15 YEARS ENTSO-E

Powering the Energy Transition

Annual Report
2024 Edition

Contents

Foreword

In 2024, ENTSO-E reached a major milestone: fifteen years of connecting Europe's electricity networks through technical excellence, cooperation, and system-wide coordination. This anniversary was not only a celebration of progress, but also a moment of strategic reflection. At our 15 year Anniversary Conference in Brussels, members, stakeholders and decision-makers from across Europe came together to recognise the achievements of the past decade and a half, and to look ahead to the challenges of delivering a fully decarbonised, digitalised and resilient power system.

Zbyněk Boldiš
President

Damian Cortinas
Chair of the Board

This reflection is rooted in our **Strategic Roadmap**, which continues to guide our work across two interconnected pillars: preparing the European power system for a carbon-neutral future, and ensuring a secure, efficient, and affordable system throughout the transition. In 2024, we made progress across both dimensions.

On network infrastructure, the Ten-Year Network Development Plan laid out the infrastructure needed to meet Europe's electrification goals, showing that every euro invested could bring back twice the value in system benefits such as cost savings, efficiency, and improved security of supply. To support faster delivery, ENTSO-E also worked to identify and address supply chain bottlenecks, recognising the need for greater manufacturing capacity and more resilient procurement across Europe. At the same time, we advanced discussions on financing frameworks that can unlock investment and ensure long-term support for transmission infrastructure at national and cross-border levels.

On system security and efficiency, the European Resource Adequacy Assessment and our Seasonal Outlook reinforced trust in Europe's ability to manage supply and demand under ever-evolving conditions. Complementing this, ENTSO-E launched a study on system flexibility needs, helping to lay the groundwork for national assessments under the reformed Electricity Market Design. ENTSO-E conducted an expert investigation into the June 2024 blackout in South-East Europe, in line with the Incident Classification Scale (ICS) Methodology. The resulting recommendations focused on improving grid observability and enhancing regional preparedness. Our work on market coupling and balancing platforms continued to support a more integrated internal electricity market, while new initiatives such as the West Balkan Joint Declaration reflected growing alignment across regions.

A defining aspect of 2024 was ENTSO-E's deepening cooperation with EU energy stakeholders. Over the year, we organised more than 120 workshops with stakeholders, reflecting the scale and intensity of our collaboration with the industry. Our close partnership with the EU DSO Entity continued to advance flexibility, digitalisation, and system coordination, reflected in joint work on demand response, data interoperability, and the Digital Twin initiative. At the same time, our collaboration with ENTSOG on the development of joint TYNDP 2024 Scenarios highlighted the importance of system-wide coherence across electricity and gas. Through sustained engagement with stakeholders from across the EU energy sector, ENTSO-E remains committed to ensuring that Europe's energy transition is coordinated, inclusive, and grounded in system-wide expertise.

These achievements would not be possible without the commitment and expertise of the entire ENTSO-E community. We would like to express our sincere thanks to our TSO members across Europe who continue to contribute to our shared mission, and to the ENTSO-E Secretariat in Brussels for its tireless support and dedication.

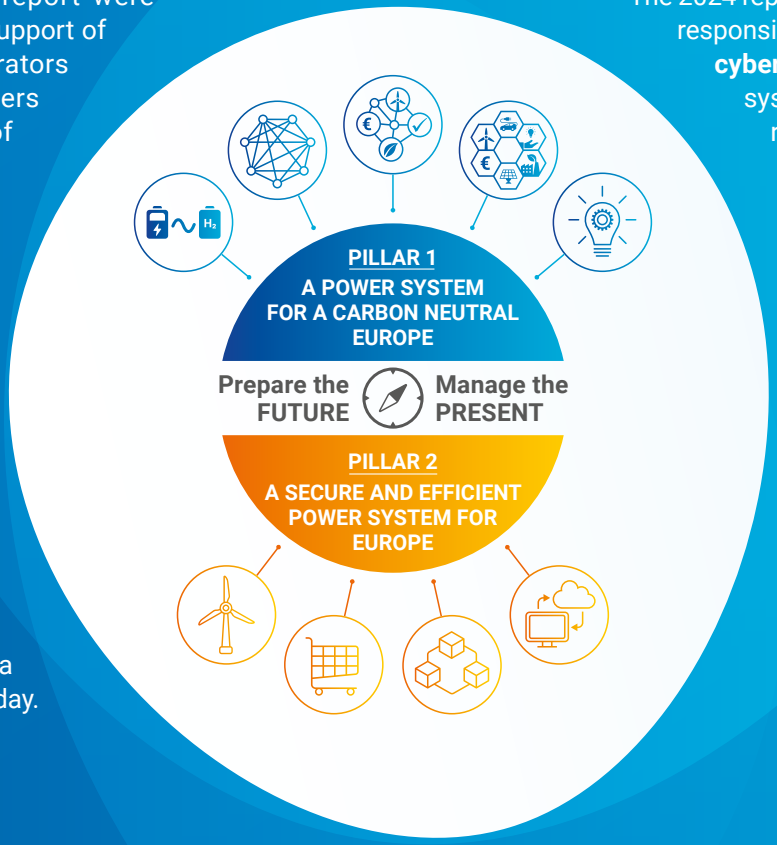
As we look ahead to the next chapter, we remain united by a clear purpose: **to deliver a secure, efficient and integrated power system that serves all Europeans**.

Introductory Statement

This Annual Report covers the period from **January 2024 to December 2024**. It presents ENTSO-E's key achievements in supporting the secure and coordinated operation of Europe's power system, while contributing to the implementation of European energy and climate policy objectives. The report highlights ENTSO-E's central role in **facilitating the energy transition**, in fulfilling its **legal mandates** under EU legislation, and in coordinating **pan-European "All TSOs" tasks** across system operation, market design, infrastructure planning, innovation, and digitalisation.

The activities described in this report were carried out with the expertise and support of the 40 Transmission System Operators (TSOs) that were ENTSO-E members in 2024. The successful delivery of these tasks also reflects the valued input of stakeholders through structured consultations, collaborative processes, and dedicated engagement forums.

A core framing element of ENTSO-E's work in 2024 is the **Strategic Roadmap 2023–2025**, which sets the vision and priorities for Europe's TSOs. The Roadmap defines a common direction based on two interconnected pillars: **Pillar 1** – Preparing a power system fit for a carbon-neutral Europe, and **Pillar 2** – Operating a secure and efficient power system today.



The 2024 report also reflects ENTSO-E's expanding responsibilities in the context of **digitalisation**, **cybersecurity**, and the integration of new system actors, including developments related to the **Network Code on Demand Response** and the **Network Code on Cybersecurity**.

In an increasingly complex and fast-changing energy landscape, ENTSO-E continues to act as a **technical leader and trusted partner**, contributing to the success of the European Green Deal and ensuring the power system remains **secure, efficient, and future-ready**.

1
About us

Our Mission, our Vision

Who We Are

ENTSO-E, the European Network of Transmission System Operators for Electricity, brings together 40 TSOs from 36 countries to ensure the secure and coordinated operation of Europe's electricity system – the world's largest interconnected grid. Created with a legal mandate under EU law, ENTSO-E serves as the common voice of European TSOs, delivering technical coordination and strategic contributions to support Europe's energy and climate objectives.

Our Mission

The Association's mission is to maintain system security across all timeframes, facilitate the efficient operation and development of the internal electricity market, and enable the integration of renewables and emerging technologies.

Our Vision

ENTSO-E's vision is to support Europe in becoming the first climate-neutral continent by 2050, by creating a secure, sustainable, and affordable electricity system. This transformation requires deep sector integration, innovation, and close cooperation between all energy actors. ENTSO-E is committed to leading this transition by applying its system-wide expertise, delivering credible planning, and promoting climate-aligned infrastructure and market design.

Our Values

As a community of TSOs acting in solidarity under a clear legal mandate, ENTSO-E contributes to EU policy development through expert input and constructive dialogue. In all its work, the Association acts with technical rigour, transparency, and a focus on social welfare, system resilience, and long-term sustainability.

Governance

In 2023, ENTSO-E elected their new governance team, effective from 28 June 2023. The new leadership is led by the President Mr Zbyněk Boldiš, Vice-President Ms Asta Sihvonen-Punkka, Chair of the Board Mr Damian Cortinas and Vice-Chair of the Board Mr Tahir Kapetanovic. Mr Kapetanovic was elected Vice-Chair of the Board on 5 October 2023.

The Chairs of the ENTSO-E Committees, of the Legal and Regulatory Group and the Members of the ENTSO-E Board were appointed by the Assembly and assumed their roles on 28 June 2023.

In 2023, ENTSO-E was governed by an Assembly representing the 40 TSOs and by a Board consisting of 12 elected members.

Assembly

Zbyněk Boldiš
President
of the Assembly
ČEPS a. s.

Asta Sihvonen-Punkka
Vice-President
of the Assembly
Fingrid

Board

Damian Cortinas
Chair of the Board
RTE

Tahir Kapetanovic
Vice-Chair of the Board
Austrian Power Grid

Johannes Bruun
Member of the Board
Energinet

Liam Ryan
Member of the Board
EirGrid

Anne Elisabeth Wedum
Member of the Board
Statnett

Dirk Biermann
Member of the Board
50Hertz Transmission

Miguel De La Torre
Member of the Board
REE

Nell Reimann
Member of the Board
Swissgrid

Eleni Charpantidou
Member of the Board
IPTO

Enrico Carlini
Member of the Board
Terna

Remigiusz Warzywoda
Member of the Board
PSE

Susana De Almeida De Graaff
Member of the Board
TenneT

Committees

Fokke Elskamp
Legal and Regulatory Group Chair
TenneT TSO B.V.

Gerald Kaendler
System Development Committee Chair
Amprion

Kjell A. Barmsnes
Market Committee Chair
Statnett SF

Olivier Arrivé
System Operations Committee Chair
RTE

Radek Hartman
Information & Communication Technologies Committee Chair
ČEPS a.s.

Uroš Salobir
Research, Development & Innovation Committee Chair
Eles

2 Highlights of 2024

2024 in a Nutshell

In 2024, ENTSO-E advanced its core responsibilities in system operation, market integration, and infrastructure planning while supporting the European Union's climate and energy objectives. The timeline below highlights the Association's key activities and milestones over the course of the year.

Q1 2024

Laying the Groundwork for Future Infrastructure

1 January

Ukrenergo, the Ukrainian TSO, became a member of ENTSO-E. This milestone underlines ENTSO-E's commitment to strengthen cooperation among TSOs at the pan-European level to foster the security, resilience and reliability of the interconnected power system.

January–March

ENTSO-E began the year with preparatory work **for the Ten-Year Network Development Plan (TYNDP) 2024**. This involved extensive stakeholder engagement and the refinement of scenarios and modelling frameworks, developed in close collaboration with ENTSOG.

15 March

ENTSO-E published an updated version of its **Cost-Benefit Analysis (CBA) Implementation Guidelines** for TYNDP 2024. The revised guidelines introduced improved modelling of hydrogen infrastructure, flexibility resources (including demand-side response and storage), offshore networks, and updated reliability standards. The update incorporated feedback from public consultations and aimed to enhance the assessment of projects of common interest.

JANUARY | FEBRUARY | MARCH

Q2 2024
Coordinating Operational Security and Market Transparency

9 April
ENTSO-E hosted a **High-Level Roundtable** on the **European Grid Action Plan** in Brussels, bringing together senior EU policymakers and industry representatives. Participants, including Energy Commissioner Kadri Simson and Belgian Energy Minister and President of the Energy Council of the European Union Tinne Van der Straeten, discussed the need for coordinated regional planning, streamlined permitting processes, and secure investment frameworks to accelerate the deployment of grid infrastructure.

8 May
ENTSO-E and the EU DSO Entity joined forces to deliver to ACER a harmonised **Network Code on Demand Response (NC DR)**. Developed with strong stakeholder engagement and support, the submitted package included amendment proposals to the regulations on electricity balancing, on electricity transmission system operation (SOGL) and on Network Code Demand Connection (NC DC), to ensure consistency, enable demand-response, and strengthen the reliability of Europe's electricity system.

14 June
The **Summer Outlook 2024** was published, which concluded that under normal weather conditions, Europe's electricity system would remain adequate throughout the summer. However, adequacy risks were identified in isolated systems, such as those of Cyprus, Malta and Ireland, due to their limited interconnection and constrained domestic capacity.

21 June
A significant **system incident** occurred in South-East Europe, affecting Albania, Bosnia and Herzegovina, Montenegro and Croatia. The event triggered automatic protection measures, leading to load shedding and temporary disruptions. ENTSO-E immediately launched a technical investigation and released an interim report outlining the causes, system response and restoration process. The incident underscored the importance of improved regional coordination and real-time system awareness.

28 June
ENTSO-E released three key publications:

- The **Market Report 2024**, reviewing market performance and price dynamics;
- The **Balancing Report 2024**, tracking the implementation of cross-border balancing mechanisms;
- The **Electricity Balancing Cost Report 2024**, detailing procurement costs and providing transparency on the functioning of balancing markets across Europe.

APRIL | MAY | JUNE

Q3 2024
Scenario Development and Sector Coupling

July–September
ENTSO-E and ENTSOG published the **draft TYNDP 2024 scenarios**, which were subject to public consultation. The scenarios – **National Trends**, **Distributed Energy** and **Global Ambition** – explored possible pathways for achieving a carbon-neutral energy system by 2050. They reflected varying assumptions regarding policy ambition, consumer behaviour, technological deployment and the integration of the electricity, gas and hydrogen sectors.

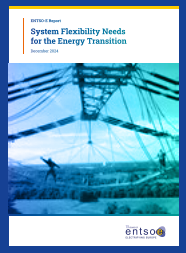
10 July
ENTSO-E published its **Research, Development & Innovation Roadmap 2024–2034**, setting out a forward-looking agenda to guide the transformation of Europe's power system. The Roadmap outlines priority areas for innovation to support the clean energy transition, from system flexibility and digitalisation to the integration of new technologies. Developed with stakeholder input and subject to public consultation, the Roadmap aims to ensure Europe's grids remain secure, sustainable and fit for the future.

JULY | AUGUST | SEPTEMBER

Q4 2024
Future-Proofing the Grid and Marking 15 Years of ENTSO-E

15 November
The **Winter Outlook 2024–2025** was published. It forecasted a generally stable adequacy situation for the coming winter, supported by high gas storage levels and increased renewable generation. However, certain regions – including Ireland, Malta, Crete and Cyprus – were identified as potentially vulnerable under severe weather scenarios. The report reiterated the need for coordinated seasonal planning and operational preparedness.

December
ENTSO-E published its landmark study on **System Flexibility Needs for the Energy Transition**, building on its Strategic Roadmap and Vision for a Carbon-Neutral Power System. The study provides a first-of-its-kind, Europe-wide assessment of future flexibility challenges through 2030 and beyond, offering key insights to support policymakers and system operators. The findings also contribute to ENTSO-E's work under the new Electricity Market Design Regulation, which mandates regular national assessments of flexibility needs.



3–4 December
ENTSO-E celebrated its **15 year anniversary** with a high-level conference and gala dinner in Brussels. The event brought together representatives from EU institutions, national authorities, regulators, and industry to reflect on ENTSO-E's role in driving system integration, operational excellence, and innovation over the past 15 years. Discussions also looked ahead to the challenges of grid digitalisation, large-scale electrification, and ensuring resilience in a changing climate.

