support coordination between the different actors in the national electricity systems.

14 Member states are responsible for implementing EU energy policy, including by jointly meeting the climate and renewable energy targets through their national strategies. The member states also create the conditions for grid investment, promote flexibility, and support their electricity systems to operate efficiently. As part of these efforts, NRAs play an important role by establishing the regulatory framework within which grid operators function (***Figure 6***).

---

[3] Electricity grids and secure energy transitions, IEA, 2023, page 25.

[4] COM(2023) 757, An EU Action Plan for Grids, point 1.

[5] Regulation (EU) 2022/869 on trans-European energy infrastructure, Directive (EU) 2019/944 and Regulation (EU) 2019/943 on the internal market for electricity.

Figure 6 – Main actors in the EU electricity system

EU Level

Agency for Cooperation of Energy Regulators - ACER

- Facilitates cooperation between NRAs and provides them with recommendations and opinions
- Monitors the roles of the ENTSO-E and the EU DSO Entity in the grid development and management
- Participates in the development of network codes
- Approves proposals related to the national and European resource adequacy assessment
- Approves terms and conditions or methodologies (TCMs) when NRAs fail to agree, including directly for EU-wide TCMs

European network of transmission system operators for electricity - ENTSO-E

- Fosters the coordination of TSOs
- Conducts the 10-year network development plan and the European adequacy assessment, including energy scenarios
- Facilitates cross-border electricity grids and the digitalisation of electricity grids
- Develops network codes

EU DSO Entity

- Fosters coordination and cooperation between DSOs and TSOs in terms of grid planning and operation
- Promotes digitalisation, smart grids, and enhanced cybersecurity and data management.
- Facilitates cross-border electricity grids and the digitalisation of electricity grids
- Collaborates with ENTSO-E on network codes and adopts best practices for grid efficiency

National level

National Regulatory Authorities - NRAs

- Set tariffs, ensure compliance and promote fair competition
- Facilitate cross-border trade and the integration of renewables
- Protect consumers and ensure quality service
- Promote energy efficiency, smart grids, and sustainability

Transmission System Operators – TSOs

- Manage the extra-high and high-voltage electricity transmission system in a country or region
- Operate, maintain and develop the transmission network within a designated area, including its interconnections with other systems
- Ensure the long-term ability of the network to meet reasonable demands for the transmission of electricity

Distribution System Operators – DSOs

- Manage the high, medium and low-voltage electricity distribution systems in a country or region
- Operate, maintain and develop the distribution network in a given area, including its interconnections with other systems
- Ensure the long-term ability of the system to meet reasonable demands for the distribution of electricity

Source: ECA, based on Directive (EU) 2019/944 and Regulation (EU) 2019/943 on the internal market for electricity, and Regulation (EU) 2019/942 establishing ACER.

Review scope and approach

15 This review takes stock of the challenges in making the electricity grid fit for net zero, and presents the current state of play of initiatives taken to address those challenges at EU and national level. Issues related to the security of the internal electricity market, i.e. cybersecurity and data protection, were not included in the scope of this review.

16 This is not an audit report; it is a review based mainly on publicly available information as well as material specifically collected for this purpose. In contrast to an audit, a review provides a descriptive and informative analysis. The purpose of the review is not to formulate recommendations; instead we have identified the challenges and opportunities for developing the EU electricity grid. We aim to raise awareness regarding the crucial role that the electricity grid plays in enabling the energy transition.

17 At EU level, we have focused on the European Commission's work in developing policies for electricity grids. We provide an overview of the EU funds available for grid infrastructure investments during the 2014-2020 and 2021-2027 programme periods (***Table 1***).

Table 1 – EU funds for grid infrastructure investments reviewed

Managing entity	Fund
Directorate-General for Energy	Connecting Europe Facility (CEF)
Directorate-General for Regional and Urban Policy	European Regional Development Fund (ERDF), Cohesion Fund (CF), Just Transition Fund (JTF)
Directorate-General for Economic and Financial Affairs	Recovery and Resilience Facility (RRF)
Directorate-General for Climate Action	Modernisation Fund

Source: ECA.

18 Looking at the situation at national level, we provide a summary of the numerous planned grid investments, the regulatory schemes used to remunerate grid operators, and the measures taken to improve the electricity system's ability to adapt to changes in supply and demand.

19 Our review drew upon publicly available information, reports and documents. We consulted external experts and used data from the ORBIS database. In addition, we did the following:

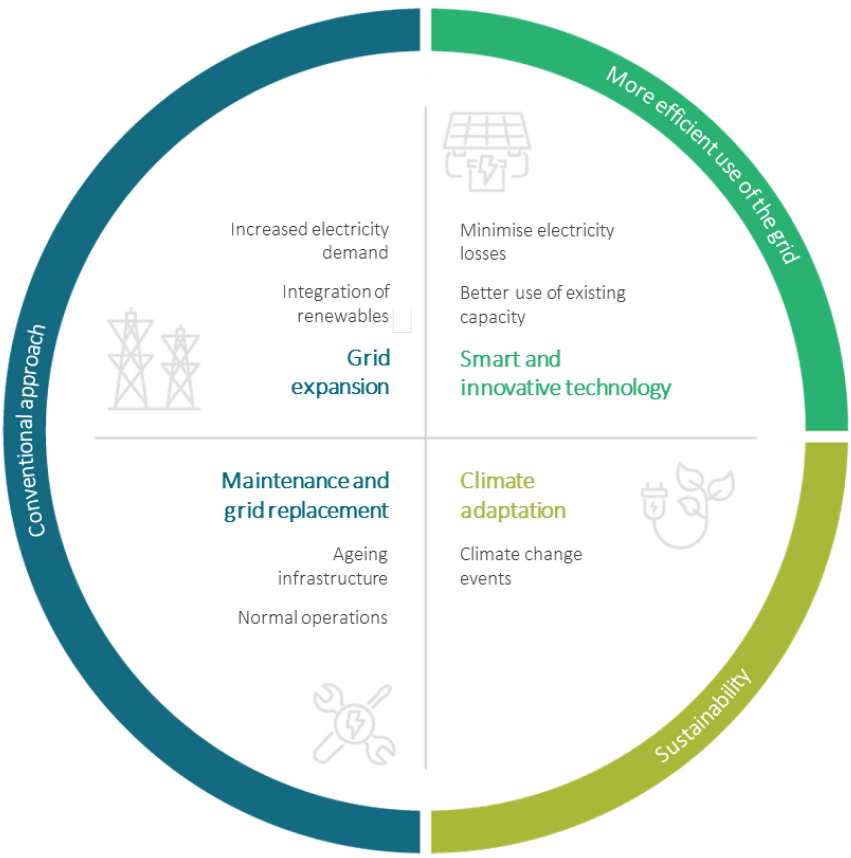
- visited two member states (Germany and Italy) to better understand those member states' grid policies and implementation. Those member states face common challenges in managing electricity flows from renewable energy generation zones to high-consumption areas, but differ in their operator structure, legislative environment, smart meter adoption and other aspects;
- had discussions with the Commission directorates-general (DGs) responsible for developing EU policies for electricity (DG ENER) and those which provide funds;
- gathered information on best practices, investments and electricity data from the NRAs in all member states, receiving replies from all but one of the NRAs;
- discussed the challenges and opportunities for making the EU grid fit for net zero with other relevant entities (ACER, the CEER, ENTSO-E, the EU DSO Entity, the E.DSO, Ember, Eurelectric, and the JRC);
- reviewed grid development plans of all 30 TSOs and the 57 largest DSOs, representing over three-quarters of the EU's electricity customers;
- analysed the financial capacity of 685 grid operators and the credit risk of 605, each representing over 90 % of the EU's electricity customers.

Grid investments in the EU

Large-scale grid investments are needed for the energy transition

20 While solar and wind power are at the forefront of the energy transition, their full potential cannot be harnessed without the infrastructure necessary to deliver clean electricity from the production sites to consumers. Transmission and distribution grids are enablers in the energy transition and must be expanded, upgraded, and maintained to handle future demand. This includes becoming increasingly digitalised and adapting to climate change (***Figure 7***).

Figure 7 – Drivers for grid investments



Source: ECA.

21 **Grid expansion** is one of the primary drivers for grid investments. It is influenced by growing electricity demand (in particular, by an expected 60 % rise in peak daily consumption between 2020 and 2050), and by the location of renewable energy sources. Carbon-emitting power plants were often strategically placed near major consumption hubs and populated areas to minimise electricity losses and reduce the need for extensive transmission lines. However, as electricity generation shifts to using renewable energy sources, generation sites are now often located in windy or sunny regions with available land, which means that the grid has to be extended to reach those locations.

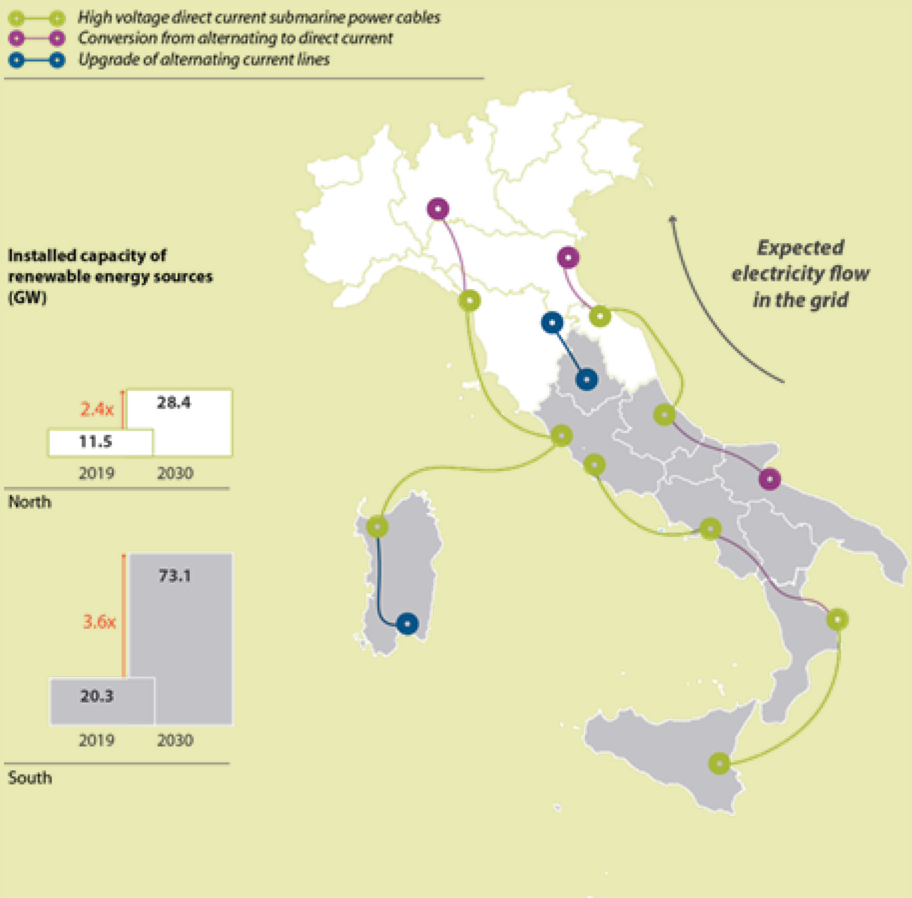
22 Moreover, renewable energy sources have higher intermittency and variability because their output depends on weather conditions, unlike traditional power plants that can adjust output to meet demand. This, in turn, makes balancing the system more challenging. In addition, the European grid was originally designed to operate using alternating current (a type of electric current that reverses its direction many times a second at regular intervals). However, many renewable energy sources generate direct current electricity (which flows in one direction only), which must be converted for grid compatibility and use. Consequently, grid reinforcement, the installation of specific equipment, and more modern, **smart and innovative technologies** may be required to accommodate these energy sources (***Box 1***).

Box 1

Transporting large amounts of renewable electricity with modern technology in Italy

By 2030, renewable energy capacity in Italy is expected to triple. It is mostly located in the sunny south, while the majority (around two thirds in 2023) of the consumption takes place in the industrial northern regions. The Italian TSO (Terna), has proposed an €11 billion project (the "hypergrid") to boost electricity exchanges between northern and southern Italy. The project will almost double the exchange capacity from 16 GW to over 30 GW by modernising power lines with high voltage direct current technology and adding new undersea connections.

The hypergrid after 2032



Source: ECA, based on TERNA's data.

23 Another key investment driver is **maintenance and grid replacement** work, especially in light of the ageing infrastructure. Adapting to **climate change** also requires investment (***Box 2***), such as stronger and more weather-resistant materials or using flood-resistant substations to protect them from rising water levels. The

Commission highlighted that without adaptation, grid damage could multiply sixfold by the middle of the century.

Box 2

The impact of climate change on electricity grids: an Italian example

In July 2023, a prolonged high-pressure weather system caused an intense heatwave in Sicily. Temperatures reached over 41 ºC and the dry conditions sparked numerous wildfires. The high temperatures damaged underground cables and led to power disruptions, with thousands of connections cut for over 24 hours.

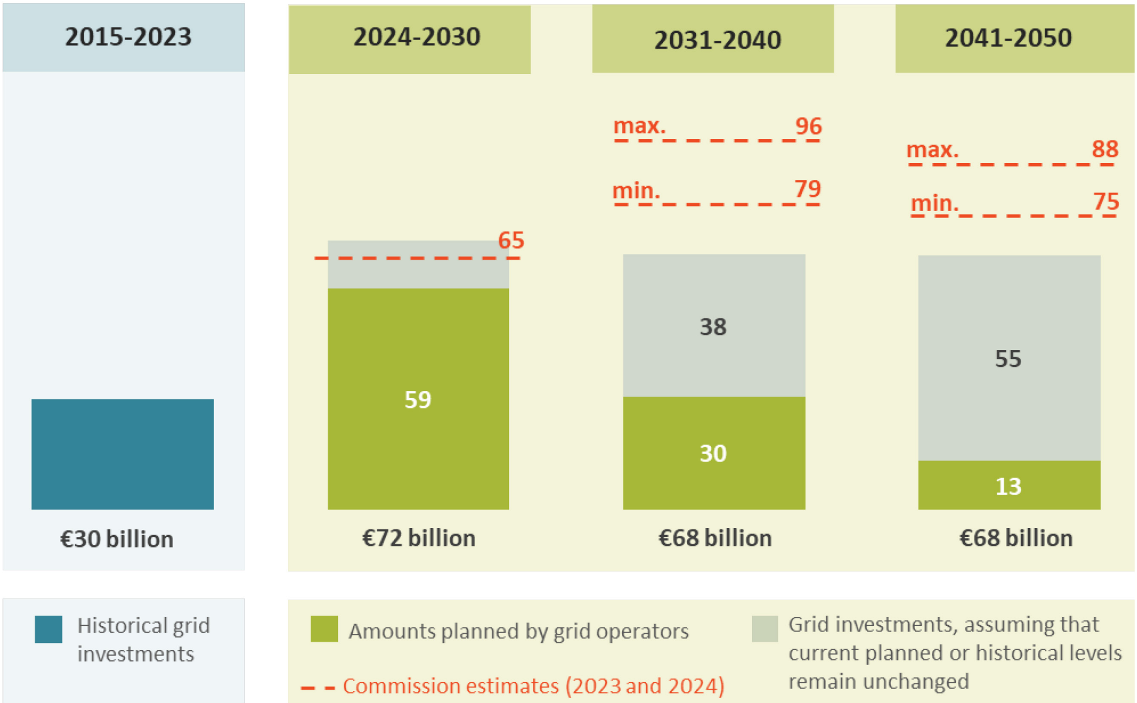
Source: ECA, based on E-Distribuzione's data.

Current pace of planned grid investments by operators is below the needs estimated by the Commission

24 Grid operators are planning substantial investments because of future needs and the energy transition's goals. To assess the **scale and timing of grid investments**, we requested the planned investment amounts from the NRAs and aggregated the information we received. Where NRA data was unavailable (for TSOs in five member states and DSOs in six), we either used the largest operators' grid development plans to gather information or based ourselves on historical investments (calculated as the variation of assets adjusted for depreciation). These cases account for 4.7 % of the total planned amounts between 2024 and 2050. We then assumed that looking forward to 2050, grid operators would continue to invest either the last planned or the latest historical amounts.

25 Based on this approach, grid investments would reach €72 billion annually until 2030, dropping to €68 billion from 2031 to 2050 (***Figure 8***), and totalling €1 871 billion over the entire period. This would be the equivalent of investing 0.41 % of 2023 EU gross domestic product every year until 2050 (ranging from 0.10 % to 1.20 % at member-state level) – roughly twice the amount of the EU's historical investments. Most planned investments are to modernise and expand the transmission grids (4 % of the total grid). Investments in the distribution grids are expected to focus on reinforcement, renewal and replacements.

Figure 8 – Investments by grid operators and the Commission's estimated investment needs (annual amounts, constant prices)



Source: ECA, based on data from NRAs, the ORBIS database, grid development plans of largest grid operators and the Commission.

26 In the long term, simply maintaining the level of the current planned investments will not be enough to meet the Commission's estimated investment needs for the electricity grid[6], which are estimated at €1 994 billion to €2 294 billion (between 2024 and 2050). That said, there is a significant and growing degree of uncertainty as plans extend into the future. This uncertainty stems not only from the time frame but also from the scenarios underpinning grid development plans. These scenarios are influenced by a range of factors, including changes in electricity demand, the uptake of electric vehicles and heat pumps, and improvements in energy efficiency and savings (*Box 3*).

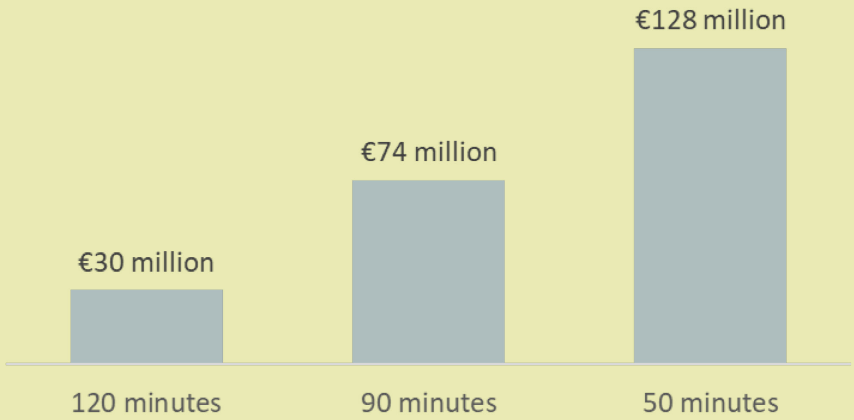
[6] COM(2023) 757, An EU Action Plan for Grids, and SWD(2024) 63, Impact assessment report accompanying the document Securing our future, part 1.

Box 3

How assumptions affect grid planning: the Estonian example

The Estonian DSO's grid development plan presents three investment scenarios to improve the medium voltage network's climate resilience by 2030. Maintaining current investment levels would result in a 120-minute average interruption duration per year, while reducing it to 50 minutes would require over four times the current level of investment. All scenarios involve replacing bare conductor lines with weather-resistant alternatives, with lower targets for the interruption duration, requiring more extensive and costly infrastructure improvements.

Impact of the average interruption duration targets on required annual grid investment (2024-2030 period)

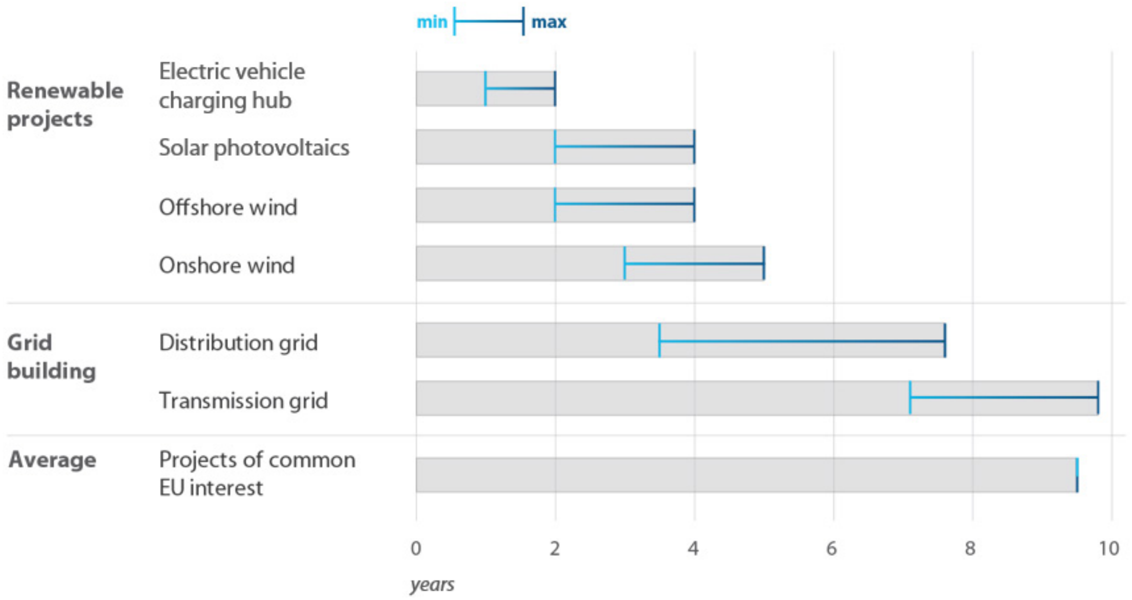


Source: ECA, based on DSO's grid development plan.

Grid infrastructure projects take longer than renewable projects

27 The EU DSO Entity has reported a rapid increase in the number of **connection requests** from renewable producers. However, grid infrastructure projects often take longer than renewable projects such as building wind or solar sites (***Figure 9***). We asked the NRAs for the total capacity of renewable projects that were awaiting grid connection in each member state. From the 12 replies received for 2023, we note that the backlog is substantial – on average it is roughly equal to the existing capacity of renewable energy sources in 2022 in those countries. We also note, however, that not all the requests are likely to be pursued in the future (e.g. immature renewable projects).

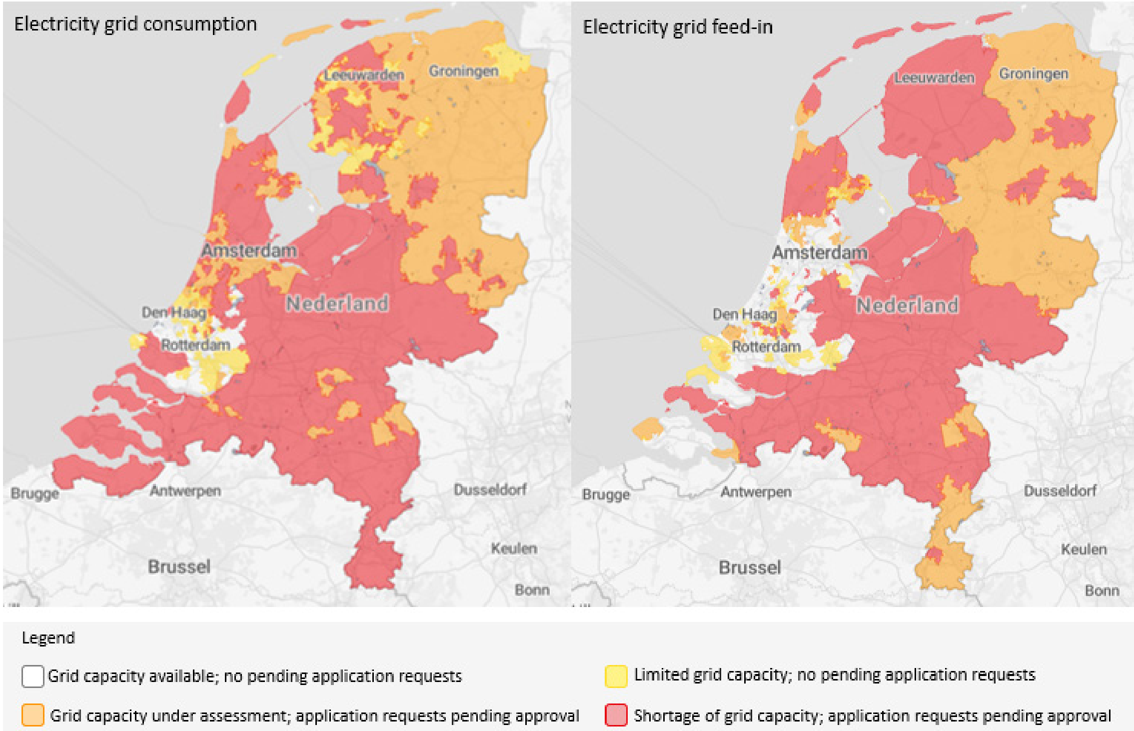
Figure 9 – Total time for the completion of grid infrastructure and renewable projects



Source: ECA, based on data from the Commission, replies from 12 NRAs and the IEA.

28 The most immediate consequence of a lag between grid and renewable-generation projects is a delay in connecting renewable energy sources to the grid. To address this challenge, some grid operators or entities provide **capacity maps** (***Figure 10***) that illustrate the current availability of grid capacity, outline planned grid expansions to increase it, and highlight the possibility of flexible connections in congested areas. With this information, these maps guide renewable energy project owners – and electricity consumers – to areas with existing spare capacity. This reduces the need for immediate grid expansion and accelerates grid connections.

Figure 10 – Example of a grid capacity map



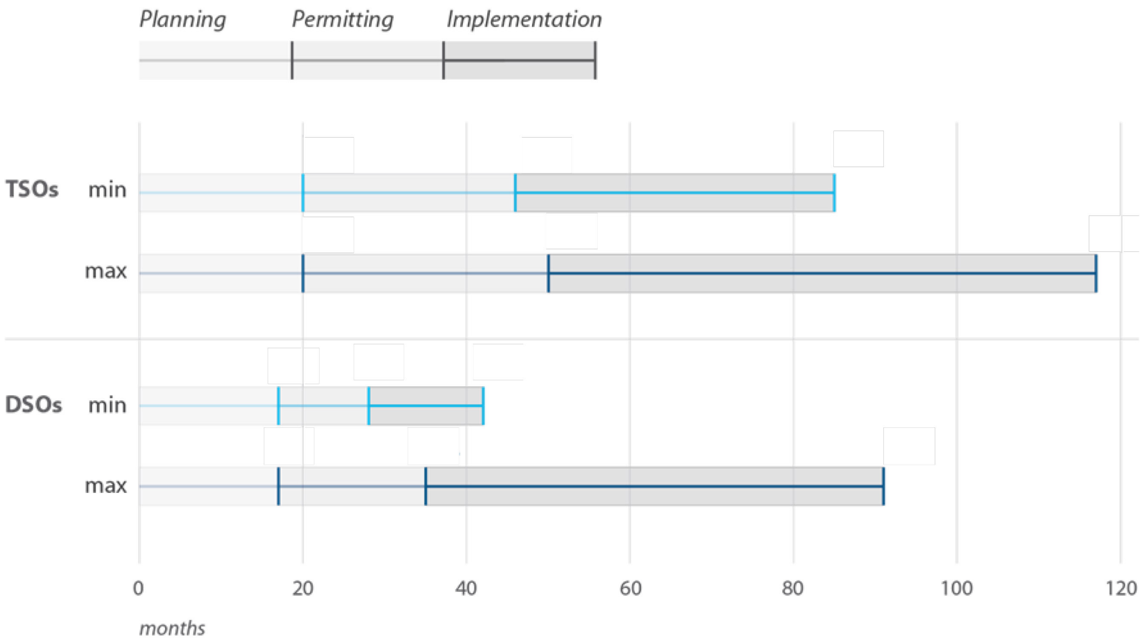
© *Netbeheer Nederland*, as of 4.10.2024 | © Esri Nederland | © MapTiler © OpenStreetMap contributors.

29 Lengthy grid investments can also lead to **congestion**, where demand for electricity transmission or distribution exceeds the available grid capacity in a given area, something which is becoming an increasingly frequent problem. According to ACER, there was a 14.5 % increase in congestion management needs in 2023 compared with 2022. This led to large system costs of €4.3 billion and resulted in over 12 terawatt-hours of electricity from renewables in the EU that were deliberately not generated (roughly equivalent to 11 % of the gross amount of electricity produced from renewables in 2022).

Lengthy and complex preparation hampers timely investments

30 According to the replies received from the NRAs, grid planning takes around a quarter of the total **time** required **for grid investment**. On average, and when combined with the permitting process, the preparation phase for grid investments takes roughly 4 years for transmission grids and about 2.5 years for distribution grids (***Figure 11***).

Figure 11 – Planning and permitting: roughly half of the total time for grid infrastructure projects



Note: Based on the information sent by the NRAs in 12 member states. Not all of these member states provided replies for each phase.

Source: ECA, based on NRAs' replies.

Grid planning

31 In the EU, grid planning involves a **wide range of entities and documents** (***Figure 12***). The process is driven by the EU's climate and energy goals, starting with long-term strategies to achieve net-zero emissions by 2050. These goals are then detailed in national and regional long-term strategies that form the basis for grid operators to plan their investments – identifying, for instance, the expected levels of electrification and the renewable energy capacity to be integrated. The grid plans are complemented by the **ENTSO-E's Ten-Year Network Development Plan** which serves as a tool to identify key cross-border infrastructure projects of common EU interest and to check the consistency of national development plans.

Figure 12 – Key entities and documents for grid infrastructure planning in the EU

* Malta has no TSO.

Source: ECA.

32 The complexity of coordinating multiple strategies and plans creates **challenges** in harmonising investments and ensuring data comparability. This is further intensified by the following points.

- Not all DSOs are required to develop grid plans (only those with more than 100 000 customers)[7].
- Not all grid projects are incorporated into these plans. According to ACER, 20 % of the projects of common EU interest are excluded for various reasons, e.g. if they are not TSO investments, or if they are not sufficiently advanced. According to the NRAs, this exclusion can also occur when investments do not require NRA approval.
- Grid data (both planned and actual) is not always publicly accessible and is often difficult to locate.

33 Furthermore, the review of the development plans from 59 grid operators (26 TSOs and 33 DSOs with the largest consumer base in the member states) revealed that there is no standardised approach to grid planning.