4 December
Western Balkan TSOs from the Energy Community, supported by ENTSO-E, adhered to a **Joint Declaration** establishing a new framework for regional cooperation. The agreement aims to strengthen power system integration in South-East Europe by establishing geographic coordination supporting both **security of supply** and **market integration** across the region in accordance with EU and Energy Community legislation.

ENTSO-E, EU DSO Entity, Europacable, and T&D Europe issued a joint statement deepening collaboration under the **European Commission's Grid Action Plan**. They commited to strengthen Europe's manufacturing base by developing common technology specifications, improving grid project visibility, and securing supply chains. Their shared commitment focuses on delivering resilient, innovative grid infrastructure supporting clean, affordable, and sovereign energy for Europe.

OCTOBER | NOVEMBER | DECEMBER

ENTSO-E's 15th Anniversary

Introduction

ENTSO-E and Europe's Transmission System Operators (TSOs) have played a foundational role in shaping the continent's power system over the past 15 years. Established in 2009 with a legal mandate under EU legislation, ENTSO-E has grown into the central platform for TSO cooperation, contributing to the implementation of European energy policy and to building an integrated, secure, and sustainable electricity system.

In December 2024, ENTSO-E marked its 15 year anniversary – a moment to reflect on past achieve-ments and reaffirm its commitment to a carbon-neutral and competitive energy future – with a high-level conference and gala dinner in Brussels. Under the theme **"Powering the Sustainable Transition: Grids for a Carbon-Neutral and Competitive Europe"**, over 250 participants from across the European energy community, including EU policymakers, regulators, TSOs, industry representatives and civil society, gathered to discuss the most pressing challenges and opportunities facing the power system.

Sonya Twohig,
ENTSO-E Secretary General

Damian Cortinas,
ENTSO-E Chair of the Board

Marie Donnelly,
Chair of ENTSO-E External Advisory Group

Zbyněk Boldiš,
ENTSO-E President

Liam Ryan,
Member of the Board

Mechthild Wörsdörfer,
Deputy Director-General ENER

Reflections on 15 Years of Regional Cooperation

Since its founding, ENTSO-E has brought together 40 TSOs from 36 countries to manage and develop the world's largest interconnected electricity grid. With the Third Energy Package and the Clean Energy Package, the Association has consistently worked to implement European electricity market rules while anticipating future challenges. From market integration and security of supply to innovation and regional activities such as the **Joint Declaration** to enhance power system Europe in South-East Europe, ENTSO-E's journey reflects a deep commitment to Europe's long-term energy goals.

A Platform for Forward-Looking Dialogue

The 2024 conference served as a platform for strategic dialogue and knowledge exchange. Highlights included panel discussions on grid security and resilience, offshore energy integration, digitalisation, and the robustness of supply chains. Speakers and participants explored the need for accelerated grid investments and closer cooperation between TSOs, EU institutions, and industrial stakeholders to deliver on Europe's climate ambitions.

Strengthening Our Role for Europe's Energy Transition

A key topic at the conference was ENTSO-E's role in key milestones, such as the emergency synchronisation of the Continental European power system with Ukraine and Moldova in 2022, and the planned synchronisation of the Baltic States in 2025. These projects demonstrate ENTSO-E's capacity to respond to crises and support geopolitical resilience through technical expertise and cooperation.

ENTSO-E Chair of the Board, **Damian Cortinas,** emphasised the Association's dual mission: to prepare a power system fit for a carbon-neutral Europe, and to operate a reliable and efficient operation today. Secretary-General **Sonya Twohig** reaffirmed the importance of partnership with policymakers and consumers, underlining that Europe's energy transition must be built on collaboration, innovation, and shared responsibility.

Zbyněk Boldiš,
ENTSO-E President

Damian Cortinas,
ENTSO-E Chair of the Board


Kristen Panerali,
Head of Clean Power and Electrification Program at World Economic Forum


Sylvia Maurer,
Director of Advocacy Coordination at BEUC


Albino Marques,
RGCE Convenor

3 Delivering in 2024

3.1 Strategic Roadmap 2023–2025

ENTSO-E's activities in 2024 were guided by the **Strategic Roadmap 2023–2025**, which sets out a shared direction for Europe's Transmission System Operators (TSOs). The Roadmap reflects the dual responsibility of TSOs: to deliver reliable operations today while preparing the power system for tomorrow's decarbonised and digitalised future. It is built around **two interconnected pillars**, each defining a strategic focus for the Association's work.

Figure 1 – Strategic Roadmap 2023–2025

Pillar 1:
A power system fit for a carbon-neutral Europe will need significant changes in five key areas.

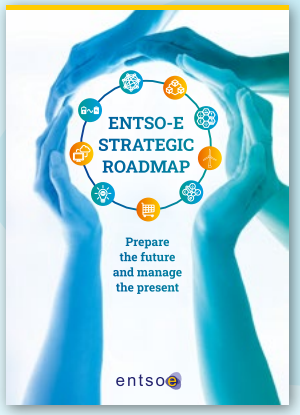
Europe's climate targets demand a structural transformation of the electricity system. TSOs are leading this shift by:

- **Enhancing system flexibility** to manage greater variability from renewables and enable demand-side participation
- **Adapting operational practices** to cope with more decentralised and digitally integrated grids
- **Scaling up infrastructure and investment** to support electrification, offshore integration and cross-border capacity
- **Modernising market design** to send the right price signals, unlock flexibility, and empower consumers
- **Driving innovation** to develop and deploy the tools, technologies and standards of the future

Pillar 2:
Securing system operations today.

As transformation accelerates, TSOs remain responsible for delivering secure and efficient system operation. This requires:

- **Operational excellence**, with robust planning, coordination and real-time oversight
- **Market development**, ensuring cross-border efficiency and system balance
- **Regional coordination**, aligning national and regional actions across Europe
- **Advanced ICT systems**, supporting digitalisation, data exchange and cybersecurity



Together, these two pillars define ENTSO-E's strategic response to a fast-changing energy landscape, and structured the work delivered throughout 2024.

3.2 Managing Complexity: Energy System Flexibility

The growing complexity of the European electricity system, driven by the rapid expansion of renewable generation, electrification of demand, and increasing interdependence across sectors, makes flexibility a defining challenge for system operators.

In 2024, ENTSO-E and its members continued to address this challenge by supporting the development and integration of **non-fossil flexibility resources**, including demand-side response, storage, and hybrid assets. These technologies are essential to ensuring system stability in an environment of greater variability and uncertainty.

Work focused on both operational and market integration aspects. Key milestones included the publication of the **Flexibility Needs Study**, which assesses system requirements across timeframes and geographic scales. The study, although not explicitly a legal mandate, aims to support national and EU-level policy and investment decisions by identifying where and when flexibility will be most critical. It constitutes the ground work for the preparation of the legally mandated Methodology for the assessment of national flexibility needs, a joint endeavour between ENTSO-E and the EU DSO Entity.

ENTSO-E also contributed to the design of future frameworks for integrating flexibility into system operation, including through participation in the **EU Action Plan for Grids** and inputs to the **Electricity Market Design Reform**. As part of its research and innovation agenda, ENTSO-E helped advance methodological work on **sector integration**, **multi-service flexibility**, and the role of digitalisation in enabling system-aware flexible behaviours.

This work reflects Pillar 1 of the Strategic Roadmap 2023–2025: preparing a future power system that can securely and efficiently integrate a high share of renewables and distributed resources.

> Flexibility is the cornerstone of a renewable future, through innovation and cooperation, ENTSO-E together with EU DSO Entity ensure Europe's power system remains stable, adaptable, and ready for the challenges of tomorrow.

Vincenzo Ranieri,
President of DSO Entity

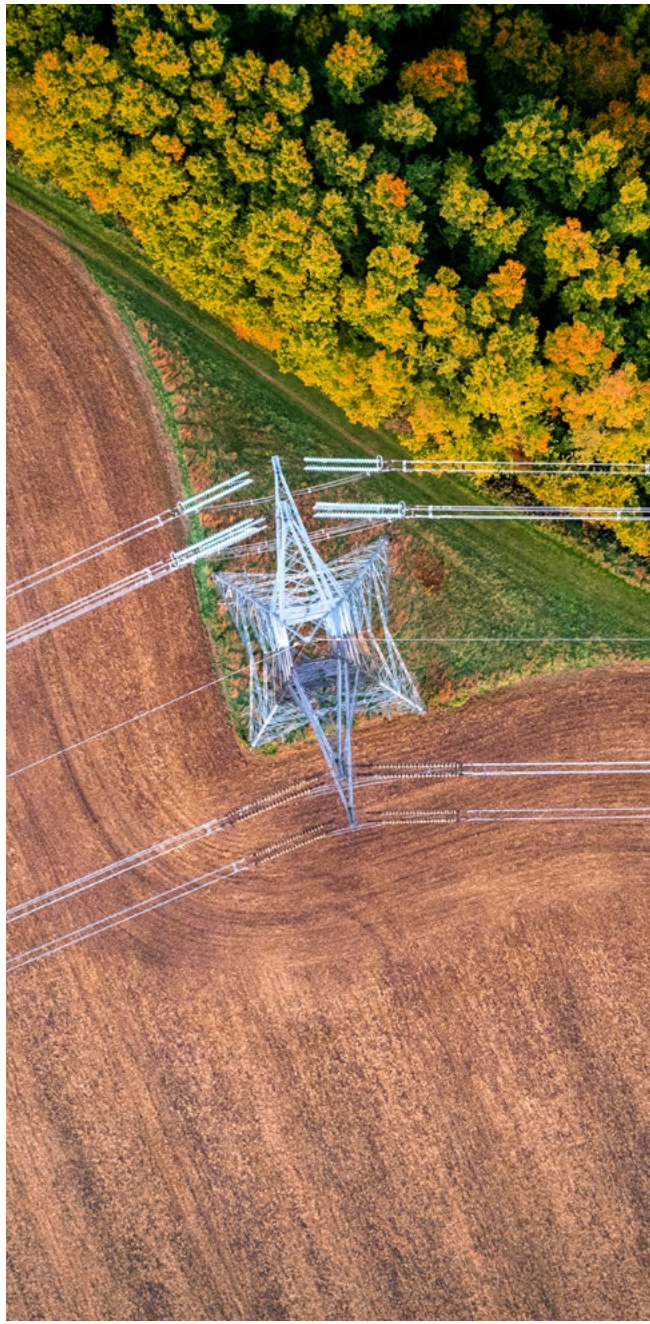
3.3 Operating the Grids of the Future: Beyond Current Practices

As the energy transition accelerates, Transmission System Operators (TSOs) must adapt their operational approaches to manage new challenges in grid stability, modelling, and system behaviour. Maintaining secure operations in a system with increasing shares of renewable generation requires evolving beyond traditional practices.

This includes addressing both conventional stability issues, such as rotor angle and frequency stability, and emerging phenomena like **converter-driven instability** and **resonance**. TSOs are conducting gap analyses to identify where existing system and asset models, as well as simulation tools, need to improve. These analyses assess how current tools simulate dynamic responses in high-renewables scenarios, and how data provision can support detection of both known and unforeseen stability risks.

Improved **data exchange mechanisms**, supported by robust security and hosting solutions, are also essential. Understanding how specific parameters affect system behaviour is key to developing accurate models and ensuring operational readiness.

In parallel, TSOs are increasingly turning to **probabilistic methods** to assess contingencies that could affect grid operations. These approaches support the development of advanced tools and methodologies aimed at improving system reliability under uncertainty.



3.3.1 Probabilistic Risk Assessment Methodology

In response to the increasing complexity of system operations, ENTSO-E is supporting its member TSOs in developing a common **Probabilistic Risk Assessment (PRA) methodology** to complement the traditional N-1 security criterion. While the deterministic N-1 approach remains a cornerstone of grid operation – ensuring resilience to the failure of any single system component – it does not account for the likelihood of multiple or rare events, or the broader uncertainty that characterises today's energy landscape.

A probabilistic framework would enable TSOs to assess not just **what could go wrong, but how likely it is to occur**, and **what the impact might be**. This would improve operational decision-making, particularly under high variability from renewable generation, more dynamic demand patterns, and increased interdependence between systems.

By estimating both the probability and impact of potential contingencies, the PRA methodology supports more efficient and targeted security measures. It helps TSOs optimise maintenance planning, determine the timing and scope of outages, and identify where remedial actions are most valuable. In doing so, it offers a more flexible and resource-efficient approach to maintaining operational security.

The development of this methodology by all TSOs is a complex task requiring and large reliable dataset and harmonisation of national, regional and pan-European processes. It is mandated under the **System Operation Guideline,** which establishes common rules for ensuring system security and efficient grid operation amid growing shares of variable renewable generation – specifically **Article 33(2)** and **Article 75(1),** as well as the methodology adopted on its basis, which require all TSOs to jointly propose a PRA methodology by **31 December 2027**.

ENTSO-E supports the TSOs in this task and published **biennial progress reports in 2021 and 2023**, which document advances in the underlying data infrastructure, including upgrades to the PRA data collection platform. These reports also outline the technical building blocks and coordination mechanisms being put in place to ensure the methodology is consistent, practical and legally robust. As highlighted in the reports, TSOs have so far improved their readiness in collecting detailed grid disturbance statistics and identifying underlying causes of these disturbances. This progress supports the development of a proof-of-concept solution to assess how the theoretical concepts of the PRA methodology apply in practice to power systems and how those concepts can support TSOs in evaluating the risk of contingencies in the transmission grids.

3.3.2 Frequency Stability Analysis in Long-Term Scenarios, Relevant Solutions and Mitigation Measures

Maintaining frequency stability in a future low-inertia system is one of the most pressing challenges TSOs are facing. As the generation mix shifts from conventional synchronous machines to inverter-based renewable sources, the system's ability to absorb and respond to disturbances weakens – raising the risk of wide-area instability.

To address this, ENTSO-E launched Project Inertia, now in its second phase. Building on its 2021 report, Frequency Stability in Long-Term Scenarios, the project investigates how potential system splits in the Continental Europe (CE) Synchronous Area would affect frequency stability in future scenarios characterised by low inertia and high renewable penetration.

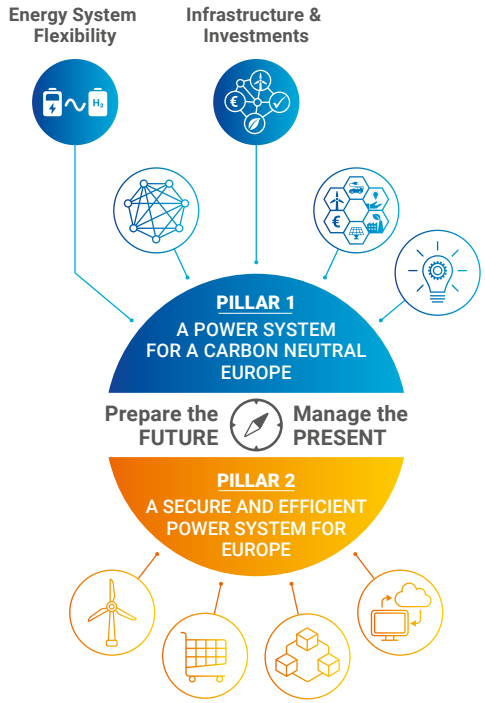
Using TYNDP 2022 long-term market studies, the project analysed numerous combinations of system split events. Results confirmed a worrying trend: by 2030 and 2040, the number of splits that exceed the critical Rate of Change of Frequency (RoCoF) threshold of 1 Hz/s rises significantly. In many cases, both islands created by a split would breach that limit – indicating a systemic decline in frequency resilience if no mitigating action is taken.