- Some grid operators present separate plans for onshore and offshore grids. However, we identified an example of integrated grid planning (***Box 4***).

Box 4

Germany's integrated network development plan: aligning grid and offshore planning with 2045 net-zero goals

Germany has four TSOs that have a joint network development plan, which was approved by the NRA in March 2024. The plan covers both the mainland grid and the offshore one. For the first time, it also includes a vision for 2045, Germany's net-zero target year. Moving forward, DSOs will also have to align their plans with the 2045 net-zero goal.

Source: ECA, based on Energiewirtschaftsgesetz (Energy Industry Act).

- Grid operators are not required to align their scenarios with EU projections, and the time horizon of their plans varies both between and within member states (***Figure 13***). Only two member states have TSOs which are planning their grid

---

[7] Electricity Directive (EU) 2019/944 on common rules for the internal market for electricity, Article 32(5).

development in line with the net-zero horizon, and the planning of just one member state's DSO stretches that far.

Figure 13 – Time horizons for grid development plans

* Germany and Italy have different time frames because not all operators apply the same planning horizon.

Source: ECA.

34 Finally, the constantly evolving **EU climate and energy targets** (*Annex III*) add further complexity to grid planning, requiring continuous adjustments that cascade from national and regional strategies to grid development plans. *Annex IV* provides an overview of the best practices and areas for improvement at EU level on the planning exercise, as highlighted by the NRAs.

Permitting, equipment and skilled labour

35 **Permitting** is one of the main causes of delay for grid investments. According to the data gathered from the NRAs, it takes up around a quarter of the total amount of time needed for grid investment (*Figure 11*). Electricity grid projects often involve multiple authorities and jurisdictions along their route, and each authority must review and approve the plans before granting approval. According to the Commission[8], public opposition frequently leads to legal challenges and extended consultations, which also contribute to delays. Cross-border coordination, environmental impact assessments and changes in the legal framework can further complicate the process (***Box 5***).

Box 5

Factors that can delay grid investments: examples from Germany

The *Bundesrechnungshof* (German supreme audit institution) audited the German energy transition and also looked at grid expansion progress. The most recent audit report highlighted that the network expansion is 7 years and 6 000 km behind schedule. According to previous findings, reasons include lengthy planning and permitting processes, and complex coordination across regions.

Source: ECA, based on audit reports of the Bundesrechnungshof from 2019 and 2024.

The *SuedLink* power line was designed to connect the windy north with the south of Germany using high voltage direct current (HVDC) technology, extending over 694 km. It was approved by the NRA for the first time in 2012. In 2015 a new law prioritised grid expansion using underground cables instead of overhead lines for HVDC technology. This law led to changes in the initial project, delaying the implementation and increasing the costs. According to the NRA, the approval process could not begin until 2017. As of November 2024, 145 km are either under or nearing construction. For the remaining 549 km, the NRA expects the approval process (including permitting) to conclude by 2025.

These delays also affected other HVDC projects which started in 2012, such as A-Nord and SuedOstLink. The NRA reported that the approval process for these projects started in 2017 and 2018 respectively, and expects this process to conclude in 2025.

Source: ECA, based on German law, the official information page SuedLink and information provided by Bundesnetzagentur (German national regulatory authority).

36 Other major economies also set ambitious energy targets, driving significant development in their electricity systems. As a result, Europe is competing with other countries for the **materials and equipment** necessary to develop its grids. This creates major challenges in securing necessary inputs as global demand surges and supply chains are put under increasing strain. The challenges will become even greater with the national energy and climate targets set by governments. Moreover, global

---

[8] SWD(2020) 346, Impact assessment accompanying a proposal for a regulation on guidelines for trans-European energy infrastructure, point 2.2.

electricity production from renewable energy sources is expected to quadruple by 2050.

37 The energy transition also requires a **skilled labour force** to carry out investment-related and grid maintenance work. The availability of skilled workers is often cited[9] as one of the key challenges in ensuring timely grid investments. Our analysis of workforce trends among grid operators revealed that the number of staff increased by 13 % from 2014 to 2022. ***Box 6*** provides an example of how grid operators are navigating the challenge.

Box 6

ENEL's initiatives to boost suppliers' technical expertise and workforce capacity

ENEL, the parent company of E-Distribuzione, Italy's largest DSO group, addressed the need for specialised technicians in the energy transition by:

- offering a free, 5-week training programme through certified institutes (through the *Energie per Crescere* programme), targeted at job seekers and unemployed people; and
- partnering technical and professional institutes to provide specialised training for final year high school students (through the *Energie per la Scuola* programme) to bridge the world of school and the world of work.

These programmes prepare people for jobs as wire pullers, cable jointers, and low-voltage operators. Successful participants can then be recruited by ENEL's partner companies.

Launched in 2022, the *Energie per Crescere* programme had received 34 300 applications (with an average applicant age of 29) by October 2024, and had trained 4 200 individuals. The target is to train 5 500 by the middle of 2025.

The *Energie per la Scuola* programme partnered with 93 schools and 54 ENEL suppliers in the 2023/2024 school year, training approximately 475 final year students for employment in the electricity grid sector.

Source: ECA, based on information from E-Distribuzione.

[9] COM(2023) 757, An EU Action Plan for Grids, points 1 and VII.

EU initiatives to speed up grid investments

38 To accelerate grid investments, in the EU Action Plan for Grids, the Commission set out the following:

- Planning – the Commission emphasises the importance of improved coordination and long-term outlook, promotes the integration of onshore and offshore networks under a common 10-year network development plan framework, and encourages consistency in network development plans.

- Permitting – the Commission promotes harmonised definitions of grid hosting capacity (to help direct connection requests to areas where grid capacity is available, thereby optimising grid development). The Commission also introduces measures to provide technical support to national authorities, including when designating areas where renewable projects can be approved more quickly due to their overriding public interest status (for grid operators to better target infrastructure upgrades).

- Supply chain challenges – the Commission promotes the standardisation of manufacturing requirements across the EU to improve the availability of grid components such as cables and substations.

39 Under the EU Action plan on digitalising the energy system[10], the Commission provides for the development and adoption of common smart grid indicators, to focus investments in digitalising the grids and help monitoring the progress made. In addition, under the Net Zero Industry Act, the Commission aims to improve the investment environment to produce critical grid technologies within the EU, thus reducing reliance on imports.

[10] COM(2022) 552, Digitalising the energy system - EU action plan, section 3.

Optimising grid investments

Flexibility measures reduce necessary grid investments

40 As electricity supply becomes more intermittent and demand increases, grids face higher peaks, greater fluctuation and unpredictability in both demand and supply. To mitigate the need for costly capacity expansion, the focus has started to shift towards making the grid and the electricity system more flexible (***Box 7***).

Box 7

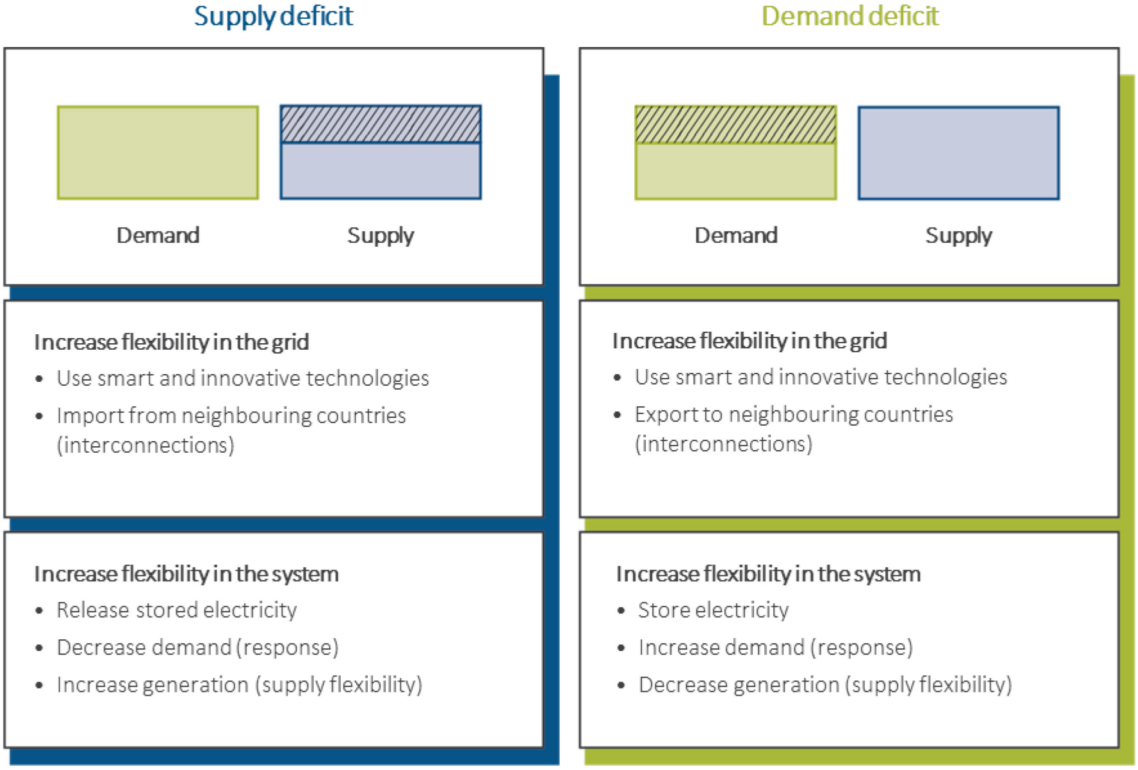
Different options to secure grid capacity: an Italian example

Areti, Rome's DSO, anticipates a significant rise in peak electricity consumption by 2032 due to the increasing use of electric vehicles, heat pumps and induction hobs, requiring around €1 075 million in infrastructure investments. However, with network capacities above 2.5 GW used only 11 % of the time, the DSO explored flexibility measures. Areti concluded that introducing flexibility measures in the system could lower the required investment to €406 million, saving €669 million over 10 years.

Source: ECA, based on information from Areti.

41 Different measures are being developed by operators to better manage their grids by adjusting when and how electricity is used (***Figure 14***).

Figure 14 – How flexibility can address fluctuations in electricity demand and supply



Source: ECA and information from EEA/ACER.

42 These flexibility measures ease pressure on the grid by adapting to daily, weekly and seasonal variations in consumption and generation patterns (***Figure 15***).

Figure 15 – Daily, weekly, and seasonal flexibility needs

Daily	Weekly	Seasonal
Morning and evening demand peaks	Weekday-weekend demand differences	Heating-cooling periods
Day-night generation differences	Wind pattern fluctuations	Seasonal weather patterns
Electricity demand is lower at night, rises in the morning and peaks in the evening when people return home. Renewable energy generation is variable during the day; solar energy in particular peaks during the day and drops by the evening.	Electricity demand is higher during the working week and lower at the weekend, due to varying patterns of human activity. Supply also varies throughout the week, with wind generation often fluctuating in response to changing weather patterns.	In winter, demand typically rises due to heating needs, and solar energy generation is lower. In summer, solar generation peaks but may exceed demand during certain periods. Wind generation can also vary significantly across seasons.

Source: ECA and EEA/ACER.

43 *Annex V* provides an overview of the best practices and areas for improvement at EU level to foster flexibility, as highlighted by the NRAs.

Potential for greater grid flexibility

44 It is possible to increase grid flexibility with stronger **interconnections** between countries, taking advantage of localised differences in geography and weather. This helps balance shifts in wind availability and solar irradiation across the EU, thereby significantly reducing the deliberately not generated cheap, clean electricity and, according to ENTSO-E, saving around €5 to 9 billion per year.

45 Achieving an internal market for electricity has been a longstanding goal for the EU, which has set a target for member states to reach 15 % interconnection capacity by 2030. This will ensure that at least 15 % of each country's installed electricity production capacity can be transmitted to neighbouring countries. In our report, we already noted that progress in electricity market integration has been slow and uneven across the EU and ENTSO-E highlighted the need for interconnections to more than double by 2040.

46 Moreover, the EU mandates that by 2025[11], 70 % of transmission capacity be made available for trading between bidding zones (large areas, often countries, where electricity is traded without limitations) to reduce constraints between them. However, ACER pointed out that the 70 % target is becoming increasingly difficult and costly to reach. There are also risks related to already existing infrastructure. Recent incidents with electricity interconnectors have prompted the EU to restate its commitment to ensuring the resilience and security of the EU's critical infrastructure. In June 2024, the Council adopted a critical infrastructure blueprint to better respond to cross-border incidents.

47 Grid operators are also deploying smarter, more **advanced technologies** to use the grid more efficiently. Some of these (e.g. dynamic line rating, which adjusts capacity in real time based on weather conditions, and flexible alternating current transmission systems, which improve grid stability and power flow) increase the available capacity of existing lines and improve control over power flows, minimising the need for infrastructure upgrades.

Supply drives system flexibility as demand-side and storage solutions emerge

Supply and demand flexibility

48 An alternative to increasing grid flexibility is to improve flexibility within the broader electricity system, which ultimately benefits the grid. Traditionally, **flexibility** has mainly been achieved by adjusting the electricity **supply** from controllable sources like fossil fuels or hydroelectric dams, which can easily be ramped up or down when needed. This is still the most common solution for backing up renewable sources.

49 In parallel, **demand-response flexibility** measures are emerging. They incentivise consumers to reduce or shift their electricity consumption during periods of high demand or grid congestion, helping to smooth out demand peaks and to use the available grid capacity more efficiently.

50 One possible flexibility measure is to use network tariffs that change based on grid congestion conditions, increasing during periods of high congestion, and dropping when congestion is low. When the network component of the electricity bill is clearly

[11] Regulation (EU) 2019/943 on the internal market for electricity, Article 16(8).

identified, this provides an incentive for consumers to react to tariff changes. However, network tariffs may not always align with electricity price trends, potentially limiting the effectiveness of this approach. Another option is to use controllable consumption devices or market-based procurement to reward consumers for their flexibility (***Box 8***).

Box 8

Examples of flexibility approaches

A Portuguese example

In 2022, E-REDES, the largest Portuguese DSO, launched a local flexibility market auction in eight areas to assess the willingness of grid users to adjust their electricity production or consumption in exchange for a compensation. Direct consumers and entities aggregating smaller consumers could participate. The first auction received 623 bids, from 21 different entities, primarily from industrial customers. Flexibility requested with 1-week of advance notice attracted the most interest and was more popular than those options requiring shorter activation times.

Source: ECA, based on a presentation of E-REDES and the FIRMe's project website.

A German example

The German energy industry act, which was updated in 2021, enables grid operators to manage demand flexibly, using economic incentives and the direct control of devices such as heat pumps and electric vehicles chargers. In exchange for cheaper network fees, users must agree to adjust their consumption based on the needs of the grid. While priority is given to economic incentives, direct control can be applied whenever necessary to maintain balance in the system.

Source: ECA, based on the Energiewirtschaftsgesetz.

51 To function effectively, demand-response measures require smart metering systems and smart appliances to enable remote real-time monitoring, communication, interoperability of data, and control of electricity usage. In 2023, 14 member states successfully installed smart meters for 80 % or more of their household consumers, meeting the EU target[12] set for member states. However, in at least seven member states, less than 20 % of household customers had smart meters (***Figure 16***). ACER

[12] Electricity Directive 2009/72/EC concerning common rules for the internal market for electricity, Annex I.2; and Directive (EU) 2019/944 on the internal market for electricity, Annex II.

identified other barriers to demand-response measures including the legal framework and the complexity of the rules for participating in flexibility markets.

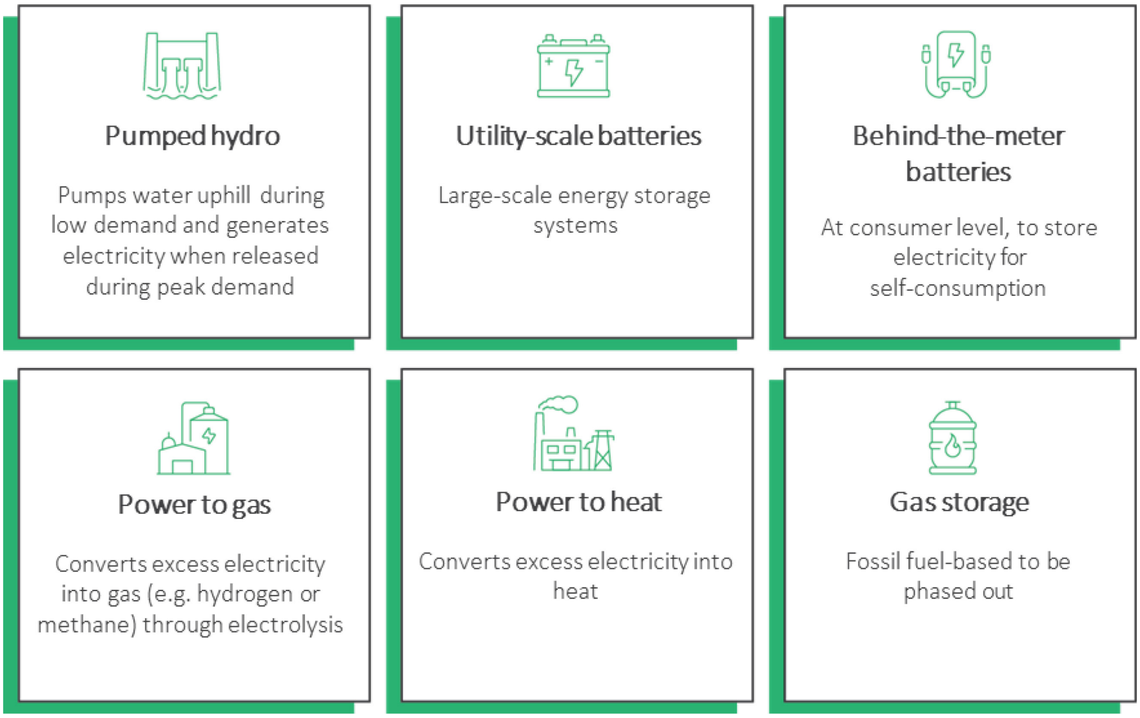
Figure 16 – Disparities in smart meter deployment across the EU

Source: ECA, based on ACER data.

Storage solutions

52 Demand-response measures become more efficient if they are combined with **storage solutions** (*Figure 17*) to store excess electricity when supply exceeds demand, and release it to supplement generation at other times.

Figure 17 – Available storage solutions



Source: ECA.

53 The total power capacity of EU storage facilities is expected to quadruple by 2040 compared to 2020. The main EU energy storage reservoir in 2020 was pumped hydro storage. Battery storage has increased exponentially since 2020[13], a trend that is expected to continue with a projected 40 % cost reduction by 2030[14]. Using electricity to produce and store hydrogen is also a potential solution but, according to our special report on hydrogen, has drawbacks such as high energy losses and high production costs. It also requires repurposing or building new infrastructure.

Prosumers and energy communities

54 Flexibility and storage solutions are easier to implement with **public engagement** and when consumers are aware of the benefits. Prosumers (consumers producing electricity) and energy communities (which collectively produce and consume electricity) can play an important role. They generate renewable energy locally, providing storage and flexibility, building awareness and investing private funds in the energy transition. Their storage and generation resources can be pooled through

[13] Solar Power Europe, European market outlook for battery storage, 2024, Figure 1.

[14] Batteries and secure energy transitions, IEA, 2024, executive summary.

aggregators, enabling them to participate collectively in electricity and flexibility markets (see ***Box 8***).

55 However, prosumers and energy communities face several challenges when providing this flexibility (***Box 9***) and they may also create pressure on the grid. For example, during peak production times, such as sunny afternoons, their electricity production may overload the grid.

Box 9

The BürgerEnergie Berlin energy community

We visited BürgerEnergie Berlin, an energy community cooperative with nearly 2 000 members, focused on promoting citizen participation and sustainable energy solutions. They collaborate with housing cooperatives to install rooftop solar panels. The community installed solar panels with a peak power output of 35.5 kW for 36 participating units. This required removing two existing connection points and building an internal grid with a central metering unit, which increased installation costs. While the community aims to share energy with neighbouring buildings, this is currently not feasible without establishing a parallel local grid. Moreover, the community expressed that providing flexibility to the system is not financially attractive due to the low €/kWh compensation they receive for the electricity provided to the grid.

Source: ECA, based on information by BürgerEnergie Berlin.

EU initiatives to foster flexibility measures

56 To foster investment optimisation, in the EU Action Plan for Grids, the Commission supports increasing grid flexibility by encouraging the use of smart grids and network efficiency technologies through Technopedia, a digital platform providing information about innovative technologies in the electricity sector. Additionally, the 2022 EU action plan on digitalisation[15] promotes data exchanges among different energy players, as well as the development of digital twins (a virtual representation) of EU electricity grids. These elements aim at unlocking demand-side flexibility, and helping the grids to make the most out of it.

57 Regarding system flexibility, the 2019 Electricity Directive established key principles for demand response and encouraged system operators to use flexibility

[15] COM(2022) 552, Digitalising the energy system – EU action plan, action areas 1 and 2, respectively.

services. The updated Electricity Regulation now requires member states to carry out assessments of flexibility needs and to define a national objective for non-fossil fuel flexibility. The reform of the electricity market design and the new network code for demand response[16] expected in 2025 are intended to accelerate the use of flexibility services and demand response.

58 The Commission also promotes energy storage to enhance system flexibility. The Electricity Directive[17] requires DSOs to include flexibility services, such as demand response and storage in their network development plans, and to clarify how they will be used as alternatives to grid expansion. In addition, the Commission has encouraged member states to integrate storage solutions into grid planning.

[16] Regulation (EU) 2019/943 on the internal market for electricity, Article 59.

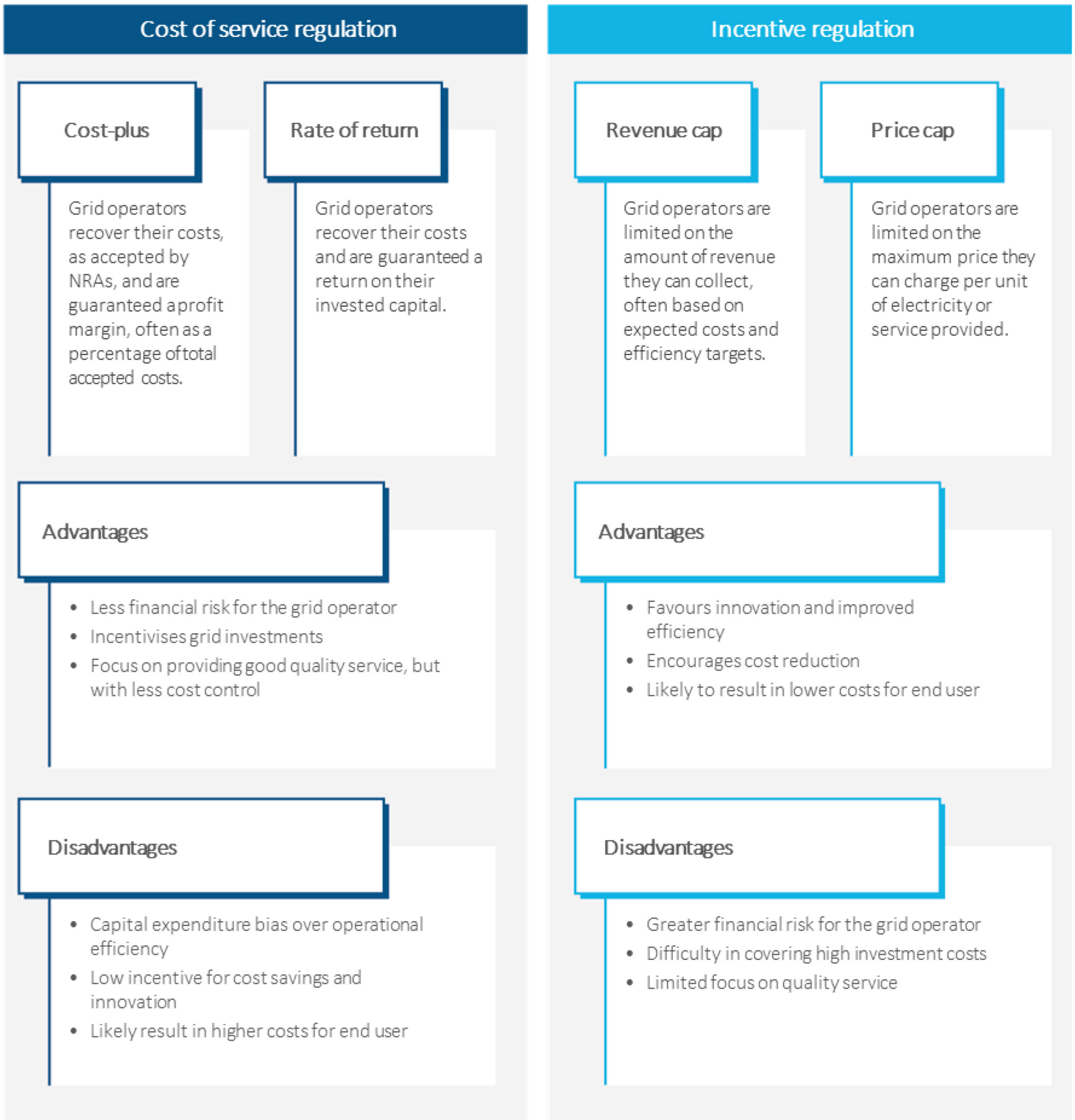
[17] Directive (EU) 2019/944 on the internal market for electricity, Article 32.

Funding grid investments

Regulatory frameworks affect investment decisions

59 Regulatory frameworks determine grid operators' revenues by balancing policy goals such as investment, cost control and efficiency. ***Figure 18*** shows the two core frameworks for remunerating grid operators.

Figure 18 – Core frameworks for remunerating grid operators



Source: ECA.

60 No single regulatory approach is optimal in every context. Regulatory frameworks that provide more advantages to grid operators to increase grid investments (i.e. cost of service regulation) can lead to inefficient spending. This means that grid operators may invest too much in grid infrastructure (e.g. new lines) and underinvest in innovation and improved efficiency (e.g. development of digital solutions). Solutions to this bias include treating grid investments and operational costs equally, encouraging firms to choose the most cost-effective option, rewarding efficiency and focusing on performance rather than spending (***Box 10***).

Box 10

Tackling the bias towards grid investments with incentives: the Italian approach

The 2024-2031 Italian regulatory framework links grid operators' revenue to efficiency rewards instead of grid investments. Grid operators can keep a part of the savings from the proposed grid investments when they are compared with other alternative solutions or historical costs. There is also an incentive for grid operators to reduce electricity interruptions and losses. The TSO is further rewarded for lowering the cost of balancing electricity supply and demand and increasing the amount of electricity that can be transported between geographical areas, especially when achieved with low capital expenditure.

Source: ECA, based on information provided by ARERA, decision 597/2021/R/EEL, TIROSS 2024-2031, output-based regulation for TSO and output-based regulation for DSOs.

Tackling the bias towards grid investments with efficiency benchmarking: the German approach

In Germany, benchmarking is used to determine the revenue of grid operators by comparing their efficiency. Operators with over 30 000 connected customers must participate. For TSOs, benchmarking may involve comparisons with national or international companies – if data allows – or against an "ideal" model network. Efficient operators can keep more of their revenue, while less efficient ones face lower revenue caps, encouraging improvement.

Source: ECA, based on the Anreizregulierungsverordnung (Incentive Regulation Ordinance).

Using planning to tackle the bias in grid investments: NOVA principle

The NOVA principle, included in the German energy industry act, mandates TSOs to prioritise grid optimisation (*Netz-Optimierung*) and grid reinforcement (*Netz-Verstärkung*) over grid expansion (*Netzausbau*) when addressing transmission needs. For example, optimisation might involve using technologies like dynamic line rating to increase the capacity of existing lines, while reinforcement could include upgrading existing cables to higher-capacity conductors. New grid expansion should only be considered if these measures are insufficient.

Source: Energiewirtschaftsgesetz.

61 ***Annex VI*** presents the regulatory frameworks used by the member states and ***Annex VII*** provides an overview of the best practices and areas for improvement at EU level on the regulatory framework for remunerating grid operators, as highlighted by the NRAs.

Impact of grid investments on electricity bills is unclear

62 The regulatory frameworks set the maximum amount that grid operators are allowed to earn from the distribution and transmission of electricity to users who are typically charged through **network tariffs**. This is called **allowed revenue**. It generally allows operators to earn a return on their grid investments, while also covering asset depreciation and the operating expenses necessary to run the grid.

63 **Network tariffs** are defined differently across the EU; each NRA sets its own methodology to allocate revenue and distribute costs among grid users (i.e. households, businesses, industry, storage units and generators). In 2023, EU households paid an average of €0.072/kWh for network tariffs and non-households paid €0.035/kWh, but these amounts vary across member states[18].

64 The long-term **impact of grid investments on network tariffs** is still unclear. We asked NRAs for their estimations in terms of the effect of increased grid investments on tariffs. The vast majority (22 for TSO tariffs and 21 for DSO tariffs) either did not reply or had no available estimates. In the short term and as was the case in the Netherlands, tariffs could increase for consumers (***Box 11***), but going forwards,

[18] ECA, based on Eurostat data on electricity prices components for non-household consumers and household consumers.

growing electricity consumption could spread the costs across a larger total quantity of kWh and a larger group of users, potentially limiting increases in tariffs per kWh.