In 2023, the project concluded its first milestone by refining the methodology used to assess these risks and identifying key scenarios that warrant targeted interventions. In 2024, the focus turned to developing a quantified roadmap – a step-by-step plan outlining potential mitigation measures and decision points for system operators and institutions.

The project also stresses that resilience planning must be a shared responsibility. Determining acceptable levels of blackout risk or system vulnerability cannot fall to TSOs alone. Policymakers, regulators and broader institutions must be part of setting these thresholds and ensuring that the right investment, regulatory, and operational frameworks are in place.

3.4 Grid Infrastructure

ENTSO-E's system planning and adequacy activities in 2024 focused on preparing Europe's grids for a decarbonised and electrified energy system. Key deliverables included the **Ten-Year Network Development Plan (TYNDP 2024)**, seasonal and long-term adequacy assessments, new initiatives on grid supply chain resilience, and progress toward future offshore grid integration. These activities reflect ENTSO-E's central role in **scaling up infrastructure investment** and preparing for **cross-border and offshore system needs** in support of the EU's climate objectives. They also support the first pillar of the Strategic Roadmap 2023–2025, in particular by **enabling system flexibility** and **reinforcing long-term grid development**. But achieving these goals in practice increasingly depends on overcoming major implementation barriers.



Europe's electricity system is undergoing structural transformation. The shift toward carbon neutrality and the further electrification of sectors demand a grid that can deliver more, more flexibly, and with greater resilience. TSOs face growing challenges from rising volumes of variable renewables, supply chain constraints, and increasing risks to physical and cyber security, factors further compounded by geopolitical uncertainty and extreme weather. The scale of infrastructure investment now required is unprecedented, particularly in regions with limited interconnection and growing demand.

While there is broad consensus among EU and national decision-makers on the urgency of grid development, implementation still lags behind. Permitting, financing, and supply chain pressures continue to delay projects that are critical to achieving Europe's goals for decarbonisation, energy security and competitiveness. In this context, ENTSO-E welcomes the forthcoming **EU Grids Package** as an opportunity to streamline legislation and accelerate project delivery. Key priorities include stronger regional coordination, simplified planning and permitting, greater investment in innovative and digital grid technologies, and more robust support for resilient supply chains. Together, these actions can help unlock the infrastructure needed to power Europe's future.

3.4.1 Ten-Year Network Development Plan (TYNDP) 2024

The TYNDP is Europe's electricity grid planning tool, providing a long-term view of how transmission infrastructure needs to evolve to support climate neutrality. **TYNDP 2024** addresses the challenges of a decarbonised, interconnected energy system by supporting renewable integration, strengthening cross-border electricity exchanges, and ensuring system resilience. The plan was developed in close collaboration with stakeholders from industry, NGOs and research institutions, and reflects a dynamic, forward-looking approach to system planning.

Scenario framework

TYNDP 2024 is underpinned by energy transition scenarios developed jointly with ENTSOG. These scenarios explore different pathways to reach the EU's 2050 climate goals, accounting for renewable integration, system flexibility and cross-border needs. While the scenarios partially implement **ACER's January 2023 Framework Guidelines**, full implementation is foreseen for **TYNDP 2026**.

The **Scenarios Stakeholder Reference Group (SRG)** provided feedback on the draft scenarios, which were approved by the European Commission and published in final form in **January 2025**.

Identifying future system needs

TYNDP 2024 identifies where cross-border investments are needed to cost-effectively meet decarbonisation targets. It emphasises the importance of strengthening interconnections to integrate renewables, support regional adequacy, and enhance the internal electricity market. The study highlights the need for 108 GW of additional cross-border capacity after 2030 to minimise total system costs. In the EU, addressing these needs will reduce renewables curtailment by 143 TWh/year, CO_2 emissions by 27 Mton/year and generation of electricity by gas power plants by 65 TWh/year. A key finding is that each euro invested in the cross-border electricity grid translates into more than two euros saved in system costs.

Offshore Network Development Plans (ONDP) 2024

For the first time, the **Offshore Network Development Plans** were published in January 2024 as part of TYNDP. They translate Member States' non-binding offshore targets into indicative transmission corridors, technology needs and cost estimates. In total, ONDP covers **496 GW** of offshore generation expected by 2050, and identifies a need for up to **€400 billion** in investment and **54,000 km** of offshore transmission routes, equivalent to 1.5 times the Earth's equator.

> For the first time, the revised TEN-E Regulation requires a close alignment between the planning of the electricity, hydrogen and methane networks, which demonstrates the importance of the continued close cooperation between ENTSO-E and ENTSOG.
>
> **Sonya Twohig,**
> ENTSO-E Secretary-General, and
> **Piotr M Kuś,**
> ENTSOG General Director

Cost–benefit analysis

TYNDP 2024 assesses the performance of infrastructure projects against multiple indicators under different scenarios, including system cost savings, renewable integration, emissions reductions, electricity losses and security of supply. A total of **177 transmission** and **33 storage** projects were evaluated.

Public consultation and stakeholder engagement

TYNDP development included **six public consultations** and **12 stakeholder events**. The full package was submitted to public consultation from **31 January to 14 March 2025**, was submitted to ACER and the European Commission for opinion and will be finalised in the third quarter of 2025.

3.4.2 Seasonal Adequacy Assessments

ENTSO-E publishes **Seasonal Outlook** twice a year to assess security of supply for the upcoming winter and summer periods.

The **Summer Outlook 2024** (published in June) found no major pan-European risks, but flagged some islands' power systems as requiring close monitoring due to limited interconnections

The **Winter Outlook 2024–2025** (published in November) also showed a favourable adequacy picture, while highlighting potential vulnerabilities for certain islands' power systems where targeted mitigation measures may be needed.

3.4.3 European Resource Adequacy Assessment (ERAA) 2024

The **ERAA** provides a pan-European view of power system adequacy up to 10 years ahead, using probabilistic modelling and state-of-the-art methods. It supports decision-makers on topics such as capacity mechanisms and system reliability.

In 2024, ENTSO-E launched a **call for evidence on preliminary input data**, allowing stakeholders to provide feedback and help shape key assumptions. The **ERAA 2024 report**, was published in **April 2025** and will support policymaking on adequacy and security of supply.

3.4.4 Grid Infrastructure and Supply Chains

The expansion of renewable generation and electrification of demand requires accelerated grid development – and that in turn depends on resilient supply chains for critical components such as **HVDC converters, cables, and transformers**. Current manufacturing capacities are insufficient to meet demand in the required timeframes, leading to **lead times of over four years**, rising costs, and dependence on non-EU suppliers.

In 2024, ENTSO-E, together with the EU DSO Entity, **T&D Europe** and **Europacable**, launched a **joint roadmap** to enhance Europe's manufacturing resilience, which was eventually published in **June 2025**. This initiative forms part of the actions foreseen in the **European Commission's Grid Action Plan (November 2023)**.

3.4.5 Preparing for Future Offshore Grid Development

As offshore wind expands across Europe's sea basins, the need for coordinated cross-border offshore grids is growing. In 2024, ENTSO-E launched work on an **Offshore Roadmap**, aimed at identifying the most pressing regulatory and technical issues to be addressed by TSOs.

The roadmap focuses on six core areas: offshore geographical zones, offshore balancing, frequency control, ramping, governance, and market frameworks. Stakeholder input has been a key component and a first **workshop** was held in **April 2024**.

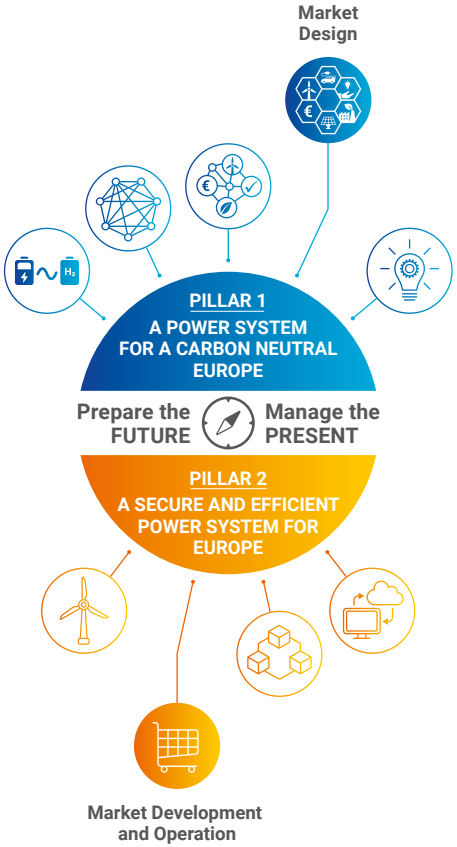
> The Offshore Roadmap brings Europe together to solve offshore challenges, ensuring our grids are ready for the scale of renewable ambition ahead.

Gerald Kaendler,
Offshore Board Group Convenor

3.5 Facilitating the Energy Transition: a Fit for Purpose Market Design

In 2024, ENTSO-E contributed to shaping and implementing a market framework capable of supporting Europe's decarbonisation objectives while maintaining secure and efficient system operation. The focus of the year was the entry into force of the **Electricity Market Design (EMD) reform**, which ENTSO-E actively supported through technical input and analysis.

The Association also advanced work on critical flexibility topics, including the design of **Contracts for Difference (CfDs)**, the evolving role of **Capacity Mechanisms (CMs)**, and the integration of **demand response** resources through the proposed **Network Code on Demand Response (NC DR)**. These efforts reflect the priorities of the Strategic Roadmap under both **Pillar 1 – modernising market design to send efficient signals and unlock flexibility**, and **Pillar 2 – developing markets that support cross-border efficiency and system balancing**.



3.5.1 Electricity Market Design

The **EMD reform** was adopted by the European Parliament and Council in April and May 2024 and entered into force on 16 July 2024. EU Member States were required to transpose its provisions into national law by 17 January 2025.

ENTSO-E welcomed the reform, noting that most objectives and measures are aligned with the Strategic Roadmap and its long-term vision for a carbon-neutral electricity system. ENTSO-E and TSOs remain fully committed to implementing the updated legislative and regulatory framework. Building on operational experience at national and European level, ENTSO-E continues to assess implementation challenges and explore market design options to support evidence-based policymaking.

In 2024, ENTSO-E focused on two key elements of the EMD reform that require national implementation and further analysis:

Strengthening Investment Signals

The new framework for two-way Contracts for Difference (CfDs) for public investment in new power generation reflects a forward-looking approach to strengthening long-term investment signals for renewable and low-carbon energy. However, the design and implementation of these instruments at national level will be key to avoiding unintended impacts on short-term and balancing markets, such as distorted price signals or higher system costs.

The Electricity Regulation (Articles 28 and 29 of Regulation 2024/1747 amending Regulation 2019/943) requires TSOs cooperate through ENTSO-E to promote the well-functioning of electricity markets and to contribute to "the efficient integration of electricity generated from renewable energy sources". Against this background, ENTSO-E supports TSOs to identify best practices and recommendations for implementing two-way CfDs.

In February 2024, ENTSO-E published a **Position Paper on Sustainable CfD Design**. While this deliverable is not strictly part of ENTSO-E legal mandates, it aligns with ENTSO-E's abovementioned role defined in EU legislation. The paper highlights that:

- Poorly designed CfDs may reduce price incentives for flexibility.
- Design choices can affect system operations and market efficiency.
- Appropriate frameworks can limit consumer exposure to high prices while supporting decarbonisation.

ENTSO-E recommends promoting CfD schemes that are cost-effective, market-compatible and aligned with the energy transition.

Capacity Mechanisms

The EMD reform acknowledges that **Capacity Mechanisms (CMs)** may be needed as structural components of electricity markets, rather than temporary backstops. This reflects a broader recognition that CMs can play a role in maintaining adequacy in systems undergoing rapid transformation.

In 2024, ENTSO-E began assessing the evolving role of CMs in Europe. The work explores how to simplify adoption procedures and promote design features that support both system reliability and long-term sustainability. A **policy paper**, published in Q2 2025, offers recommendations to ensure that CMs contribute to competitiveness, decarbonisation and efficient cross-border integration.

Structural Flexibility Challenges

Throughout 2024, several European electricity markets increasingly experienced periods of negative prices – often linked to surplus renewable generation exceeding demand and limited export capacity.

KEY DATES & DOCU-MENTS

20 April 2024
Publication of ENTSO-E Position on the **Sustainable Contracts for Differences Design**

These events are typically accompanied by system imbalances requiring TSO intervention. Through internal knowledge exchange, ENTSO-E noted that while renewable curtailment remains a practical tool for grid security, greater market-based flexibility is needed. Under current rules, renewable power generators are often not incentivised to provide downward flexibility. In some cases, they are even encouraged to remain online despite negative prices, creating inefficiencies and operational stress.

In response, ENTSO-E launched a study on turning renewable sources into a **source of flexibility**, rather than a constraint. The study, to be published in Q2 2025, investigates how renewable resources can be incentivised to support system balancing, particularly during periods of excess generation and low demand.

3.5.2 Network Code on Demand Response

On **9 March 2023**, the European Commission invited ENTSO-E and the EU DSO Entity to submit a proposal to ACER for a **Network Code on Demand Response (NC DR)**, in line with the ACER Framework Guideline.

To develop the proposal, ENTSO-E and the EU DSO Entity established a joint TSO–DSO Development Team, supported by a stakeholder drafting committee. To ensure transparency and engagement, two public workshops were held (in April and October 2023), alongside a public consultation (from 29 September to 10 November 2023). Key stakeholder associations were informed of developments and had access to monthly draft versions.

The final **NC DR package** was submitted to ACER on **8 May 2024**. Its objectives include:

- Simplifying market access requirements such as registration and prequalification procedures, and the definition of aggregation models.
- Establishing principles for the market design for congestion management and voltage control services.
- Facilitating the standardisation of products for these services at national level.
- Enhancing the framework for cooperation between TSOs and DSOs by ensuring access to the necessary data from each other and from grid users to operate the system.

The Network Code will be complemented by national terms, conditions and methodologies. Their development through common proposals is part of the system of systems perspective.

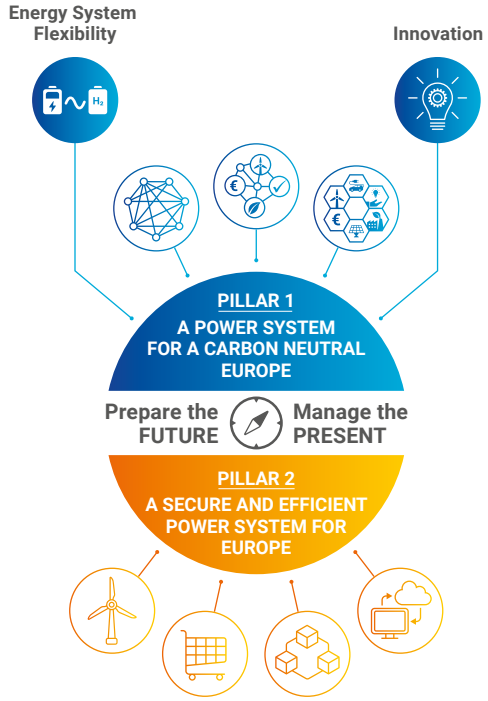
After receiving ACER's **final recommendation in March 2025**, ENTSO-E and the DSO Entity will support the European Commission during the adoption phase and prepare for implementation, expected to begin in 2026.