Box 11

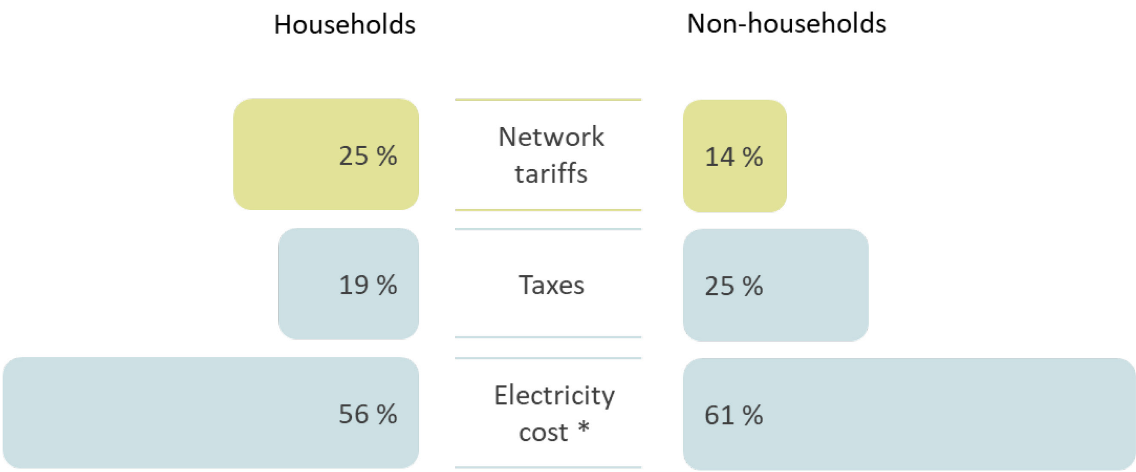
Tariff increases driven by operational and investment costs: a Dutch example

In recent years, the Dutch authority for consumers and markets, the energy sector regulator, has approved tariff increases for both DSOs and TSOs, driven by rising operational costs and the need for major grid investments to support the energy transition. For households, grid tariffs rose by an average of €10 per month in 2023 and €7 in 2024, with a projected rise of approximately €5 in 2025. Similarly, small and medium-sized businesses experienced increases of between 30 % and 53 % in 2023, and a further 11 % increase is anticipated for 2025. Large-scale users connected directly to the national extra high and high voltage grid faced a steep increase in 2023 and 2024 but are expected to either face a limited increase or benefit from a decrease in 2025.

Source: ECA, based on the Dutch authority for consumers and markets: 2023 tariff proposal, 2024 tariffs, 2024 TSO tariff decision, 2025 tariffs, TSO tariff decision 2025.

65 Network tariffs are generally not the largest component in **consumers' electricity bills**. The electricity bill is composed of three elements: network tariffs, taxes and the cost of electricity itself, which usually makes up the larger part of the total (***Figure 19***). This means that the overall electricity bill is affected by other factors beyond network tariffs.

Figure 19 – The structure of the electricity bill (average figures, 2023)



* Electricity price times consumption.

Source: ECA, based on Eurostat.

66 Industrial consumers in the EU traditionally pay lower network costs than households, but face higher **electricity prices** than in other countries, such as the United States. According to the Commission[19], historically, the EU retail electricity price has been one and a half to two times more expensive than in the United States. Between 2021 and 2023, however, EU industry paid two to three times more than their counterparts in the United States. This disparity could affect the **EU's competitiveness** and presents a challenge for NRAs in addressing the growing investments needed for grid infrastructure. As a result, there may be pressure to either redistribute network tariff costs among consumers, or spread these costs through the tax system[20].

67 The Commission estimates that as fossil fuels are replaced with increasingly cheaper renewables, **electricity prices** will remain relatively stable in the long term[21]. That said, the need to dispatch electricity from often distant renewable generation sites could add costs to the system[22] – costs which are not currently a factor in defining electricity prices.

Grid operators need access to finance

68 The electricity sector is highly capital-intensive, with significant upfront investment costs required for infrastructure development. Although grid operators recover their investments over time through remuneration (see paragraph ***62***), they must secure the financing in advance. This can be done through internal resources (equity capital) or by borrowing from the financial markets. However, various stakeholders have emphasised a key challenge: the gap between the significant upfront investment and the available funding.

69 We analysed the **financial capacity** data of grid operators using Moody's probability of default and the implied credit rating for 631 grid operators, along with financial data from the ORBIS database for 711 operators. Grid operators' credit rating indicates their capacity to meet payment obligations to creditors. The analysis includes all the TSOs and DSOs who are members of the EU DSO Entity and GEODE and for

[19] COM(2024) 163, A strong European industry for a sustainable Europe, point 4.

[20] Challenges of the future electricity system, ACER, 2024, point 4.1.

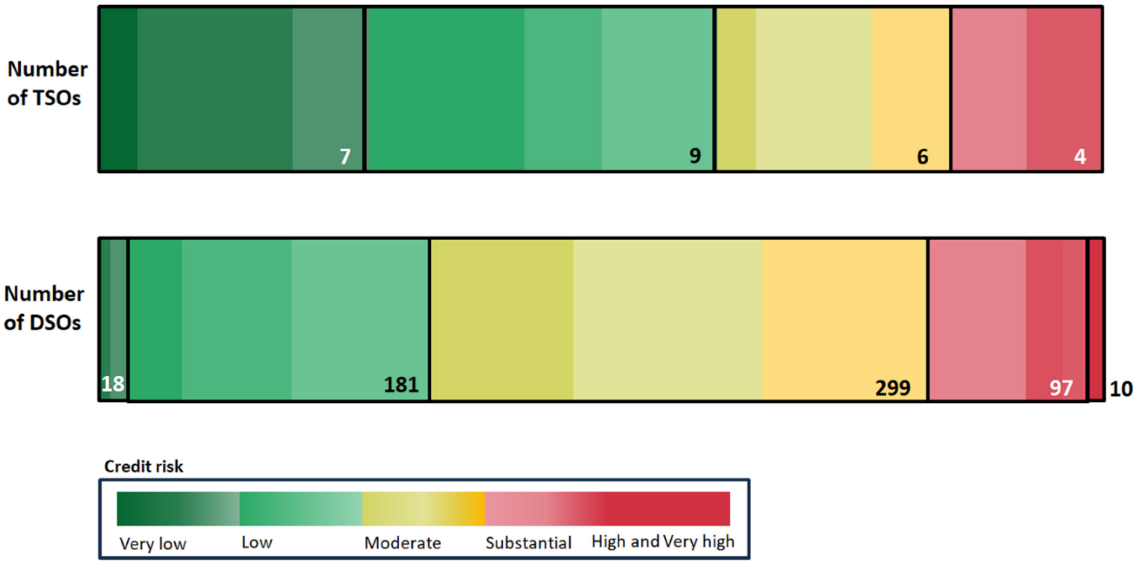
[21] SWD(2024) 63, Securing our future, part 3, tables 36, 37 and 47.

[22] Redispatch and congestion management, JRC, 2024.

whom we obtained up-to-date data from ORBIS.

70 Most of the analysed grid operators have very low to moderate **credit risk ratings**, with less than 18 % considered to be at a substantial to very high risk of defaulting on their financial obligations, making them less attractive to banks. TSOs in particular tend to have lower credit risk. The risks are more prominent for DSOs. Around 34 % of them, which together serve more than a quarter of the customers connected to the grid operators analysed, are in the lowest credit rating tiers, – including the speculative category – (*Figure 20*). Those operators may face problems in securing affordable financing for future grid investments.

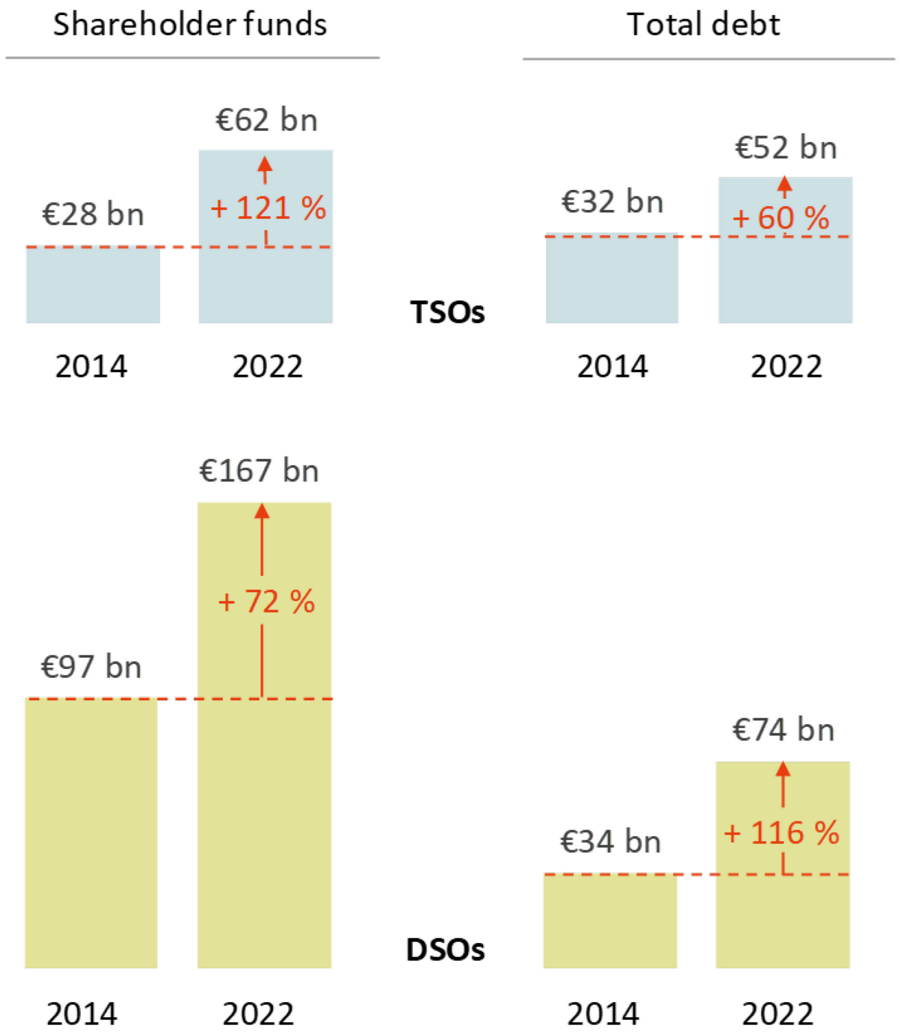
Figure 20 – Credit risk landscape: stable for TSOs, riskier for DSOs



Source: ECA, based on the most recent data available in the ORBIS database (2022 or 2023).

71 In our analysis, we noted that grid operators' balance sheets show increased **funding efforts**, with rising levels of debt and shareholder funds (*Figure 21*). To strengthen their financial positions, grid operators are employing strategies such as selling non-core assets, recapitalisation, or issuing hybrid debt securities that combine debt and equity elements.

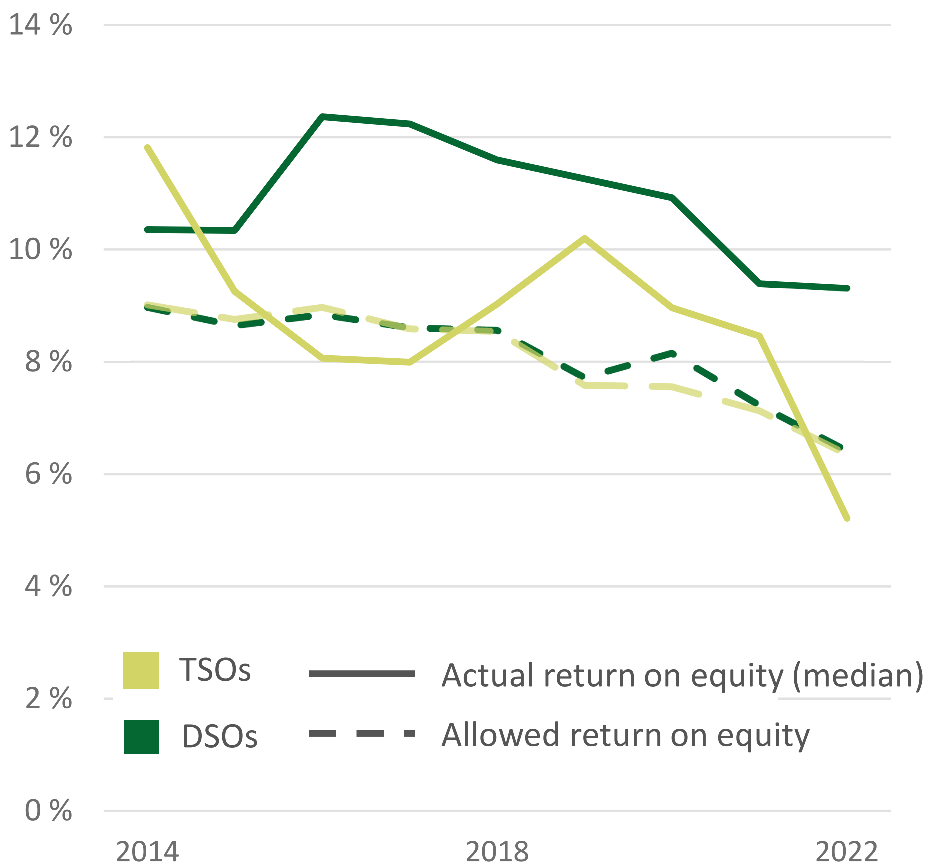
Figure 21 – Greater funding efforts by grid operators



Source: ECA, based on the ORBIS database.

72 Our analysis also showed a declining trend in returns on equity. Distribution grid operators, especially small ones, have higher returns than transmission grid operators (*Figure 22*). In most years, grid operators achieve returns above the allowed revenue amount. This is because **actual returns** can differ from the allowed amounts due to several factors, such as operational efficiency and, specifically for distribution grid operators, additional revenue sources beyond the electricity sector.

Figure 22 – Lower returns on equity for grid operators



Source: ECA, based on information from NRAs for allowed returns and the ORBIS database for actual returns.

73 To attract investors, grid operators must remain appealing, with **regulatory frameworks** playing a key role. These frameworks face the challenge of having to adapt to market conditions, such as rising interest rates or increasing operational costs, while still ensuring fair returns on investment for the operators (***Box 12*** for an approach to addressing this challenge).

Box 12

Providing financial stability: the Italian approach

The 2024-2031 Italian regulatory framework reduces the financial risk for grid operators by balancing actual and allowed revenues through compensatory mechanisms. If actual revenues fall short, this is compensated through specific tariff components. The regulatory authority monitors the return on regulatory equity and debt levels to ensure financial health, helping to secure favourable loans. The framework also foresees a compensation for incremental operational costs and unforeseen cost changes, such as regulatory or service obligation modifications, and allows for ex-post inflation adjustments.

Source: ECA, based on information from ARERA.

74 Another way NRAs can support grid operators in having access to finance is by allowing them to invest based on anticipated future needs, preparing the grid for future demand rather than waiting for these needs to be confirmed. While this strategy includes the risk of investments being underutilised or becoming obsolete before they have been fully utilised, it helps to mitigate the increased uncertainty faced by grid operators. According to ACER and the CEER, NRAs could allow grid operators to start pre-construction activities on grid projects before giving full project approval. This would help speed up the process but requires careful assessment and planning to ensure that such investments are needed.

EU initiatives on funding

75 To ease grid operators' access to funding, the Commission, in the EU Action Plan for Grids:

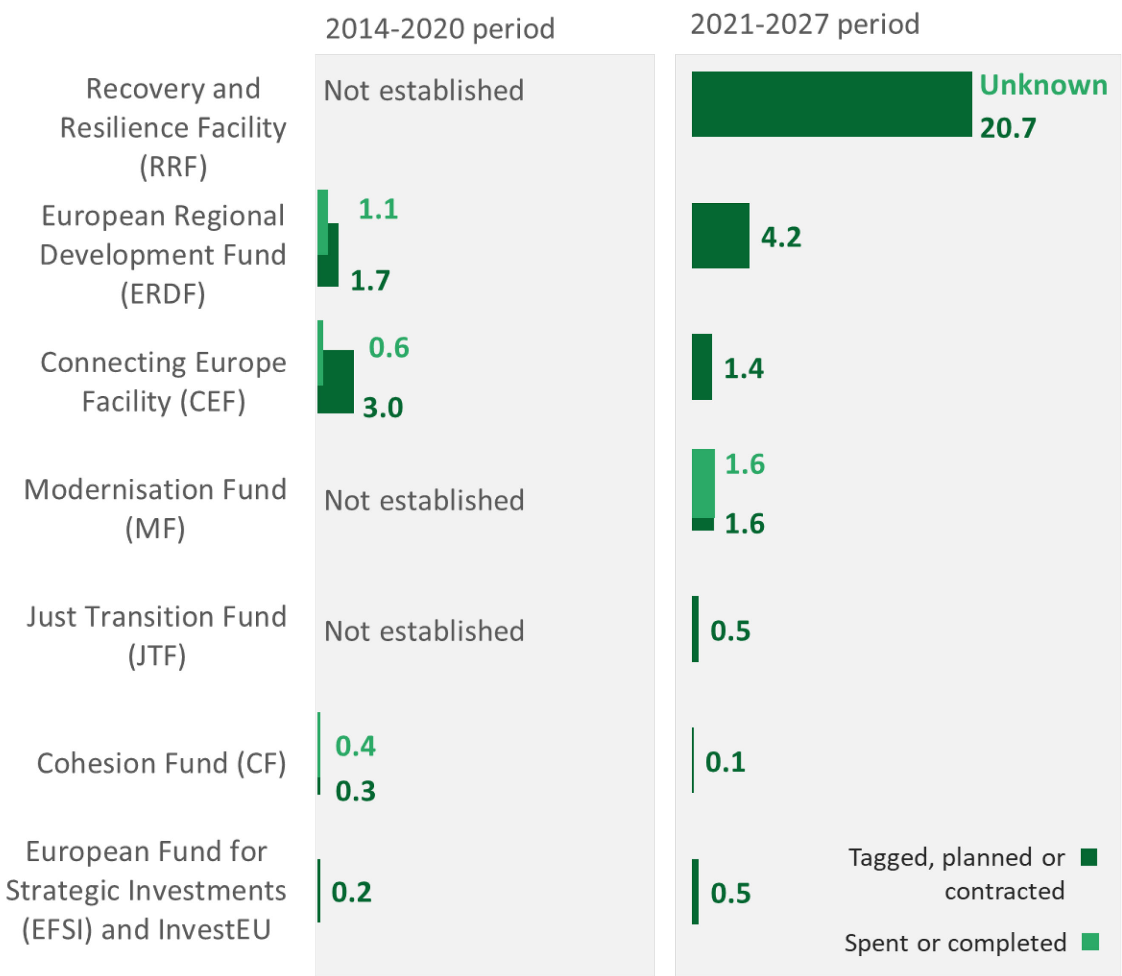
- incentivises forward-looking investments, working with institutions like the European Investment Bank to explore new funding tools, and aims to increase the attractiveness of EU funding opportunities;
- encourages NRAs to revise network tariff methodologies on a regular basis, shifting from models driven by grid investments to more flexible approaches that align with the energy system's evolving needs, while promoting the dissemination of best practices.

76 Several **EU instruments** are available to support electricity grid infrastructure investments (***Annex VIII***). During the 2014-2020 period, roughly €5.3 billion in EU funding was available for grid investments. In 2021-2027 period, the amount increased to approximately €29.1 billion, mainly due to the Recovery and Resilience Facility (RRF) which is the largest funding source. These amounts represent a fraction of the total grid investments needs.

77 The EU funding for grid investments has also encountered some implementation challenges. The Commission reported that certain funding possibilities have been under-utilised[23]. For both periods, a total of €3.7 billion was used as of 2024 (***Figure 23***). Regarding the RRF specifically, member states are not required to report on incurred expenditures, making the amount spent unknown. Additionally, as stated in a previous audit report, the RRF is progressing with delays and facing risks related to the completion of its measures. Moreover, it is also a temporary instrument, which limits its suitability for addressing investment needs in the long term.

[23] COM(2023) 757, An EU Action Plan for Grids, point I.

Figure 23 – EU amounts for grid investments in the 2014-2020 and 2021-2027 periods (billion euro)



Notes: for 2014-2020, ERDF and CF amounts correspond to intervention fields 005, 006 and 015 (electricity and smart grids); for 2021-2027, ERDF, CF and JTF amounts correspond to intervention field 053 (smart energy systems and storage).

Source: ECA, based on cohesion open data platform for ERDF, CF and JTF (data from June, May and March 2024, respectively); Commission for EFSI and InvestEU, CEF and RRF (data from May, June and November 2024, respectively); and online for the Modernisation Fund.

Closing remarks

78 The EU has set forward-looking climate and energy goals to effectively fight against climate change and has already made progress toward achieving them. In recent years, several initiatives and legislative packages have been developed to reach those targets, including efforts to produce electricity from renewable energy and to develop the electricity grid. Russia's war of aggression against Ukraine increased the need for alternatives to gas, including the electrification of the EU economy (paragraphs ***01***-***14***).

79 Large-scale grid investments are crucial to support the energy transition and to modernise the ageing network. The first part of this review explores the fundamentals of grid investments, detailing their importance and examining the current investment plans of grid operators until 2050 (paragraphs ***20***-***39***). If the current pace of planned investments is maintained, grid investments will total €1 871 billion between 2024 and 2050. This is below the Commission's estimated investment needs of €1 994 billion to €2 294 billion for the electricity grid. We have highlighted several challenges in accelerating the investments in grid infrastructure:

- ineffective, complex and fragmented grid planning;
- lengthy permitting processes and limited public acceptance;
- shortages of equipment, materials and skilled labour.

The above challenges can be mitigated by:

- better coordinated and integrated grid planning practices;
- streamlining permitting and enhancing public engagement;
- the use of modern technology solutions and more use of transparent processes and tools such as capacity maps;
- training and upskilling initiatives to address the labour shortage.

80 The second part of the report presents strategies for optimising grid development and reducing investment needs (paragraphs ***40***-***58***). These strategies focus on easing the pressure on the grid by better adapting to daily, weekly and seasonal fluctuations in energy consumption and generation. More efficient solutions to manage energy demand and supply can reduce the need for large-scale grid expansion. We identified the following opportunities:

- strengthening interconnections between member states;
- the widespread use of advanced grid technologies;
- employing demand-response measures to smooth out demand peaks;
- developing and scaling up new storage solutions;
- increasing the role of prosumers and energy communities.

Taking full advantage of these opportunities is hampered by:

- the slow roll-out of smart meters in some member states;
- storage solutions such as batteries and renewable hydrogen that are either not sufficiently advanced or are too expensive.

81 The last part of the review examines how grid investments are funded, the influence of regulatory frameworks on grid operators' investment decisions and the financial capacity data of these operators (paragraphs ***59***-***77***). It underlines three main challenges:

- striking a balance between the investment needs and keeping the electricity bills affordable for consumers, particularly households and energy-intensive industries;
- maintaining grid operators' access to finance;
- speeding up investments while limiting the risk of resources being spent on projects that may be underused or unnecessary.

At the same time, opportunities to facilitate the funding include:

- using appropriate regulatory frameworks to incentivise efficient investment;
- utilising the full potential of EU funding initiatives.

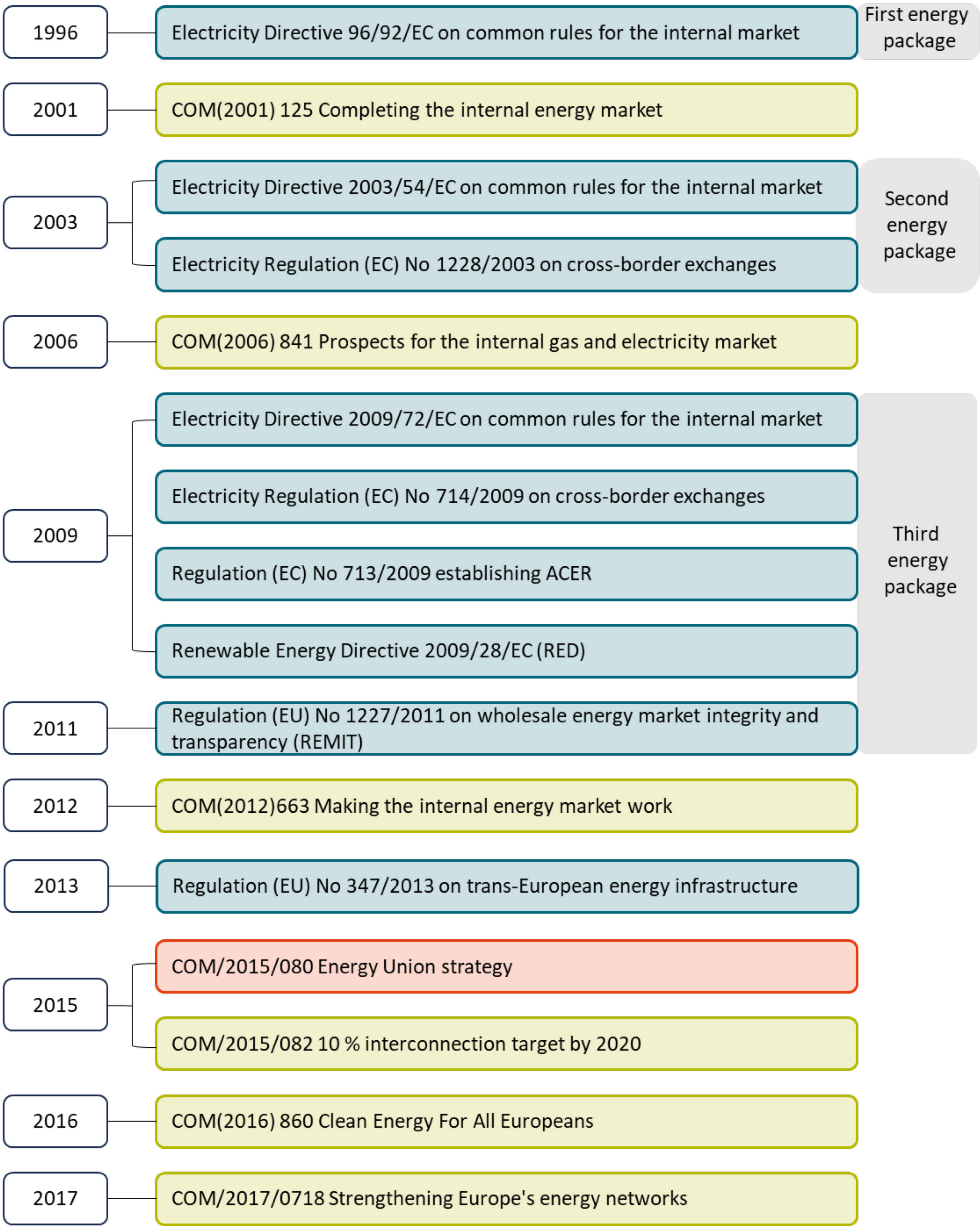
82 To make the EU electricity grids fit for net zero, all parties involved need to work together. The European Union, and the Commission in particular, play a key role in this process, by improving overall governance and planning, creating the necessary legislative environment and providing funding. At the same time, member states and grid operators are responsible for developing the grids and addressing the related practical, regulatory and financial challenges. Consumers will become increasingly important as producers of energy and active members of the future electricity system.

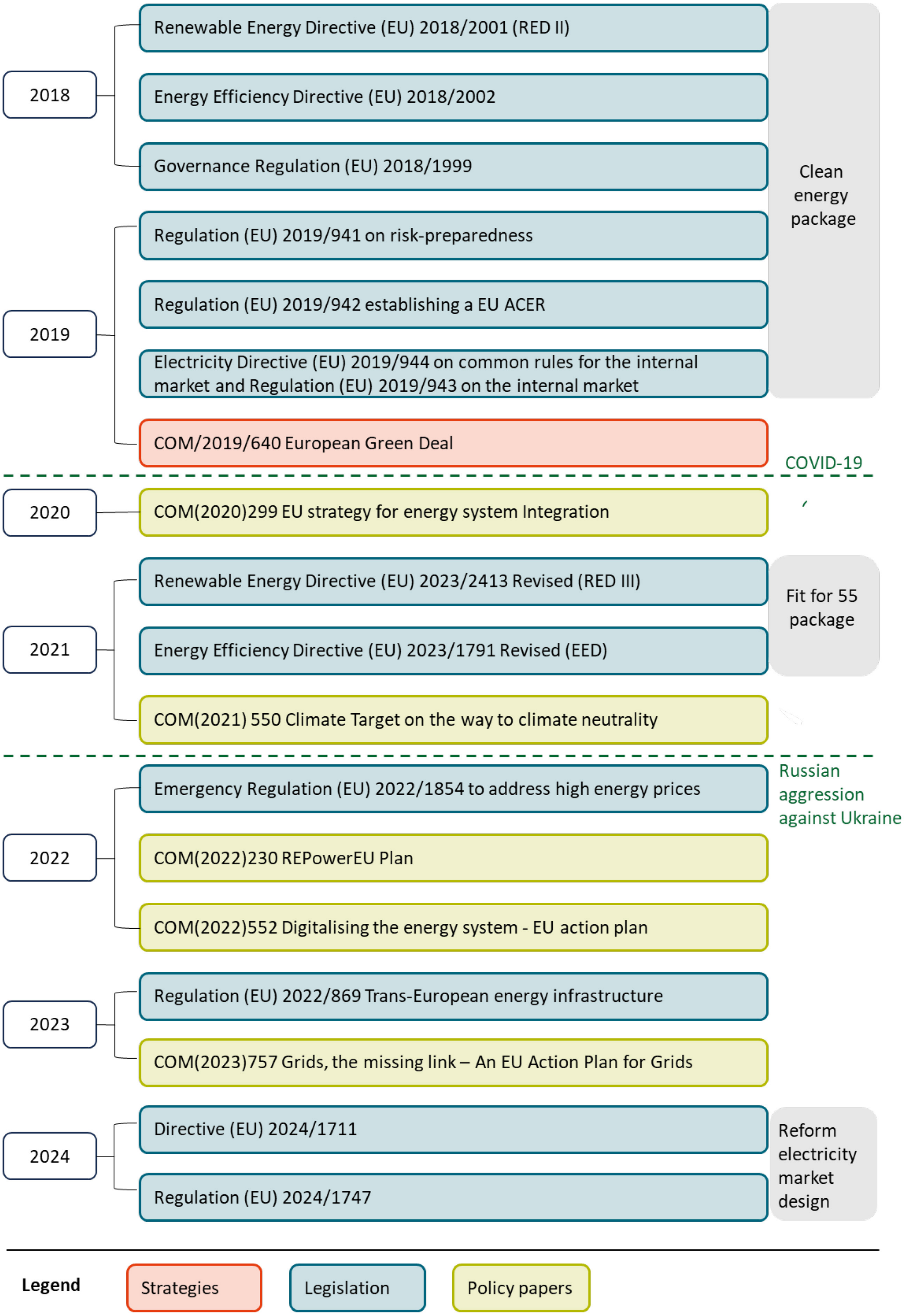
This review was adopted by Chamber I, headed by Ms Joëlle Elvinger, Member of the Court of Auditors, in Luxembourg at its meeting of 12 February 2025.