> ENTSO-E is driving innovation to ensure renewables not only generate power but also provide flexibility, helping Europe's grids adapt to evolving market realities.

Kjell A. Barmsnes,
Chair of the ENTSO-E Market Committee

3.6 Innovative Solutions

In 2024, ENTSO-E continued to coordinate research, development, and innovation efforts that support the long-term transformation of Europe's electricity system. Key milestones included the publication of the **RDI Roadmap 2024–2034**, contributions to the **EU Action Plans on Grids and Digitalisation**, and active participation in EU-funded projects on system flexibility, interoperability, and digital twins. These activities directly support **Pillar 1** of the Strategic Roadmap 2023–2025, by **driving innovation to develop the tools, technologies and standards of the future**, and by **enhancing system flexibility** to accommodate greater variability and new forms of decentralised participation in an affordable and efficient manner.



3.6.1 RDI Roadmap 2024–2034

The RDI Roadmap 2024–2034 is a legally mandated document that outlines key research, development and innovation priorities for modernising the EU power grid over the next decade. It builds upon its predecessor (2020–2030), evolving in response to the rapidly changing energy landscape. This 4th version aligns closely with the EU Energy and Climate Policy Framework and integrates recent technological advancements and emerging TSO challenges identified over the past four years.

It strengthens the focus on decarbonisation, digitalisation and system integration, ensuring that research efforts drive innovation in grid resilience, interoperability and sector coupling. By prioritising sustainability, security and affordability, the roadmap serves as a strategic guide for TSOs and stakeholders, fostering collaboration and accelerating the transition toward a future-proof, carbon-neutral energy system.

Key themes of the new roadmap include:

- **Power Grid as the backbone for the energy system:** improving resilience, efficiency and sustainability from planning to operation.
- **Digitalised power systems:** leveraging data and automation to manage increasingly hybrid grids.
- **One-System of integrated systems:** enabling cross-sectoral system flexibility and coordination across resources.

The RDI Roadmap focuses on six missions to drive the evolution of the energy system. Each mission represents a key achievement to be reached to keep the power system secure, adequate and cost efficient, while allowing the increasing penetration of variable and distributed energy sources.

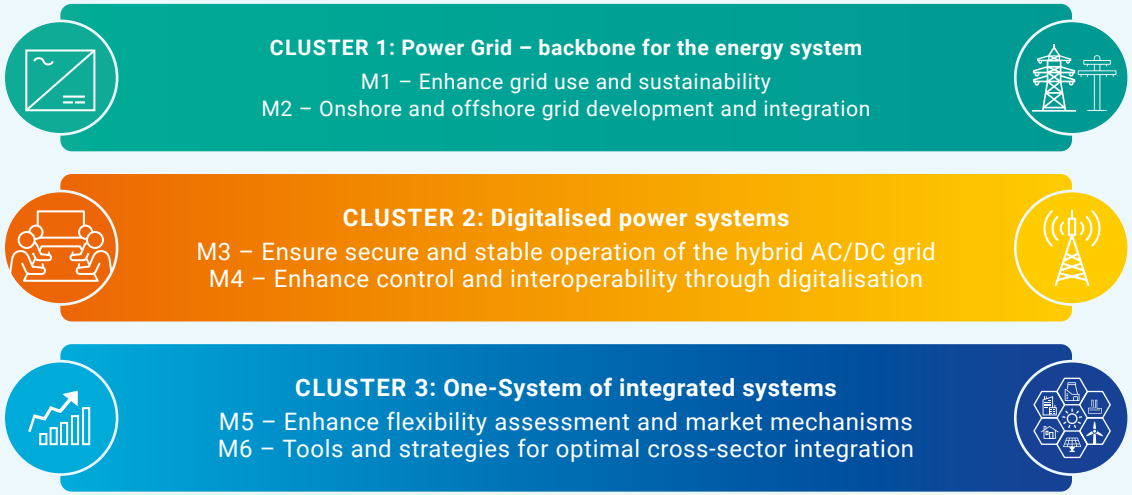


Figure 2 – RDI Roadmap 2024–2034

3.6.2 Support for the EU Action Plan on Digitalisation

ENTSO-E remains a key player in implementing the EU Action Plan for Digitalising the Energy System. Following up the signature of a Declaration of Intent, ENTSO-E and the EU DSO Entity worked during 2024, within a joint project called Digitalisation of Energy Action Plan (DESAP) on defining a common framework to support the development of a **digital twin** of the electricity grid enhancing efficiency, planning, and operational awareness. Digital twins are virtual replicas of assets, systems, or processes that use real-time data to simulate, analyse, and optimise performance.

In 2024, ENTSO-E and its partners completed a milestone report identifying key digitalisation challenges for TSO–DSO coordination, including grid planning, real-time monitoring and customer integration. It also provides a comprehensive compilation of anticipated priority challenges in the transition toward a fully digitalised electricity system.

ENTSO-E maintained a strong cooperation with policymakers, regulators and stakeholders across the European research and innovation sphere incorporating insights and expectations regarding digital twin solutions. This will support the work in 2025 in developing representative use cases and a Roadmap to guide the phased implementation of digitalisation strategies, ensuring that investments align with long-term European energy goals.

3.6.3 Support for the EU Action Plan for Grids – Technopedia

In line with Action 7 of the EU Action Plan for Grids, ENTSO-E worked in cooperation with the EU DSO Entity on a concept for a **DSO/TSO Technopedia** platform to be further developed and implemented in 2025. This will be a collaborative, knowledge-sharing platform about grid technologies and use cases for transmission and distribution system operators. The platform is expected to be developed further in 2025, with engagement from the European Commission, vendors, and industry associations.

> “Technopedia embodies the spirit of cooperation between ENTSO-E and DSO Entity, linking TSOs, DSOs, and industry to share knowledge, inspire innovation, and accelerate Europe’s energy transition.

Peter Vermaat,
Secretary-General of DSO Entity

3.6.4 Support for the EMD Reform – Flexibility Needs Assessment

ENTSO-E also contributed to a methodology for defining the type and format of data and the analyses feeding in to the national flexibility needs assessments under the EU Electricity Market Design (EMD) reform and Article 19e of Regulation (EU) 2019/943. Developed jointly with the EU DSO Entity, the national assessment based on the inputs required by the methodology will inform decisions around the deployment of non-fossil flexibility resources. Coordination with the European Commission and ACER continued throughout the year, with further work ongoing in 2025. ACER released its decision on the final version of the methodology on 25 July 2025.

In preparation for developing the mandated **Methodology for National Flexibility Needs Assessments** under the EMD reform, ENTSO-E developed and published an in-depth analysis focused on system flexibility needs. The **System Flexibility Needs for the Energy Transition** study was initiated by European TSOs as a follow-up to ENTSO-E's **Strategic Roadmap** and **Vision: A Power System for a Carbon Neutral Europe**, both of which identified flexibility as a critical enabler for the present and future power system. The study highlighted the urgent need for **quantitative analysis of flexibility requirements** to foster a deeper understanding of the topic, support the development of a robust methodology, and contribute to the broader policy discussion at national and EU levels.

3.6.5 Collaboration and Strategic Engagement

ENTSO-E has strengthened its cooperation with key stakeholders across the European RDI ecosystem. This year, ENTSO-E actively participated in:

- The **European Technology & Innovation Platform on Smart Networks for Energy Transition (ETIP SNET)**.
- Initiatives under the European Commission's **Strategic Energy Technology (SET) Plan** (e.g., Direct Current (DC) technologies**,** high-voltage grid integration and interoperability).
- Monitoring **Horizon Europe** calls, promoting TSO participation in European RDI projects.

Contributions to these platforms have reinforced ENTSO-E's role in shaping Europe's future energy system and accelerating the adoption of innovative energy solutions. In 2024, ENTSO-E continued its efforts strengthening relationships and collaboration among TSOs. Multiple knowledge sharing webinars have been organised during which TSOs shared information on their ongoing innovation projects in areas of cybersecurity, hydrogen, resilience and early-detection systems.

3.6.6 Participation in EU-Funded Projects

ENTSO-E has played a significant role in several EU-funded projects, advancing critical research areas in energy digitalisation and system flexibility:

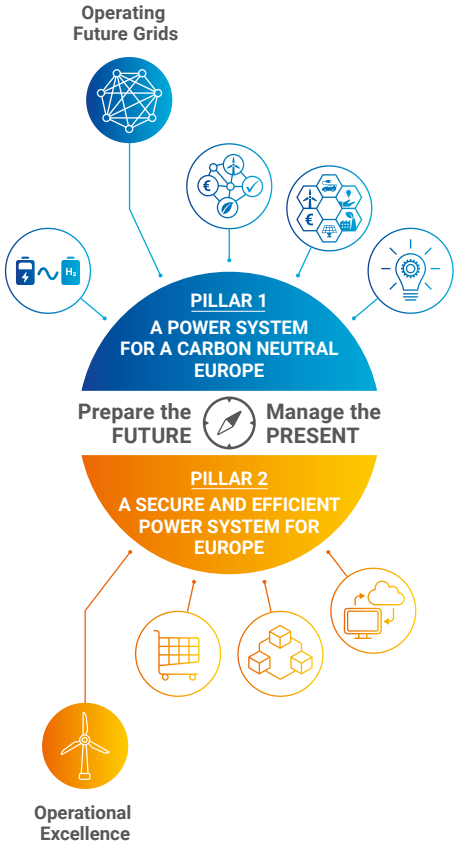
- **OneNet (2020–2024)** – The largest project of its kind, OneNet brought together 72 partners, including 14 TSOs, to develop an open and flexible architecture for a smarter European electricity system. Building on previous initiatives like INTERRFACE and CoordiNet, the project focused on optimising local flexibility markets and strengthening TSO-DSO coordination. The OneNet Framework, validated through pilots in 13 EU countries, has been adopted by the Linux Foundation for Energy. In addition, the project delivered 24 key recommendations to address barriers in market design and interoperability, supporting process standardisation, enhanced cybersecurity, and broader stakeholder engagement.
- **IntNET (2022–2025)** – With 12 partners, including E.DSO and the Florence School of Regulation, IntNET aims to create a unified knowledge base for interoperability in energy services. The project is developing a comprehensive **Interoperability Maturity Model (IMM)**, compiling over 500 use cases and analysing 17 testing approaches to harmonise interoperability practices across the energy sector.
- **BD4NRG (completed in 2024)** – This project focused on applying big data and artificial intelligence to support next-generation energy systems. Its key achievement was the development of an **open-source, modular analytics framework** tailored to smart grids. The framework integrates and aligns different architecture models and standards, including BRIDGE, RAMI, GAIA-X, and FIWARE, to support interoperability, data sovereignty, and near real-time decision-making. Validated across 12 large-scale pilots, the framework enables enhanced technical and economic management of the electric power and energy system value chain, and opens new market opportunities for data-driven energy solutions.
- **TwinEU (2024–2027) –** As the flagship project supporting the **EU Action Plan for Digitalising the Energy System**, TwinEU is designing a **pan-European digital twin**, based on a federation of local system models. These tools aim to enable reliable, resilient, and secure grid operations, while supporting the large-scale integration of renewable energy. ENTSO-E plays a key role in ensuring the project aligns with the broader **DESAP initiative**.

3.6.7 Conclusion

As ENTSO-E advances its RDI initiatives, 2024 marks a successful year in the pursuit of a sustainable, digitalised, and resilient electricity system. Through fulfilment of legal mandates, strategic collaboration, innovative research, and targeted investments, we continue to support the EU's energy transition goals and ensure that European TSOs are equipped to meet future challenges. Looking ahead, ENTSO-E remains committed to fostering research excellence, driving technological advancements, and strengthening the security and efficiency of Europe's electricity infrastructure.

3.7 Ensuring Efficient, Resilient and Secure System Operation

In 2024, ENTSO-E and TSOs continued to implement the requirements of the **System Operation Guideline (SOGL)** and related frameworks, supporting secure and efficient grid operations across Europe. This work included coordinating pan-European activities, facilitating regional initiatives, and addressing emerging challenges such as frequency deviations, grid incidents, and the integration of new system participants. These efforts reflect priorities under the **Strategic Roadmap 2023–2025**, contributing to **Pillar 1** by adapting operational practices to a more decentralised and digitally integrated system, and to **Pillar 2** by reinforcing operational excellence through planning, coordination and real-time system oversight.



3.7.1 The System Operation Guideline

The **System Operation Guideline**, established under **Commission Regulation (EU) 2017/1485**, sets out common rules for maintaining system security and operating Europe's electricity grid efficiently, particularly in a context of increasing variable renewable generation. Implementing these rules involves complex tasks for TSOs at three levels: across Europe, within synchronous areas, and at regional level. While ENTSO-E coordinates work at the pan-European level, each synchronous area manages its own activities through its respective group of TSOs.

The following SOGL implementation activities were carried out in 2024:

SOGL deliverables in 2024	Key documents and dates
Article 14.2 List of information to be delivered to ACER for monitoring purposes.	Project established to work on the necessary business and technical requirements for the data delivery solution.
Article 15 Annual report on operational security indicators (report titeld 2023 Incident Classification Scale Annual Report).	**25 September 2024** Publication of the 2023 Annual Incident Classification Scale report.
Article 16 Annual report on load-frequency control.	**25 September 2024** Publication of the 2023 Annual Load-Frequency Control report.
Article 75.1 Methodology for coordinating operational security analysis.	**13 May 2024** ACER decision on the approval of the amendment proposal to CSAM.

Table 1 – SOGL implementation activities in 2024

The Incident Classification Scale (ICS) report showed a continued increase in voltage violations, largely due to the rising share of renewables and the reduced availability of conventional generation. Affected TSOs are taking steps to reduce these violations in the future.

The Annual Load-Frequency Control (ALFC) report highlighted that the **Continental Europe (CE) area** did not meet its frequency quality target in 2023, primarily due to persistent **long-lasting frequency deviations (LLFD)**, especially in the first half of the year. The main contributors were the **Bulgaria** and **France** control blocks.

To support upcoming regulatory developments, ENTSO-E also began reviewing the SOGL provisions in light of the forthcoming **Network Code on Demand Response (NC DR)**, and continued technical preparations for improved **data delivery infrastructure**.

Regular updates were provided to stakeholders through the **System Operation European Stakeholder Committee**.

3.7.2 Implementation Monitoring

Under Article 14 of the SOGL, ENTSO-E monitors implementation across a number of dimensions, including:

- **a)** Operational security indicators in accordance with Article 15;
- **b)** Load-frequency control in accordance with Article 16;
- **c)** Regional coordination assessment in accordance with Article 17;
- **d)** Identification of any divergences in the national implementation of this Regulation for the terms and conditions or methodologies listed in Article 6(3);
- **e)** Identification of any additional improvements of tools and services in accordance with subparagraphs (a) and (b) of Article 55, beyond the improvements identified by the TSOs in accordance with Article 55(e);
- **f)** Identification of any necessary improvements in the annual report on incidents classification scale in accordance with Article 15, which are necessary in order to support sustainable and long-term operational security; and
- **g)** Identification of any difficulties concerning cooperation on secure system operation with third country TSOs.

In 2024, the ICS and ALFC reports fulfilled the monitoring requirements under Articles 15 and 16. Additionally, under Article 65, ENTSO-E released the **All TSOs' Scenario Definition for 2025** in July 2024.

3.7.3 The Emergency and Restoration Network Code

The **Network Code on Electricity Emergency and Restoration (NC ER)**, in force since December 2017, governs how TSOs prepare for and respond to system emergencies. In 2024, TSOs and Regional Coordination Centres (RCCs) collaborated to assess the consistency of **defence and restoration plans** (Art. 6 NC ER, Art. 37(1)(d) Electricity Regulation).

TSOs also collaborated on test planning for **inter-TSO communication systems** (Art. 48(3)) and monitored how decentralised generation affects restoration planning.

3.7.4 Frequency Stability

No major pan-European grid incidents were recorded in 2024. However, ENTSO-E continued implementing recommendations from the 2021 ICS expert panel to strengthen operational procedures across TSOs.

3.7.5 ENTSO-E Awareness System

The **ENTSO-E Awareness System (EAS)** provides a real-time, pan-European view of the state of transmission systems. All TSOs input measurement indicators, such as frequency and cross-border exchanges, which are combined to give each TSO a comprehensive overview through the platform.

In 2024, ENTSO-E monitored the system to ensure continuous operation within agreed service level agreements (SLAs). Several improvements were implemented based on findings from the **8 January 2021 system separation event**, which had **split the Continental Europe Synchronous Area into two zones** due to cascading trips. A detailed technical analysis following that event identified areas for improvement.

As a result, the following actions were delivered:

1. Integration of **Wide Area Monitoring System (WAMS)** data, such as voltage phase angles and frequencies, into EAS, enabling development of new alarms to detect significant system deviations.
2. Configuration of **island detection alarms** using data from **Synchronous Area Monitors (SAMs)** provided by Amprion and Swissgrid.
3. Regular **training sessions for operators** to ensure full awareness of EAS functionalities.

In 2024, the **WAMS protocol converter** was developed, tested, and went live in the EAS production system on **15 January**. Additionally, RCC operator access to EAS was approved by ENTSO-E's System Operations Committee in 2023, and implementation progressed throughout 2024.

The Ukrainian TSO **Ukrenergo's** adherence to the **EAS Data Exchange and Delivery Agreement** was also approved, and an interim solution was implemented to enable the transmission of SCADA and PMU data. These inputs are now visualised in the EAS map and made available to other TSO operators. Due to the approaching end of support for the current platform, ENTSO-E is actively working on a full replacement system, scheduled to go live in **April 2027**.

KEY DATES & DOCUMENTS

25 September 2024
Publication of **2023 Annual Load-Frequency Control Report**

5 July 2024
Publication of **All TSOs' scenario definition and scenario description for the year 2025 CGM creation (in accordance with article 65 of the Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation)**

25 September 2024
Publication of **ICS 2023 Annual Report**

3.7.6 Preparation of Baltic States Power System with Continental Europe

Each year on 7 February, the Belarus-Russia-Estonia-Latvia-Lithuania (BRELL) agreement is automatically renewed for one more year. On 7 August 2024, Litgrid, Elering and AST jointly notified the non-renewal of the agreement, confirming their intention to disconnect from the IPS/UPS system as of 7 February 2025.

Since 2019, ENTSO-E's **Project Group Baltic** has supported synchronisation with the **Continental Europe (CE)** system. This includes technical compliance checks, infrastructure readiness, and external coordination.

In 2024, ENTSO-E supported the **final preparations for trial synchronisation**, working closely with TSOs in Estonia, Latvia and Lithuania, as well as key partners in Continental Europe, including **PSE** and **Amprion**. Activities focused on technical coordination, operational readiness and infrastructure validation, ensuring the Baltic States were fully prepared to operate synchronously with the Continental Europe grid.

3.7.7 Integration of Ukrenergo and Moldelectrica in Continental Europe

The emergency synchronisation of Ukrenergo and Moldelectrica with CE was initiated in March 2022. Following the confirmation of Ukrenergo's permanent synchronisation in 2023, efforts in 2024 focused on helping Moldelectrica meet its Catalogue of Measures – a set of requirements based on SOGL, NC ER, EB GL and the Synchronous Area Framework Agreement (SAFA). Full integration is expected by 2026.

Commercial electricity exchanges between Ukraine-Moldova and CE began in July 2022 and have since expanded, with increasing capacity in both directions.

> The integration of Ukraine and Moldova strengthens Europe's power system – uniting nations through shared infrastructure, trust, and commitment to a sustainable future.

Olivier Arrivé,
Chair of ENTSO-E System Operations Committee

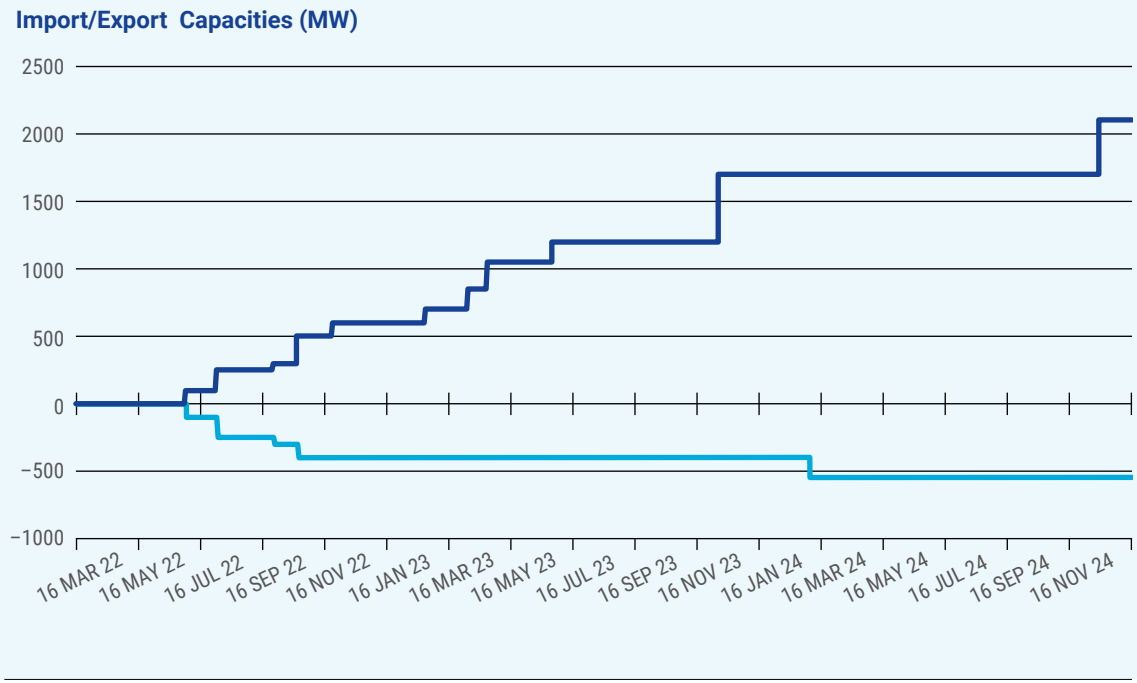


Figure 3 – Commercial exchanges between Ukraine/Moldova and Continental Europe

ENTSO-E also supported the inclusion of Ukrenergo in CE Operational Processes, coordinating Operational, Legal, and IT dimensions of the process.

3.7.8 Tasks for Synchronous Areas

Depending on the specific arrangements within each Regional Group corresponding to Synchronous Areas (SAs), ENTSO-E provides support on an ad-hoc basis or serves the SA on a continuous basis. ENTSO-E supports the Regional Group Continental Europe (RGCE) with implementation processes and supports the synchronisation project between the Baltic TSOs and CE and the synchronisation project between Ukraine and Moldova and CE.

3.7.9 Risk Preparedness

Reliable electricity supply is essential to modern society. With growing interconnectedness, geopolitical risks, digitalisation and changing weather patterns, risk preparedness is a shared European responsibility. Article 6 of the Risk Preparedness Regulation (RPR) obliges ENTSO-E to identify the most relevant regional electricity crisis scenarios, and to update these at least every four years. This report is a result of the implementation of that article, having taken into consideration learnings from the first cycle, concluded in 2020.

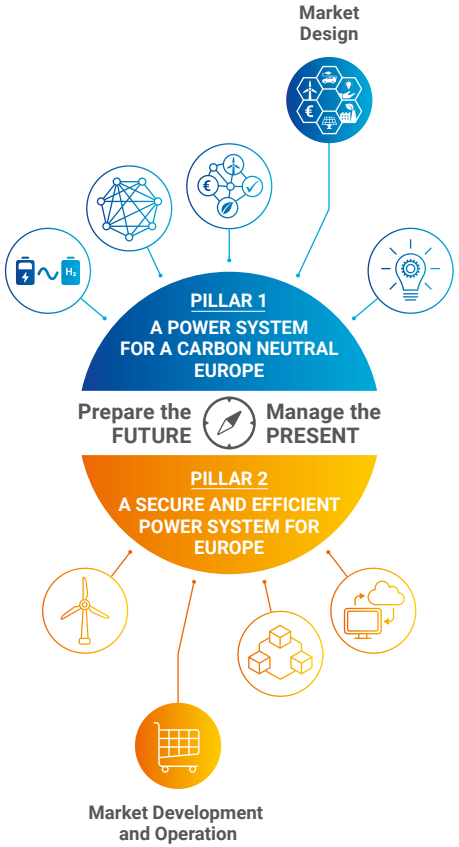
In 2024, the most relevant electricity crisis scenarios were compiled, evaluated, and ranked by ENTSO-E, working closely with the Regional Coordination Centres (RCCs), competent authorities, and regulatory authorities. The ranking was applied at a regional and subgroup level in accordance with the requirements of the updated **Methodology for Identifying Regional Electricity Crisis Scenarios**, developed by ENTSO-E and approved by ACER on 8 March 2024.

After the regional electricity crisis scenarios had been identified, the work on risk preparedness shifted its focus towards identifying learnings from the 2024 cycle and implementing improvements in preparation for the next cycle in 2028.

3.8 Market Development and Operation: Completing the Internal Energy Market

In 2024, ENTSO-E and Europe's TSOs continued implementing and evolving the regulatory and technical foundations of Europe's internal electricity market. Key activities included the application and review of the **CACM**, **FCA**, and **Electricity Balancing Regulations**, the development of methodologies, and the operation of key European platforms for capacity allocation and balancing.

ENTSO-E also advanced integration efforts with Ukraine and Moldova, contributed to evolving market design proposals, and worked on offshore balancing concepts and long-term capacity allocation. These actions support the Strategic Roadmap under **Pillar 1**, by helping to **modernise market design to unlock flexibility and empower consumers**, and under **Pillar 2**, by strengthening **cross-border market efficiency and real-time system balance**.



3.8.1 The Capacity Allocation and Congestion Management Regulation

The **Capacity Allocation and Congestion Management Regulation** (**CACM)** defines the framework for implementing a single energy market across Europe. It sets out rules for allocating transmission capacity in the **day-ahead (DA)** and **intraday (ID)** timeframes, as well as for **calculating capacity across bidding zones**. By enabling harmonised cross-border markets, the regulation contributes to increased efficiency and benefits for consumers. In 2024, all **Terms and Conditions** stemming from the CACM Regulation had been submitted, and implementation is ongoing. TSOs also continued preparing for the upcoming amendment of the regulation, providing technical input to the European Commission, national regulatory authorities (NRAs), and Member States.

Key milestones in 2024 include:

3.8.1.1 Determination of Capacity Calculation Regions

In 2024, the **Energy Community Task Force (EnC TF)** continued examining options for updating the default configuration of **Capacity Calculation Regions (CCRs)** as set out in **Annex I** to the adapted CACM Guideline. For certain default CCR configurations, such as **Italy–Montenegro (IT–ME)** and **East Europe (EE)**, no alternative proposals to the default configurations were submitted. In contrast, substantial work was undertaken towards an alternative to the **South-East Europe (SEE) CCR**. Energy Community TSOs from the West Balkans region – **EMS, CGES, MEPSO, NOSBiH, KOSTT, and OST** – collaborated with neighbouring EU TSOs to strengthen regional power system cooperation. With ENTSO-E's facilitation, these discussions resulted in a **comprehensive cooperation framework** that reflects the needs and realities of all TSOs involved.

The agreed solution defines a geographical structure for capacity calculation, to be followed by **coordinated system operation** and further market integration. It links the West Balkan TSOs to existing organised areas in **Central and South-East Europe**, helping to reinforce both **market integration** and **security of supply** across the wider region. This new framework was formalised during the **ENTSO-E 15th Anniversary Conference** in Brussels on **4 December 2024**, where **West Balkan TSOs adhered to a Joint Declaration** outlining their commitment to implementing the proposal. The declaration was also endorsed by TSOs from all neighbouring EU Member States.

3.8.1.2 Technical Report on the Current Bidding Zone Configuration

In 2024, ENTSO-E worked on the **Technical Report on structural and other major physical congestion in the Current Bidding Zone Configuration** for the **2021–2023** period. The report provides a transparent, data-driven overview of congestion patterns across the EU and supports the wider Bidding Zone Review process.

The report includes:

- An assessment of congestion levels across bidding zone borders
- Analysis of scheduled flows outside of the market
- Evaluation of the **costs associated with congestion**
- A review of compliance with the **Clean Energy Package's 70% minimum capacity requirement**

The report's findings are intended to inform the evaluation of the current bidding zone setup and its efficiency in supporting efficient congestion management and well-functioning electricity markets. The final report was published **on 24 February 2025**.

3.8.1.3 Congestion Income Distribution

On 21 December 2023, ACER approved an amendment to the Congestion Income Distribution (CID) methodology in accordance with Article 73 of the CACM Regulation. The update addresses how to manage unintuitive flows caused by mechanisms such as Allocation Constraints (AC) and Advanced Hybrid Coupling (AHC), by introducing a virtual hub approach.

In 2024, TSOs impacted by allocation mechanisms with cross-CCR impact in the Single Day-Ahead Coupling (SDAC) or Intraday Auctions (IDA), particularly those involving AHC or AC, began the implementation phase. This process is being supported by ENTSO-E.

The Joint Allocation Office (JAO) has been designated to develop the Congestion Revenue Distribution System (CRDS), which will calculate, distribute, and settle congestion income among the Core, Hansa, Nordic, and Baltic CCRs, as well as the Bulgarian TSO.

3.8.1.4 Day Ahead Scheduled Exchanges Methodology (Article 43 of the CACM regulation)

The **Scheduled Exchange Calculation (SEC) methodology** defines how commercial flows between bidding zones are derived from the day-ahead market coupling algorithm. These calculated scheduled exchanges are used alongside net positions and prices – key outputs of the market coupling process.

In preparation for the transition from a 60-minute to a 15-minute market time unit (MTU) in the day-ahead market coupling process, scheduled for 30 September 2025, with first delivery day 1 October 2025, the algorithm underwent performance upgrades to manage increased data volumes and ensure timely results. In response, TSOs submitted an **amendment proposal** in Q2 2024. The amendment proposal introduced by TSOs in Q2 2024, was approved by ACER **in this decision** on 25 September 2024.

3.8.1.5 Single Day-Ahead and Intraday Coupling

In accordance with **Article 10 of the CACM Regulation**, TSOs cooperate with **Nominated Electricity Market Operators (NEMOs)** to manage the operation and development of the **Single Day-Ahead Coupling (SDAC)** and **Single Intraday Coupling (SIDC)**.