For the Court of Auditors

Tony Murphy
President

Annex I – Evolution of the EU policy for electricity grids




2018
Renewable Energy Directive (EU) 2018/2001 (RED II)
Energy Efficiency Directive (EU) 2018/2002
Governance Regulation (EU) 2018/1999
2019
Regulation (EU) 2019/941 on risk-preparedness
Regulation (EU) 2019/942 establishing a EU ACER
Electricity Directive (EU) 2019/944 on common rules for the internal market and Regulation (EU) 2019/943 on the internal market
Clean energy package
COM/2019/640 European Green Deal
COVID-19
2020
COM(2020)299 EU strategy for energy system Integration
2021
Renewable Energy Directive (EU) 2023/2413 Revised (RED III)
Energy Efficiency Directive (EU) 2023/1791 Revised (EED)
Fit for 55 package
COM(2021) 550 Climate Target on the way to climate neutrality
Russian aggression against Ukraine
2022
Emergency Regulation (EU) 2022/1854 to address high energy prices
COM(2022)230 REPowerEU Plan
COM(2022)552 Digitalising the energy system - EU action plan
2023
Regulation (EU) 2022/869 Trans-European energy infrastructure
COM(2023)757 Grids, the missing link – An EU Action Plan for Grids
2024
Directive (EU) 2024/1711
Regulation (EU) 2024/1747
Reform electricity market design
Legend
Strategies
Legislation
Policy papers

Source: ECA.

Annex II – Key characteristics of EU electricity grids

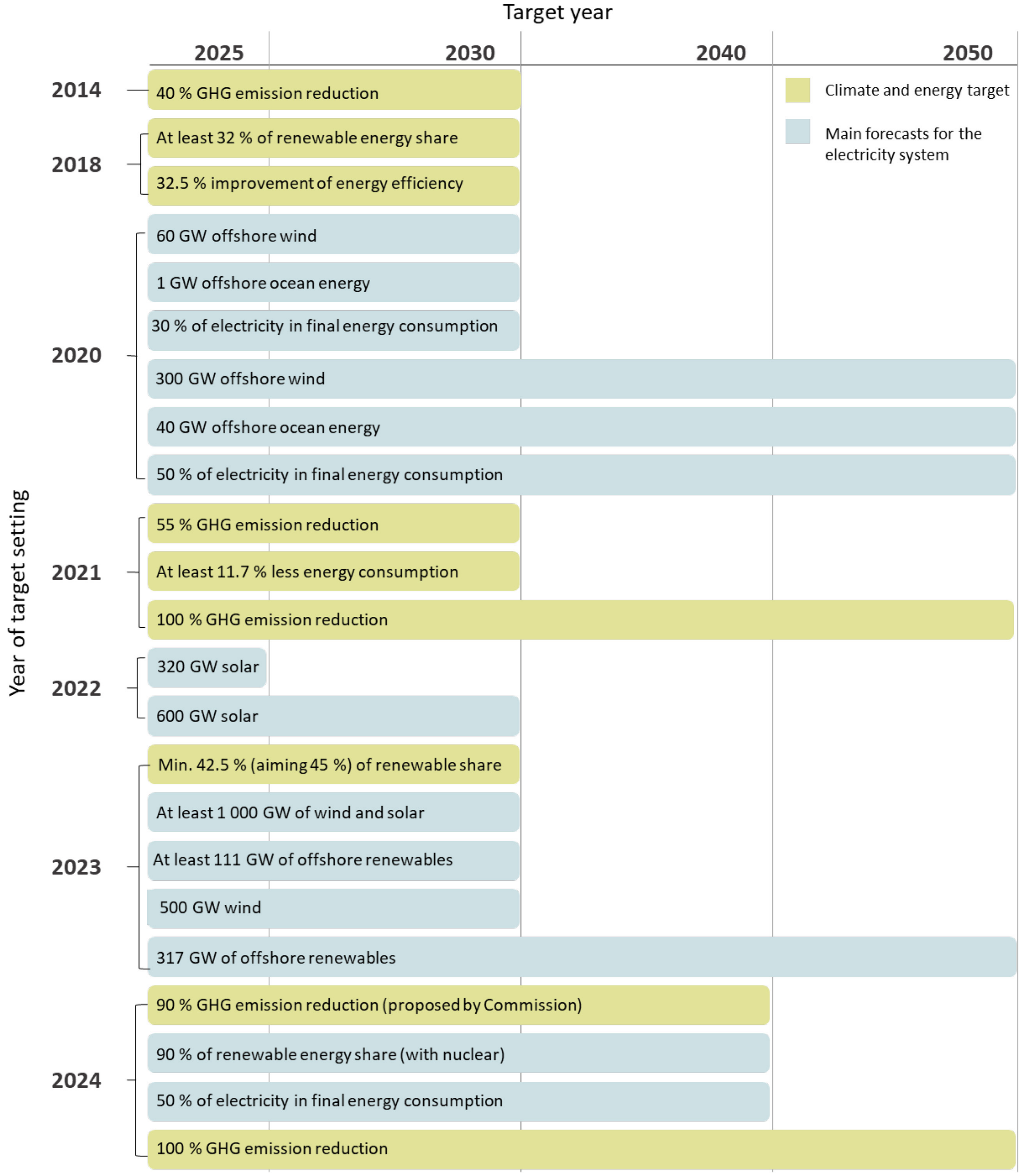
	Grid operators			Length of the grids				Age of the grids	
	DSOs	TSOs	Connected customers	Distribution	Transmission	Direct current	Total	Distribution	Transmission
	Number	Number	Million	Km	Km	Km	Km	Years	Years
Austria	124	2	4.9	263 875	6 769	*	270 644	*	*
Belgium	16	1	6.3	208 632	4 287	*	212 919	32.6	24
Bulgaria	4	1	4.5	161 826	15 384	*	177 210	N/A	N/A
Croatia	1	1	2.5	143 130	7 861	*	150 991	*	*
Cyprus	1	1	0.5	28 708	1 286	*	29 994	N/A	N/A
Czechia	252	1	6.2	249 887	5 642	*	255 529	*	*
Denmark	38	1	3.2	158 320	6 100	*	164 420	*	*
Estonia	32	1	0.6	66 203	5 100	139	71 442	25	*
Finland	77	1	3.8	423 586	14 159	320	438 065	12.0	31.2
France	138	1	40.2	1 409 117	106 602	1 400	1 517 119	17 (underground) 25 (the rest)	50 (overhead) 20 (underground) 30 (substations)
Germany	866	4	52.2	2 199 306	36 988	*	2 236 294	N/A	13
Greece	1	1	7.7	247 317	13 531	267	261 115	*	*
Hungary	6	1	7.5	165 917	4 897	*	170 814	*	27
Ireland	1	1	2.4	181 181	7 191	*	188 372	*	*
Italy	123	1	37.1	1 286 215	72 655	2 797	1 361 667	*	*
Latvia	10	1	1.1	92 323	5 555	*	97 878	19.4	15.1
Lithuania	5	1	1.9	128 405	7 299	*	135 704	35	36.5
Luxembourg	5	1	0.3	12 636	163	*	12 799	23-27	9-40
Malta	1	no TSO	0.3	6 175	0	*	6 175	N/A	N/A
Netherlands	6	1	9	262 000	10 000	*	272 000	*	*
Poland	231	1	19.1	893 295	16 341	127	909 763	*	*
Portugal	13	1	6.5	234 669	9 409	0	244 078	18	14

	Grid operators			Length of the grids				Age of the grids	
	DSOs	TSOs	Connected customers	Distribution	Transmission	Direct current	Total	Distribution	Transmission
	Number	**Number**	**Million**	**Km**	**Km**	**Km**	**Km**	**Years**	**Years**
Romania	8	1	9.4	506 716	9 115	0	515 831	110kV lines: 47 Medium voltage lines: 43 Low voltage lines: 38 110kV substations: 44 Medium voltage substations: 34	Overhead lines 110kV: 36 Overhead lines 220kV: 52 Overhead lines 400kV: 44 Transformers: 20
Slovakia	146	1	2.7	94 790	3 126	*	97 916	*	*
Slovenia	1	1	0.8	65 477	3 114	*	68 591	*	*
Spain	333	1	29.6	825 765	45 222	*	870 987	22.67	14
Sweden	150	1	5.6	577 004	17 000	*	594 004	28	35
TOTAL	2 589	30	265.9	10 892 474	434 795	N/A	11 332 320		

* No information provided by the NRA.

Source: Based on the questionnaires sent to the NRAs; CEER, Report on Regulatory Frameworks for European Energy Networks 2023 (February 2024); and EU DSO Entity, Map the Green Deal's drivers: Distribution grids across the EU (2024) based on information reported to the EU DSO Entity by distribution grid operators.

Annex III – Evolution of EU climate and energy targets



Source: ECA, as of June 2024.

Annex IV – Member states' views: best practices and areas for improvement at EU level on the planning exercise

Best practice highlighted on the planning exercise
Scenario-based planning integrating the national development plan process with the ten-year network development plan process regarding data sets, scenarios and modelling.
Public consultation of scenarios and early input from stakeholders, including NRAs, in order to be taken into account in setting up scenarios and modelling assumptions.
NRAs' full access to data with spatial resolution at substation level and differentiation between existing and planned connections by connection type and according to grid planning methodologies.
NRAs should have the legal power to challenge TSOs in the planning phase.
Robust cost-benefit analysis for each investment.
Methodological framework for distribution network development plans.
Parallel use of technical analysis alongside economic and market analysis.
Assessing the optimal increases in cross-zonal capacities in the transmission grid and infrastructure gaps at EU level.
Use the same calculation methodology and input parameters in the DSO and TSO planning process. Joint committee decisions on investment solutions, development solutions to solve congestions. This results in a more coordinated and transparent planning process where the NRA can also gain insight to better monitor the plan.
Areas for improvement at EU level
Setting up a common EU vision on definition of needs and use of common scenarios.
Ensuring wider powers for the NRAs to set up an official national development plan approval (correction) process to be carried out by NRAs (both TSO and DSO), and the right to demand more detailed information in a national development plan. The EU should ensure that NRAs have full powers regarding infrastructure planning.
Affordability for users should also be taken into consideration in decision-making (decision influence will increase system tariffs).
Drafting of a general manual or guide for national development plans (both TSO and DSO) about the more precise information needed and the layout of the plans.
Allocation of European funds for the development of networks for the purpose of energy transition.
More flexible regulation and targets for each member state, as the situation and possibilities in each country differ.
Set out clearly defined rules around when low-carbon technologies can be prioritised over high-carbon emitting technologies. With the growing presence of data centres and other large energy users in Europe, more EU standards may need to be set to address issues with system stability and growing demand. Standards throughout the EU could avoid individual member states from having to pass standards on an ad-hoc basis and possibly jeopardising future investments.

Source: Information provided by NRAs to the ECA.

Annex V – Member states' views: best practices and areas for improvement at EU level to foster flexibility

Best practice highlighted to foster flexibility
All member states should honour the user pays principle in grid tariffs for storage. Generous discounts (especially for battery systems) are not justified and are likely to result in counterproductive competition between member states.
Incentive regulation based on KPIs linked to costs of flexibility and volumes of flexible capacity bidding.
Short-term solution for the integration of heat pumps and private charging devices which are generally used simultaneously by different grid users. Such a solution may give the DSO the right to control flexible devices at the low voltage level to avoid emergency situations. The intervention by the DSO must be based on observed grid constraints and requires digitalisation of the low voltage level including smart meters and control devices needed to foster flexibility. As a reward for the potential controllability, the customer gets a discount on their grid fee. DSO's interventions are considered a last resort measure and should not take place on a routine basis. If frequent interventions take place, the DSO has to expand its grid.
Incentive for innovation in electricity transmission and distribution with precise goals and penalties if the operator fails to achieve them. Such innovation may, for example, be a specific action to increase electricity storage and resolve congestion instead of making new investments.
Deployment of new-generation smart meters, through a subsidised remuneration scheme to allow real-time monitoring of consumption, enabling suppliers or third parties to offer flexible demand-management solutions. This helps to access fine-grained flexibilities that smaller consumers may offer.
Set up a demand-side national strategy by consulting various stakeholders to address key flexibility fostering levers such as implicit flexibility, explicit flexibility, and mandatory legal requirements. For implicit flexibility, or flexibility as a form of response to incentives, regulatory frameworks can be made around the time of use and dynamic tariffs, electric vehicles charging, and overall demand response with smart meters and communication systems. For explicit flexibility, or flexibility that is procured with contracts or specifically designed products that deliver a defined flexibility response, regulatory frameworks can be built to approve the procurement of necessary services by grid operators. Lastly, mandatory requirements are associated with connection to the electricity system or with planning requirements and can elicit flexibility through requiring assets seeking a demand connection to have flexibility services in place at the time of connection.
Offer the possibility to increase the contractual capacity (kW) of households at night and on Sundays (low-consumption hours), free of tariff increases for the additional power (kW) needed to recharge electric vehicles at home. This measure is intended to drive the additional demand to power electric vehicles in the low-consumption periods.
Pilot projects to foster local flexibility markets and to incorporate flexibility to complement network investment.
Areas for improvement at EU level
Provide good practices for flexibility.

Source: Information provided by NRAs to ECA.