Key developments in 2024:

- On **13 June 2024**, **SIDC** was extended to support both **cross-border continuous trading** and **Intraday Auctions (IDAs)** across Europe.
- Work progressed on implementing the **15-minute Market Time Unit (MTU)** in the **day-ahead timeframe**, enabling more granular trading and improved alignment with physical system needs.
- On **24 July 2024**, NEMOs and TSOs published the **2023 CACM Cost Report**, providing a detailed account of expenditures related to the development and operation of SDAC and SIDC.

Co-optimisation in market algorithms

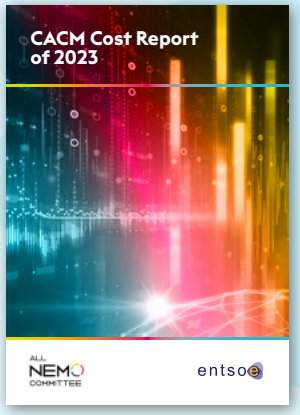
At the request of **ACER**, NEMOs amended the **Algorithm Methodology (Article 37)** to reflect requirements submitted by TSOs – specifically related to the **co-optimisation of balancing energy**.

- **24 November 2023**: NEMOs submitted the amended methodology to ACER
- **23 September 2024**: ACER issued its **final opinion**, incorporating revisions aimed at enabling **co-optimised allocation of cross-zonal capacity**

Product design updates for day-ahead coupling

On **23 September 2024**, ACER adopted its opinion **on SDAC Products**, based on NEMO proposals. Key elements included:

- Support for the implementation of **15-minute MTU products** in SDAC
- Removal of entry barriers for participants trading at 15-minute granularity
- Enabling market participants to **buy and sell electricity in 15-minute intervals**, enhancing market flexibility



3.8.1.6 Development in the Capacity Calculation Regions

	DA and ID CapCalc (Article 20.2)
Baltic	Publication of explanatory note including consultation results in January 2024. DA & ID go-live in February 2025.
Core	› IDCCM: Partially implemented in 2024 › 2nd and 3rd amendment were published by ACER in March 2024 › DACCM: 3rd RfA was approved by NRAs in July 2024
Hansa	Phase II go-live in Q4 2025 for all borders except: › DE/LU-SE4 › DE/LU-DK2 These will go live within 12 months of Phase II.
Nordic	DACC and IDCC went live in Q4-2024.

Table 2 – CACM Capacity Calculation methodologies in 2024

3.8.2 Trade Development with Ukraine and Moldova

In 2024, progress continued on enhancing electricity trade between the EU and its eastern neighbours, particularly **Ukraine** and **Moldova**. This work builds on the joint allocation framework developed in 2023 by ENTSO-E, TSOs, and the **Joint Allocation Office (JAO)**.

Daily joint auctions go live

Daily auctions, organised by JAO, went live on the following borders:

- **Poland-Ukraine**
  - Rules entered into force: 16 January 2024
  - First bidding: 18 January 2024
- **Hungary-Ukraine**
  - Rules entered into force: 22 February 2024
  - First bidding: 23 February 2024
- **Slovakia-Ukraine**
  - Rules entered into force: 4 March 2024
  - First bidding: 6 March 2024

Long-term and intraday auction development

In June 2024, the expert group initiated work on **long-term (LT)** and **intraday (ID)** auction design. The following developments were agreed:

- **Monthly long-term auctions** for:
  - Slovakia-Ukraine
  - Hungary-Ukraine
  - Romania-Ukraine

    → to be organised by JAO
- **Intraday explicit auctions** for:
  - Slovakia-Ukraine and Hungary-Ukraine → by JAO
  - Romania-Ukraine → by a bilateral auction platform

Auction rules and implementation (June–December 2024 and ongoing)

Work is ongoing to develop tailored rules for each border:

- **Long-term auctions**: will apply the **EU Harmonised Allocation Rules (HAR)** with **Border-Specific Annexes (BSA)**
- **Explicit intraday auctions (JAO borders)**: will apply updated **CH ID rules**
- **Romania–Ukraine**: will use bilateral rules developed by **Ukrenergo** and **Transelectrica**

Regarding Moldova, in 2024:

- On the **Moldova–Romania** border, **intraday auctions** went live on **12 July 2024**
- In H2 2024, Moldova experienced lower domestic generation and announced that **gas transit would stop as of 1 January 2025**

To support Moldova, neighbouring TSOs agreed in December 2024 to **reallocate non-used capacity** from Ukraine-EU borders (Poland, Slovakia, Hungary, Romania) to intraday auctions on the Moldova border.

3.8.3 Bidding Zone Review

In 2024, TSOs in the **Central Europe** and the **Nordic bidding zone review regions** continued their joint work on the **Bidding Zones Review (BZR)**, as required under **Article 14** of **Regulation (EU) 2019/943**. The review is aimed at identifying optimal bidding zone configurations that improve market efficiency, cross-zonal trading, and grid stability.

Between 19 July and 4 September 2024, the TSOs held a public consultation regarding the following aspects:

- The impacts of alternative BZ configurations on the following criteria: 'Market liquidity and transaction costs' and 'Transition costs' based on the reports on both criteria that will be provided with the public consultation material;
- Possible measures to mitigate negative impacts of specific alternative BZ configurations regarding the reports on 'Market liquidity and transaction costs' and 'Transition costs' criteria; and
- The identification of practical considerations which may need to be considered in case of a possible BZ configuration change as set forth in Article 14(10) of the Electricity Regulation, including possible timescales for implementation of alternative BZ configurations.

As part of the public consultation, the TSOs published:

- On 1 February 2024, the **transition costs study report** for the public consultation, and
- On 19 July 2024, **the liquidity and transaction costs study** for the public consultation.

The **BZ Study** was finalised, submitted to Member States and published on 28 April 2025.

3.8.4 The Forward Capacity Allocation Regulation

The **Forward Capacity Allocation (FCA) Regulation**, in force since **17 October 2016**, sets out rules for allocating **long-term transmission rights (LTTRs)** via explicit auctions, and for compensating right-holders in the event of curtailment. The regulation's objective is to promote the development of **liquid and competitive forward markets**, giving market participants the ability to hedge cross-border trading risks. Implementation of all **Terms, Conditions and Methodologies (TCMs)** under the FCA Regulation is ongoing. In 2024, ENTSO-E began reviewing the **Harmonised Allocation Rules (HAR)** methodology, as required by **Article 68(5)** of the HAR. The review involves the **Single Allocation Platform (SAP)**, relevant TSOs, and **Registered Participants**, and is conducted at least every two years.

Long-term flow-based allocation project

TSOs and JAO continued preparing for the implementation of the **Long-Term Flow-Based Allocation (LT-FBA)** project in the **Core** and **Nordic Capacity Calculation Regions (CCRs)**, for a go-live in November 2026. Multiple workshops were organised to share progress and present expected outcomes.

Forward market advocacy

In 2024, ENTSO-E published an advocacy note on forward markets, where TSOs call for alternatives to the Virtual Hub model. TSOs argued that:

- Regional Virtual Hubs are **untested** and **not widely supported** by market participants
- Alternative solutions, such as improved auction designs based on options or obligations, may be more effective and faster to implement

Capacity calculation regions

	Splitting of the Long-Term cross-zonal capacity (Art 16)
Baltic	ACER in its opinion has stated that as there was no proper LT CCM, capacity splitting methodology could not be amended. New Splitting methodology shall consider the EE-FI border.
Core	1st amendment of Core CCR TSOs' methodology for splitting long-term cross-zonal capacity approved by NRAs in April 2023.
Italy North	19 Sep–20 Oct 2023 – Public Consultation

KEY DATES & DOCU-MENTS

3 July 2024
ENTSO-E Advocacy Note on Forward Markets

3.8.5 The Electricity Balancing Regulation

The **Electricity Balancing (EB) Regulation** establishes a common framework for cross-border balancing in Europe. Its goal is to ensure system security at the lowest possible cost, while promoting equal market access for all balancing resources and delivering environmental benefits by reducing the need for backup generation.

In 2024, TSOs continued work on both the development of methodologies and the implementation of European balancing platforms, with ENTSO-E acting as facilitator.

Key dates and documents in 2024

Date	Event
7 February 2024	The Pricing Methodology for balancing energy and cross-zonal capacity (The Implementation Framework for the aFRR platform submitted to ACER, for which the decisions adapted by ACER on 5 July [see below]).
17 April 2024	EB stakeholders group meeting
28 June 2024	**EB Cost Report 2024** published and submitted to ACER
5 July 2024	ACER issued two decisions on the All TSOs' proposed amendments: › **Decision No 08/2024** on the second amendment to the implementation framework for a European platform for the exchange of balancing energy from frequency restoration reserves with automatic activation pursuant to Article 5(2)(b) and Article 5(6) of Regulation (EU) 2019/942, and Article 5(1), Article 5(2)(a), Article 6(3) and Article 21(1) of Commission Regulation (EU) 2017/2195 ('EB Regulation'); and › **Decision No 09/2024** on the second amendment to the methodology for pricing balancing energy and cross-zonal capacity used for the exchange of balancing energy or operating the imbalance netting process (Article 30(1) of EB Regulation).
31 July 2024	Submission of **All TSOs' amended methodology for a harmonised allocation process of cross-zonal capacity for the exchange of balancing capacity or sharing of reserves per timeframe** to ACER
23 September 2024	ACER **issued** its **Decision No 11/2024** on amendments to the price coupling algorithm and the continuous trading matching algorithm, including the common sets of requirements.
6 November 2024	EB stakeholders group meeting
11 December 2024	**Annual Balancing platforms stakeholders' workshop**
10 December 2024	Submission of updated Balancing Performance Indicators to ACER

3.8.6 Offshore Balancing Concept

The concept of **co-optimisation**, as described in **Articles 38(3)** and **40** of the Electricity Balancing (EB) Regulation, aims to achieve optimal allocation of cross-zonal capacity through joint procurement of energy and balancing capacity, particularly within the Single Day-Ahead Coupling (SDAC) framework.

Following a request from **ACER** in November 2022, NEMOs submitted an updated **Algorithm Methodology** on **24 November 2023**. After two public consultations and a hearing in 2024, **ACER adopted** Decision No 11/2024 on 23 September. This decision incorporates concerns from both TSOs and NEMOs and sets the direction for ongoing R&D work on co-optimisation.

Balancing market design improvements

TSOs identified the need for updates to the regulatory framework to improve market efficiency across several dimensions and submitted proposals to amend:

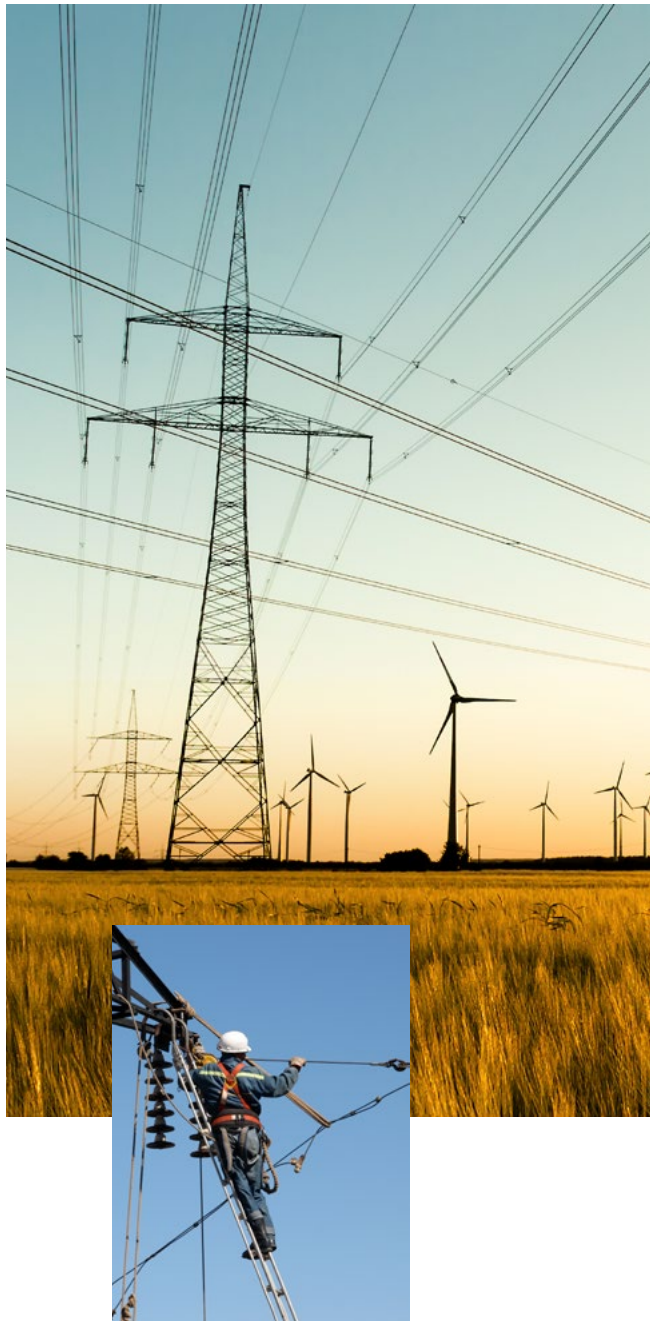
- The **Pricing Methodology for balancing energy and cross-zonal capacity**
- The **Implementation Framework for the aFRR platform**

These proposals were submitted to ACER on **7 February 2024.** ACER Decisions No 08/2024 and No 09/2024, both adopted on **5 July 2024**, introduce important updates to the EU electricity balancing framework under the EB Regulation (EU) 2017/2195, with amendments included in:

- **Decision No 08/2024**: Second amendment to the aFRR implementation framework
- **Decision No 09/2024**: Second amendment to the pricing methodology (Article 30(1), EB Regulation)

Harmonised Cross-Zonal Capacity Allocation Methodology

In line with **ACER Decision No 11/2023** (19 July 2023), TSOs submitted an **amended harmonised methodology for cross-zonal capacity allocation**, covering the exchange of balancing capacity and sharing of reserves across timeframes, to ACER on **31 July 2024**.



3.8.7 The European Balancing Platforms

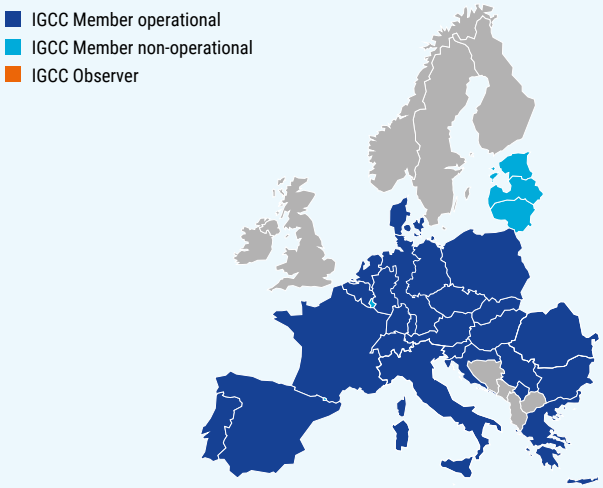
All TSOs continued operating and expanding participation in Europe's four cross-border balancing platforms in 2024. These platforms are central to implementing the **Electricity Balancing (EB) Regulation**, ensuring efficient exchange and procurement of balancing energy across synchronous areas.