Annex VI – Regulatory frameworks for the remuneration of grid operators in EU member states

	TSO		DSO		WACC[1]		Beta[2]		Regulatory debt ratio[1]		Allowed return on equity[2]	
	CAPEX[3]	OPEX[4]	CAPEX[3]	OPEX[4]	TSO	DSO	TSO	DSO	TSO	DSO	TSO	DSO
Austria					4.88 %	4.16 %	0.85	0.86	60 %	60 %	7.84 %	6.93 %
Belgium			Flanders Wallonia Brussels	Flanders Wallonia Brussels	4.10 %	3.50 %	0.69	Brussels 0.7, Flanders 0.39	40 %	Flanders- 60 %	6.11 %	Flanders 5.44 %, Brussels 4.44 %
Bulgaria					3.00 %	7.00 %	N/A	0.99		50 %	n/a	6.90 %
Cyprus					1.75 %	4.60 %	0.33	0.52	0 %	31 %	1.92 %	4.26 %
Czechia					6.63 %	6.63 %	0.89	0.89	49 %	49%	9.97 %	9.97 %
Germany					N/A	N/A	0.81	0.81			5.07 %	5.07 %
Denmark					2.71 %	5.44 %	N/A	0.70		50 %	6.78 %*	7.00 %
Estonia					6.22 %*	6.27 %	0.69	0.71	50 %	50 %	7.99 %	8.09 %
Greece					7.51 %	7.66 %	0.80	0.8	45 %	43 %	10.33 %	10.33 %
Spain					5.58 %	5.58 %	0.72	0.72	50 %	50 %	8.53 %	8.53 %
Finland					6.67 %	7.37 %	0.56	0.93	41 %	54 %	7.82 %	9.95 %
France					4.60 %	N/A	0.78	no WACC	60 %		7.80 %	N/A
Croatia					4.03 %*	4.03 %*	0.38*	0.38*	60 %*	60 %*	N/A	N/A
Hungary					no info	no info	0.66*	0.66*			4.38 %*	4.38 %*
Ireland					3.80 %	3.80 %	0.35-0.4	0.35-0.40			4.80 %-6.88 %	4.80 %-6.88 %
Italy					5.80 %	6.00 %	N/A	N/A			7.91 %*	8.34 %*
Lithuania					5.00 %	5.09 %	0.74	0.77	50 %	50 %	6.54 %	6.70 %
Luxembourg					4.81 %	4.81 %	N/A	N/A	50 %	50 %	7.44 %	7.44 %
Latvia	TOTEX[5]		TOTEX[5]		1.48 %	1.48 %	0.74	N/A	50 %	50 %	6.36 %	6.36 %
Malta	No TSO				no TSO	6.62 %**		0.87**		53 %**		10.40 %**
Netherlands	TOTEX[5]		TOTEX[5]		2.7-2.8 %	2.7-2.8 %	0.63	0.63	45 %	45 %	5.85 % (*ex ante* value)	5.85 % (*ex ante* value)
Poland					7.47 %	8.48 %	0.72	0.72*	50 %	50 %	9.70 %	7.84 %*
Portugal	TOTEX[5]		TOTEX[5]		5.25 %	5.55 %	0.62	0.69	50 %	50 %	5.50 %	6.10 %

	TSO		DSO		WACC[1]		Beta[2]		Regulatory debt ratio[1]		Allowed return on equity[2]	
	CAPEX[3]	OPEX[4]	CAPEX[3]	OPEX[4]	TSO	DSO	TSO	DSO	TSO	DSO	TSO	DSO
Romania					6.39 %	6.39 %	0.70	0.70	40 %	40 %	8.15 %	8.15 %
Sweden					4.53 %	no info	0.54	0.52*	36 %	N/A	8.59 %	5.52 %*
Slovenia					5.15 %	5.15 %	N/A	N/A	40 %	40 %	5.95 %	5.95 %
Slovakia					5.00 %*	4.99 %*	1.05	1.05	N/A	N/A	8.40 %*	8.40 %*

*data from 2023

**data from 2022

Colour	Framework
	Cost plus
	Rate of return
	Price cap
	Revenue cap
	Not applicable or not available

Notes:

(1) $WACC\ (weighted\ average\ cost\ of\ capital) = allowed\ return\ on\ equity \times regulatory \frac{equity}{assets} + debt\ interest\ rate \times regulatory \frac{debt}{assets}$

(2) *Allowed return on equity* $= risk - free\ rate + beta \times market\ premium.$

(3) CAPEX (Capital expenditure): Long-term expenses on fixed assets, usually recovered during the asset's long-term life via depreciation – may include new lines, substation updates, smart grid technologies, grid modernisation projects.

(4) OPEX (Operational expenditure): Day-to-day expenses associated with operating, maintaining and managing the grid infrastructure – may include repairs, grid monitoring and control, balancing, dispatching and re-dispatching electricity, salaries, administrative expenses, costs related to ICT systems.

(5) TOTEX (Total expenditure): The sum of capital and operational expenditure. TOTEX regulation is a regulatory approach in which costs are treated equally regardless of whether they are capital or operational expenditure so that there is no incentive to prefer one type of expenditure over the other.

Source: Information provided by NRAs to the ECA.

Annex VII – Member states' views: best practices and areas for improvement at EU level on the regulatory frameworks for remunerating grid operators

Best practice highlighted on the regulatory framework for remuneration of grid operators
Provide financial remuneration through incentive regulation to foster the 70 % cross-zonal interconnection target.
Use of benchmarking – encourages operators to improve. Appropriate dialogue between the regulator and the operators before setting up the remuneration levels to have a proper understanding of the various issues at stake. The methodology used to determine the value of assets and the associated tariff parameters should be transparent and stable so that the operators are aware of what is expected from them in terms of efficiency. In case of anticipatory investments, the methodology for including in the regulated asset base must be well described so that the operators have sufficient information for taking decisions to implement a new project.
Output-based remuneration regulation, as it pushes the operators to improve the service and performance delivered to network users.
Partially linking the rate of return of the regulatory asset base to the evolution of the yield of the long-term government bonds and, therefore, to the financial market, reducing the financial risk to the operators.
Areas for improvement at EU level
Provide good practice guidelines for anticipatory investments.

Source: Information provided by NRAs to ECA.

Annex VIII – EU funds for electricity grid infrastructure investments

Period / legal basis	Fund/ management	Objective	Pre-conditions	Scope of financing	Financing rate
Grid development					
2014-2020 Regulation (EU) No 1316/2013	Connecting Europe Facility (CEF) Direct management	Increase competitiveness by contributing to the integration of the internal energy market and promoting the interoperability of networks across borders. Promote sustainable development and decarbonisation by integrating renewable energy sources, developing smart and carbon dioxide networks. Ensuring supply security.	Funding exclusively reserved for projects of common EU interest relating to the priority corridors and areas identified in the TEN-E Regulation, creating significant positive externalities for multiple member states and where the project is not commercially viable.	Studies, equipment, works and other accompanying measures. Cross-border infrastructure with no requirements on the eligibility of grid operators. Disbursed in the form of grants.	Maximum 50 % for studies and works. Up to 75 % if providing a high degree of regional or EU-wide security of supply, strengthening EU solidarity or offering highly innovative solutions. Actual financing rate not available.
2021-2027 Regulation (EU) 2021/1153		Same as above. Aim is also to facilitate cross-border cooperation in the area of renewable energy.	Same as above. For renewable energy cross-border projects: fulfilling the criteria laid down in Article 7 of Regulation (EU) 2021/1153.		Maximum 50 % for studies. Actual financing rate not available.
2014-2020 Regulation (EU) No 1300/2013	Cohesion Fund (CF) Shared management	Reduce economic and social disparities in the EU, by supporting electricity infrastructure that contributes to this goal in member states whose gross national income per capita is less than 90 % of the EU average, while simultaneously addressing energy security, market integration, and climate change objectives.	Plans describing the national energy infrastructure priorities and a national renewable energy action plan.	Develops smart energy systems outside the Trans-European Energy Network. Funds available for TSOs and DSOs. Disbursed in the form of grants and financial instruments.	Maximum of 85 %. Actual average rate of 85 %.
2021-2027 Regulation (EU) 2021/1058			Alignment with national energy and climate plan.		Maximum of 85 %. Average planned rate of 85 %.
2014-2020 Regulation (EU) No 1301/2013	European Regional Development Fund (ERDF)	Improve competitiveness of regions through the development of smart energy distribution, storage and transmission systems and through	Plans describing the national energy infrastructure priorities and a national renewable energy action plan.	Mature projects, mostly in smaller low-voltage distribution infrastructure,	Maximum of 85 %, depending on region. Actual average rate of 67 %.

Period / legal basis	Fund/ management	Objective	Pre-conditions	Scope of financing	Financing rate
2021-2027 Regulation (EU) 2021/1058	Shared management	the integration of distributed generation from renewable sources.	Alignment with national energy and climate plan.	that leverage private investment. Funds available for TSOs and DSOs. Disbursed in the form of grants and financial instruments.	Maximum of 85 %, depending on region. Average planned rate of 74 %
Energy transition and decarbonisation					
2021-2027 Regulation (EU) 2021/1056	Just Transition Fund (JTF) Shared management	Reduce the social and economic costs resulting from the transition to the EU's climate targets, for the regions most affected given their dependence on fossil fuels.	Alignment with just transition plans.	Activities to alleviate the negative socio-economic impact of transition. Disbursed in the form of grants, procurement and financial instruments. Funds available for TSOs and DSOs.	Maximum of 85 %, depending on region. Average planned rate of 71 %.
2021-2030 Regulation (EU) 2020/1001 ETS Directive 2003/87/EC, amended by Directive (EU) 2023/959	Modernisation Fund Not subject to the Financial Regulation.	Modernisation of energy systems and improvement of energy efficiency of lower-income member states, including updating electricity grids to facilitate the integration of renewable energy sources.	At least 80 % of funds to be invested in priority investments. Compliance with state aid rules if co-financed.	Modernisation of energy grids, including demand-side management, district heating, electricity transmission, and increased interconnections between member states. Funding primarily through grants but can also include premiums, guarantees, loans, or capital injections.	As per requirement under relevant State aid provision. Actual rate not available.

Period / legal basis	Fund/ management	Objective	Pre-conditions	Scope of financing	Financing rate
Recovery and resilience					
2021-2026 Regulation (EU) 2021/241 as amended by Regulation (EU) 2023/435	Recovery and Resilience Facility (RRF) Direct management for EU-level payments to member states	Support reforms and investments to mitigate the economic and social impact of the COVID-19 pandemic and make EU economies and societies more sustainable and resilient for the future. In this context, it specifically aims to increase the resilience, security and sustainability of the EU's energy system, including by supporting electricity infrastructure.	Achievement of the milestones and targets pre-defined in the Council implementing decisions.	Defined by member state in their recover and resilience plans. Some measures target TSOs or DSOs, others include both.	Defined by member states.
2015-2020 Regulation (EU) 2015/1017	European Fund for Strategic Investments (EFSI) Indirectly managed	Development and modernisation of energy infrastructure (in particular interconnections, smart grids at distribution level, energy storage and grid synchronisation).	The project must be economically and technically viable, maximise private sector investment; be consistent with EU policies; and address market failures or suboptimal investment situations.	No restriction.	Not applicable.
2021-2027 Regulation (EU) 2021/523	InvestEU Indirectly managed	Development, smartening and modernisation of a sustainable energy infrastructure, in particular storage technologies, electricity interconnections between member states and smart grids, both at transmission and distribution level.		No restriction.	Not applicable.

Source: ECA.

Abbreviations

CEER: Council of European Energy Regulators

DSO: Distribution system operator

ENTSOG: The European Network of Transmission System Operators for Gas

GW: Gigawatt

kWh: Kilowatt-hour

NRA: National regulatory authorities

TSO: Transmission system operator

Glossary

Distribution: Transport of electricity on high, medium and low voltage networks, prior to its supply to customers.

Electricity system: Infrastructure and networks for generating, transmitting, distributing and delivering electricity from producers to consumers, supported by control systems and communication networks for monitoring and management.

Electricity grid: Interconnected network of power lines and cables and associated infrastructure and equipment (e.g. substations, transformers) used to transmit and distribute electricity over a geographical area to consumers.

Net-zero: Climate target in which carbon emissions from human activities are reduced to a residual amount that can then be removed, or absorbed and permanently stored by nature (i.e. in trees, soil), leaving zero in the atmosphere.

Smart grid: Electricity network that uses digital technologies to better match electricity supply and demand in real time while minimising costs and remaining stable and reliable.

Transmission: Transport of electricity on extra high and high voltage interconnected networks, prior to its delivery to distribution system operators and supply to final customers.

ECA team

This report was adopted by Chamber I – Sustainable use of natural resources, headed by ECA Member Joëlle Elvinger. The task was led by ECA Member Keit Pentus-Rosimannus, supported by Annikky Lamp, Head of Private Office and Daria Bochnar, Private Office Attaché; Emmanuel Rauch, Principal Manager; Sara Pimentel, Head of Task; Dirk Neumeister, Ilka Raab, Lucia Roșca, Michal Szwed, Auditors. Laura McMillan and Zoe Amador Martínez provided linguistic support. Alexandra Damir-Binzaru and Dunja Weibel provided graphical support and Frédérique Hussenet provided secretarial support.

From left to right: Emmanuel Rauch, Frédérique Hussenet, Annikky Lamp, Lucia Roșca, Keit Pentus-Rosimannus, Daria Bochnar, Sara Pimentel, Dirk Neumeister, Michal Szwed.

COPYRIGHT

© European Union, 2025

The reuse policy of the European Court of Auditors (ECA) is set out in ECA Decision No 6-2019 on the open data policy and the reuse of documents.

Unless otherwise indicated (e.g. in individual copyright notices), ECA content owned by the EU is licensed under the Creative Commons Attribution 4.0 International (CC BY 4.0) licence. As a general rule, therefore, reuse is authorised provided appropriate credit is given and any changes are indicated. Those reusing ECA content must not distort the original meaning or message. The ECA shall not be liable for any consequences of reuse.

Additional permission must be obtained if specific content depicts identifiable private individuals, e.g. in pictures of ECA staff, or includes third-party works.

Where such permission is obtained, it shall cancel and replace the above-mentioned general permission and shall clearly state any restrictions on use.

To use or reproduce content that is not owned by the EU, it may be necessary to seek permission directly from the copyright holders.

Figure 2: icons: Adobe Stock/SkyLine.

Figures 3 and 4: icons ©stock.adobe.com and icons that have been designed using resources from Flaticon.com. © Freepik Company S.L. All rights reserved.

Figure 5: Data from EU DSO-Entity. All rights reserved.

Figures 7 and 15: icons have been designed using resources from Flaticon.com. © Freepik Company S.L. All rights reserved.

Figure 10: maps © *Netbeheer Nederland*, as of 4.10.2024 | © Esri Nederland | © MapTiler © OpenStreetMap contributors.

Figure 17: icons: Adobe Stock/SkyLine/stockgood.

Figures 20, 21 and 22: data based on information from Orbis database. © 2025 Moody's Analytics, Inc. and/or their licensors and affiliates. All rights reserved.

Software or documents covered by industrial property rights, such as patents, trademarks, registered designs, logos and names, are excluded from the ECA's reuse policy.

The European Union’s family of institutional websites, within the europa.eu domain, provides links to third-party sites. Since the ECA has no control over these, you are encouraged to review their privacy and copyright policies.

Use of the ECA logo

The ECA logo must not be used without the ECA’s prior consent.

PDF	ISBN 978-92-849-4748-5	ISSN 2811-8197	doi:10.2865/8522579	QJ-01-25-017-EN-N

HOW TO CITE

European Court of Auditors, review 01/2025: “Making the EU electricity grid fit for net-zero emissions”, Publications Office of the European Union, 2025.

We often take electricity for granted, expecting it at the flick of a switch. Yet behind the scenes, 11.3 million Km of electricity lines and cables bring electricity to 266 million customers. Combating climate change and enhancing the EU's energy independence requires a modernised electricity grid, capable of integrating more renewable energy and adapting to rising electrification. This review examines the state of the EU's electricity grids, key trends, and policies and outlines the challenges and opportunities of having a grid fit for net zero. We highlight the need to accelerate the large-scale investments for the energy transition, ways to reduce investment needs through electricity system and grid flexibility, and the important role of regulatory frameworks in securing funding.

EUROPEAN COURT OF AUDITORS
12, rue Alcide De Gasperi
1615 Luxembourg
LUXEMBOURG

Tel. +352 4398-1

Enquiries: eca.europa.eu/en/contact
Website: eca.europa.eu
X: @EUAuditors

CURIA RATIONUM

EUROPEAN
COURT
OF AUDITORS