IGCC – Imbalance Netting Platform

The **International Grid Control Cooperation (IGCC)** was established in 2011 to avoid counteracting activations of automatic Frequency Restoration Reserve (aFRR) energy by applying imbalance netting. The platform became legally operational in **June 2021**, fulfilling EB Regulation requirements.

In 2024:

- IGCC operations continued without major incidents
- As more TSOs joined the **PICASSO** platform, the overall volume of explicit netting decreased, as expected



PICASSO – aFRR Energy Exchange Platform

The **PICASSO** platform for **automated Frequency Restoration Reserves (aFRR)** went live in **June 2022**.

In 2024:

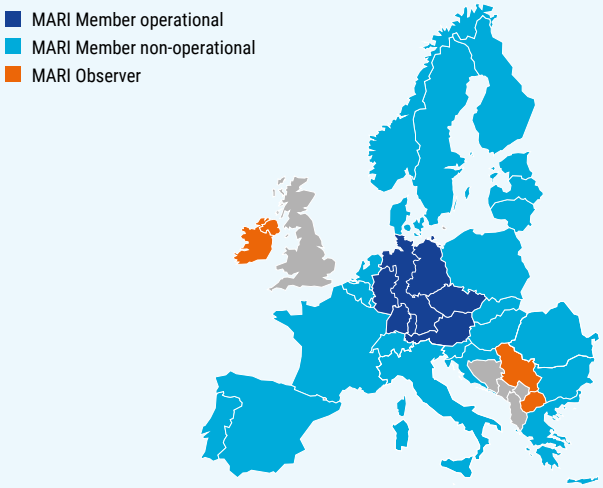
- Four TSOs joined: **Energinet** and **TenneT Netherlands** (October), **SEPS** and **Elia** (November)
- **TERNA** suspended its participation in **March 2024**
- Additional accessions are planned for 2025 (see **accession roadmap** from **26 September 2024**)

MARI – mFRR Energy Exchange Platform

The **MARI** platform for **manual Frequency Restoration Reserves (mFRR)** launched in **October 2022**.

In 2024:

- TSOs joining included the three Baltic TSOs (**Elering, AST, Litgrid**) in October, **REN** in November, and **SEPS** and **REE** in December
- Further accessions are scheduled for 2025 (see **accession roadmap** from **10 October 2024**)

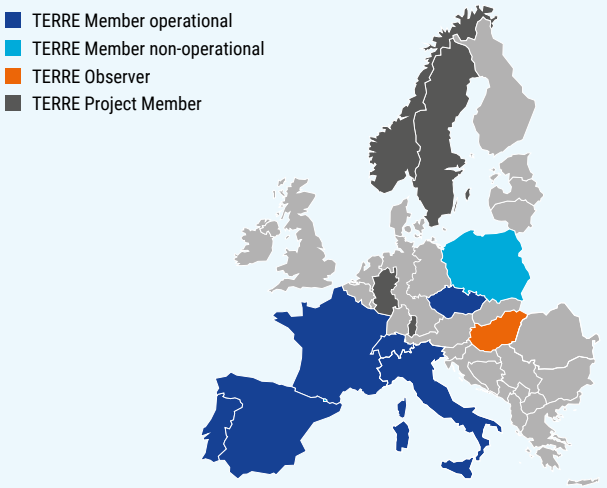


TERRE – Replacement Reserves Exchange Platform

The **TERRE** platform, operational since **January 2020**, facilitates the exchange of **Replacement Reserves (RR)**.

In 2024:

- After consultation with **RR National Regulatory Authorities (NRAs)**, participating TSOs agreed to phase out **LIBRA**, the TERRE platform's technical backbone, by **end of 2025**
- Disconnections: **ČEPS** (1 July 2024) and **Terna** (30 December 2024)
- **PSE** withdrew its connection proposal in 2024



ENTSO-E and all TSOs continue to monitor the platforms' development and performance, regularly engaging stakeholders. The annual Balancing Platforms Stakeholders Workshop was held online on 11 December 2024. For more information, please refer to this **webpage**.

In addition, following the technical go-live of the Capacity Management (CM) IT Solution in 2023, the CM IT Solution saw the further accession of Litgrid in 2024, as well as the go-live of one major Common Management Module platform releases with improved and new functionalities (version 2) on 30 July 2024.

Offshore balancing concept

ENTSO-E also launched work on an **Offshore Balancing Concept** to support the integration of **Offshore Bidding Zones (OBZs)** and **Offshore Wind Farms (OWFs)** into European balancing markets. The work focuses on identifying regulatory gaps and proposing solutions related to:

- Real-time imbalance steering via **HVDC systems**
- Integration of OBZs into EU platforms
- Imbalance pricing design
- Dimensioning and sharing of offshore reserves
- Cost allocation for procurement and activation
- Roles and responsibilities of market participants in offshore balancing

This initiative is part of ENTSO-E's broader effort to align offshore operations with the European balancing framework and support the evolving market design.

3.8.8 Implementation Monitoring

On **28 June 2024**, ENTSO-E published its annual **Market Report 2024**, covering implementation progress under the **CACM**, **FCA**, and **EB Regulations**. The report tracks how these frameworks continue to bring the internal electricity market closer to full realisation.

This publication was prepared in accordance with:

- **Article 82** of the CACM Regulation
- **Article 63** of the FCA Regulation
- **Article 59** of the EB Regulation

In addition, ENTSO-E released the **Balancing Report 2024** (biennial), in line with **Article 59(2)(a)** of the EB Regulation. This report provides an overview of balancing market design and implementation at pan-European, regional, and national levels. It also highlights progress on:

- Cross-border balancing capacity procurement
- Harmonisation of methodologies
- Development of European balancing platforms
- Implementation of common imbalance settlement procedures

KEY DATES & DOCU-MENTS

28 June 2024
Publication of the **Annual Market Report 2024**, **Balancing Report 2024**, **CACM Cost Report** and **EB Cost Report 2024**.

Cost reports

In 2024, ENTSO-E also coordinated the publication of:

- The **CACM Cost Report**, developed with relevant NEMOs and TSOs, outlining costs related to the operation and evolution of the SDAC and SIDC (Article 80, CACM Regulation)
- The **EB Cost Report 2024**, in line with **Article 23 of the EB Regulation**, covering costs linked to balancing platforms

Quarterly pricing reports

All TSOs continued publishing **Quarterly Pricing Reports** on the ENTSO-E website. These reports support transparency and are mandated under the pricing methodology for balancing energy and cross-zonal capacity (Article 30(1), EB Regulation).

Monitoring information provided to ACER

ENTSO-E is responsible for compiling and transmitting data to ACER to support regulatory monitoring under several guidelines, including:

- **Article 82(4)** of CACM
- **Article 63(3)** of FCA
- **Article 63(3)** of EB Regulation
- **Article 14** of SOGL

To meet these obligations, ENTSO-E maintains a **comprehensive, standardised digital data archive** to facilitate timely information exchange with ACER. In 2024, this included updating the **EB Regulation list of information** and progressing the implementation of the **SOGL list of information**.

3.8.9 ITC – Inter-Transmission System Operator Compensation

The **Inter-Transmission System Operator Compensation (ITC) Agreement** is a multiparty arrangement between ENTSO-E and its member TSOs – alongside **KOSTT**, **National Grid ESO**, and **Ukrenergo** – referred to collectively as "ITC Parties". The ITC mechanism provides a framework for compensating TSOs for **hosting transit flows**, i.e. electricity flows across national transmission systems that are neither generated nor consumed within that system. By compensating for these costs, the mechanism encourages cross-border electricity flows and supports an **efficient, competitive internal electricity market**.

How the ITC mechanism works

The ITC Agreement requires all parties to participate in an **annual process** in which they:

- Provide data and verify values used to calculate the **perimeter fee**
- Determine **transit flows**, including imports and exports with third countries

ENTSO-E is mandated to ensure the smooth operation of the mechanism in accordance with Regulation (EU) 828/2010 and to ensure that all Data Administrator tasks necessary for its smooth operation are carried out. The Data Administrator tasks are:

- Calculating **transit-related losses** on each transmission system
- Estimating the difference between actual losses and the hypothetical scenario without transit
- Publishing data and overseeing related administrative tasks

The ITC mechanism is governed by **Article 49 of the Electricity Regulation** and further detailed in **Regulation (EU) 838/2010**, which sets guidelines for:

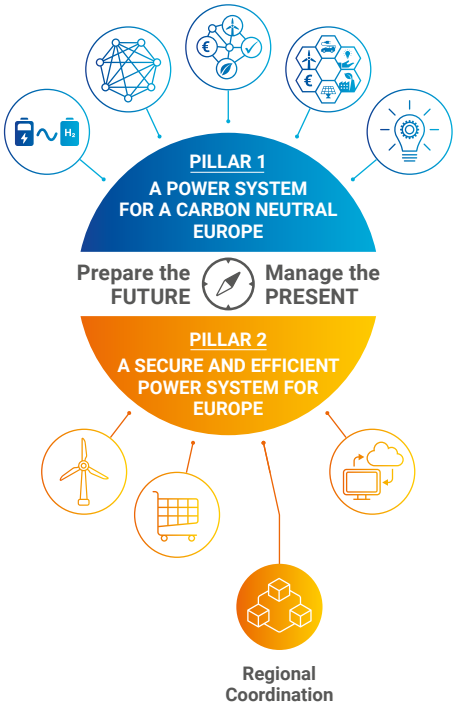
- The compensation methodology
- Transmission charging approaches

Key Milestones in 2024

- 1 July 2024: Ukrenergo formally joined as a new ITC Party
- September 2024: Publication of the ITC Transit Losses Data Report 2023

3.9 Regional Coordination

Regional coordination is a critical component of secure and efficient electricity system operation in an increasingly interconnected and interdependent European grid. In 2024, ENTSO-E and TSOs advanced the implementation of **Regional Coordination Centre (RCC)** tasks. ENTSO-E's role in the context of RCC tasks is manifold from taking responsibility for the methodologies and reporting obligations, facilitating knowledge-exchange, alignment and harmonization across the regions to being directly in involved in the operational processes. These activities underpin the Strategic Roadmap's **Pillar 2 objective** of **aligning national and regional actions across Europe** to ensure system-wide efficiency, security of supply, and effective integration of decentralised resources.



Reporting Obligation in Regional Coordination

On **26 September 2024**, ENTSO-E published the **Annual Report on Regional Coordination Assessment 2023**, reviewing progress and performance of key regional coordination tasks in line with SOGL Article 17.

Methodologies in relation to RCC tasks

A task team was created to facilitate the alignment across System Operation Regions (SOR) and Regional Coordination Centres (RCC) for the implementation of the task for sizing and procurement of reserve capacity (Art. 37(1)(j),(k) Electricity Regulation) with a particular focus on the definition of parameters to be submitted in requests for amendment of the methodologies by ENTSO-E in 2025 and 2026.

Implementation and Operation of RCC tasks

The SOGL and CACM extended by Article 37(1) of the Electricity Regulation lay out the tasks of Regional Coordination Centres (RCCs). In 2024, the implementation and evolution of tasks continued, with particular involvement of ENTSO-E in the following areas of tasks under the SOGL and CACM Regulation as well as Article 37(1) of the Electricity Regulation:

- **(a) Coordinated Capacity Calculation (CCC)**: Implementation continued according to regional methodologies. ENTSO-E is particularly involved in relation to interdependencies between the regions or with other regional coordination tasks to ensure consistency between market and system operation processes and finding the balance their respective business needs.
- **(b) Coordinated Security Analysis (CSA)**: Implementation continued according to regional methodologies. ENTSO-E keeps its
- **(c) Common Grid Model (CGM)**: **Individual Grid Models (IGMs)** are submitted by TSOs via the **Operational Planning Data Environment (OPDE)** provided by ENTSO-E to create pan-European CGMs
- **(d) Consistency assessments** for system defence and restoration plans are in place. In line with **Article 6 of the NC ER**, RCCs supported the delivery of the regular report of ENTSO-E in 2024
- **(e) Short-Term Adequacy (STA)** and **(f) Outage Planning Coordination (OPC)**: Both services are operational and undergoing constant evolution

ENTSO-E remains actively engaged in supporting these tasks, especially for pan-European parts of the STA (Art. 81 SOGL), OPC (Art. 80 SOGL), and CGM (Art. 64 SOGL) processes. CSA (Art. 75 SOGL) and CCC (Art. 25 CACM) are mainly implemented by the RCCs at regional level. Nevertheless, ENTSO-E takes responsibility in improving and harmonizing the regional processes and methodologies as it was done with the proposed updates to the CSAm which were approved by ACER in 2024 (ACER decision 07/2024). Besides that ENTSO-E enables discussions and solution seeking on the interface between regions whenever necessary.

- **(g) Training and certification**: Execution phase ongoing, to be completed by 2026
- **(h) Supporting restoration**: Drafting of methodology proposal.
- **(j)** and **(k) Balancing capacity sizing and procurement**:
  - Work continued in line with **ACER Decision No 13/2023**
  - TSOs and RCCs are coordinating on required parameters for the SOR methodology, to be submitted by **October 2025**
- **(l) Inter-TSO settlement**: To be implemented where applicable, if requested
- **(o) Maximum Entry Capacity**: Task initiated in 2024, with ongoing process development
- **(p) Identification of new infrastructure needs**: Currently on hold pending full CGM and CSA/CCC implementation

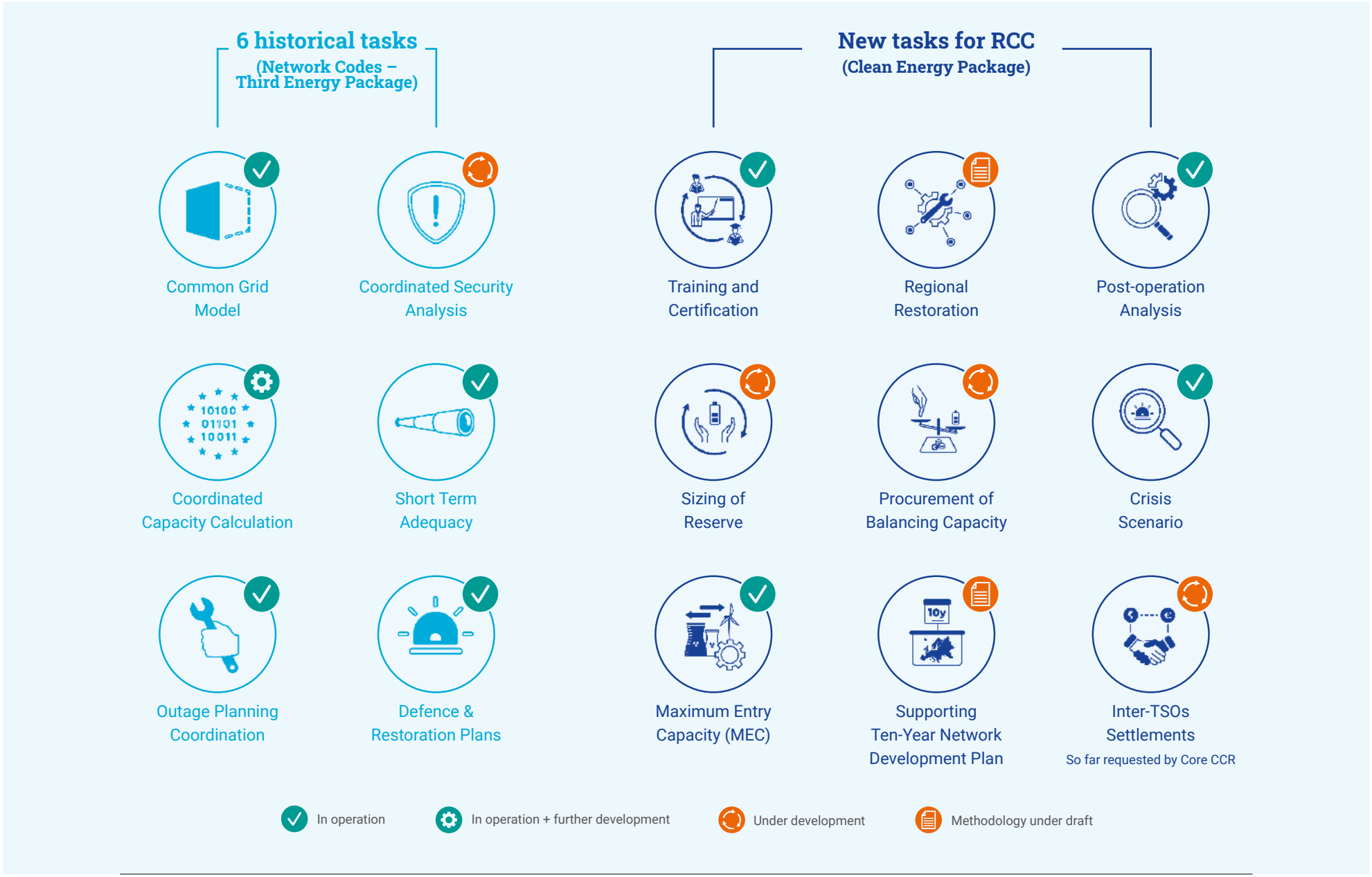


Figure 4 – New RCC tasks under the electricity regulation

3.9.1 Other regional developments

ENTSO-E supports the IT operations and evolution of key regional coordination tools, particularly the **Outage Planning Coordination (OPC)** and **Short-Term Adequacy (STA)**, and **Maximum Entry Capacity (MEC)** processes. These tools enable RCCs and TSOs to coordinate and assess regional grid conditions efficiently.

Pan-European OPC and STA IT tools

- The **OPC IT tool**, operational since **March 2020**, enables TSOs and RCCs to coordinate planned outages across the European grid
- The **STA IT tool**, launched in **May 2020**, uses generation and demand forecasts submitted by TSOs to assess regional adequacy for the week ahead

In 2024, ENTSO-E continued to enhance both tools, incorporating feedback from TSOs and RCCs to improve usability and service delivery.

3.9.2 Common Grid Model

The **Common Grid Model (CGM)** and the supporting **Operational Planning Data Environment (OPDE)** are critical enablers of operational coordination and security of supply at the European level. Enhancing visibility into pan-European interconnection flows is a key step toward strengthening grid security, enabling cost-efficient operation, and fostering closer cooperation between TSOs and RCCs.

The legal basis for CGM and OPDE is established in three Network Codes:

- **SOGL** – Article 64
- **CACM Regulation** – Article 17
- **FCA Regulation** – Article 18

The CGM is a prerequisite for several harmonised services defined in the Network Codes, such as:

- **Coordinated Capacity Calculation (CCC)**
- **Coordinated Security Analysis (CSA)**
- **Outage Planning Coordination (OPC)**
- **Short-Term Adequacy (STA)**

> With improved OPC and STA tools, ENTSO-E drives regional coordination forward, turning shared data into decisive action for Europe's power system.

Carla Wolf and Andrea Mannocchi,
Convenors of Steering Group Regional Coordination

A CGM is built from Individual Grid Models (IGMs) submitted by each TSO, covering timeframes for the scenario date being from one year ahead (Y-1) down to one hour ahead of real time. After undergoing a quality assessment and a pan-European alignment process, the IGMs are merged by the RCCs into a single **pan-European CGM**. Each IGM and CGM is validated and assessed for quality through the **OPDE**, ensuring the models are fit-for-purpose for operational planning and coordination tasks. Add a part that also other Regional Coordination Process data is progressed/ shared via OPDE. ENTSO-E initiated their connection in 2024.

3.9.3 Achievements and Challenges

The **CGM Build Process**, jointly managed by ENTSO-E, TSOs, and RCCs, went live on **8 December 2021**. ENTSO-E's primary responsibility is to operate and maintain the **OPDE**, which enables the exchange of IGMs and CGMs between TSOs and RCCs.

Under the current setup:

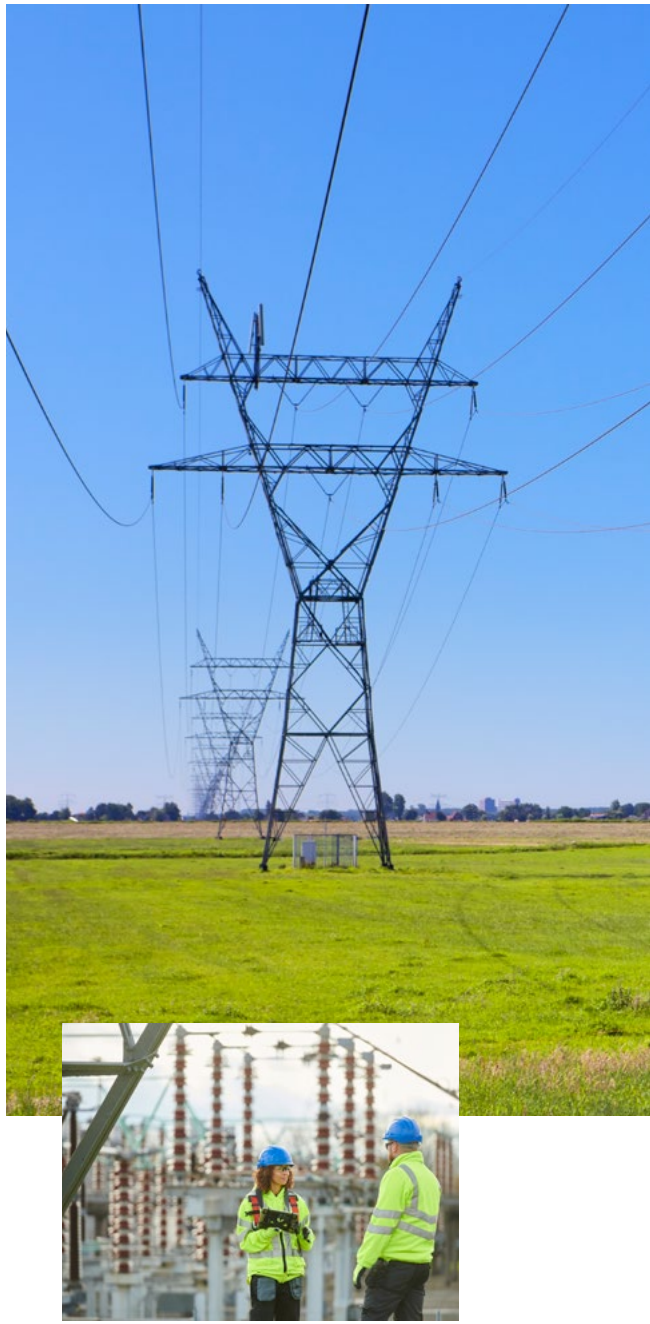
- IGMs from each TSO are submitted for timeframes ranging from one year ahead to one hour ahead of real time
- After validation and alignment, these IGMs are merged into pan-European CGMs by RCCs
- To ensure redundancy, two RCCs act as merging agents, rotating monthly this role among five participating RCCs

Current status and progress

Since go-live, both the **number** and **quality** of submitted IGMs, and their successful inclusion in CGMs, have fluctuated. To address the fluctuation and completeness of CGMs, the **System Operations Committee (SOC)** developed a detailed **CGM Action Plan**, which was presented to the **ENTSO-E Board (April 2024)** and **Assembly (June 2024)**. The plan was launched in **mid-2024** and focuses on five key workstreams:

- **Governance and organisation**
- **IGM quality improvement**
- **Transition to CGMES (Common Grid Model Exchange Standard)**
- **Regional coordination processes**
- **OPDE optimisation**

These efforts aim to improve model quality, expand coverage, and bring the CGM process in line with operational and regulatory expectations.



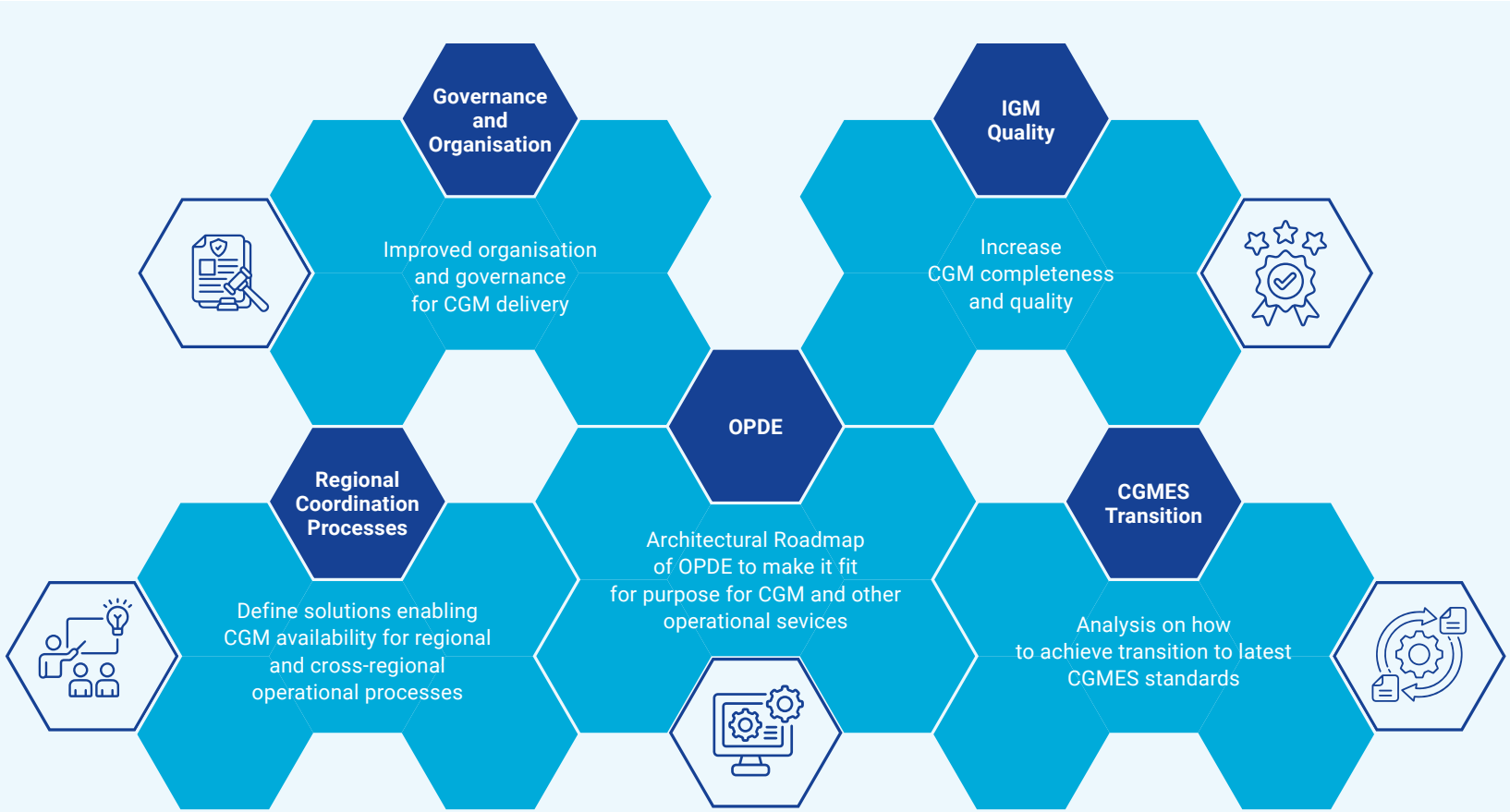
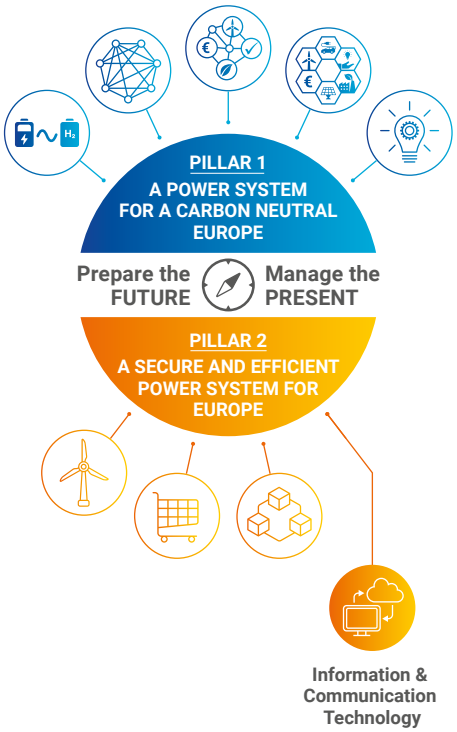


Figure 5 – CGM action plan – Streams and objectives

3.10 Information and Communication Technology

In 2024, ENTSO-E strengthened the digital foundations that underpin secure, coordinated grid operations in an increasingly interconnected and cyber-sensitive environment. Key developments included the implementation of new security tools and policies, enhanced software assurance processes, active participation in EU-wide cybersecurity initiatives, and support for the **Network Code on Cybersecurity (NCCS)**. These efforts reflect the Strategic Roadmap's **Pillar 2 priority** of deploying **advanced ICT systems that support digitalisation, secure data exchange, and system resilience** across the European power grid.



ENTSO-E's **Internal Security Controls environment** remained effective, with **no Critical or High-rated security incidents reported** over the year. An external audit identified areas for improvement but confirmed that ENTSO-E's **Information Security Management System (ISMS)** continues to mature and remains fit for purpose for a pan-European system operator association. Several new security policies were introduced to reflect developments in the ICT landscape, including one focused on Artificial Intelligence (AI). Significant effort was dedicated to cybersecurity awareness training, delivered across teams and staff levels to highlight risks, threats, and the potential impact of cyber-attacks.

To enhance technical defences, ENTSO-E deployed new security tools in 2024, including:

- Umbrella (DNS-layer protection)
- Lansweeper (IT asset management)
- FortiNAC (network access control)
- Delinea (privileged access management)

As ENTSO-E increases its use of Microsoft Azure (public cloud) to host applications, the IT Security Team continues to invest in new tools and internal training to ensure a high level of in-house security expertise. A successful disaster recovery rehearsal was conducted for the Oxygen building, validating that core business applications can be restored in the event of a site-wide failure.

Secure Software Development and Testing

The Secure Software Development Life Cycle (SSDLC) programme remained active in 2024, monitoring the security and code quality of over 30 ENTSO-E-developed applications. External experts conducted testing throughout the year, identifying vulnerabilities and coding issues, which were remediated by development teams as part of a structured feedback loop.

All ENTSO-E applications continue to undergo:

- Penetration testing
- Threat modelling
- Security review prior to release

These steps ensure that all software made available to the TSO community meets rigorous cybersecurity standards.

Network Code on Cybersecurity

The Network Code on Cybersecurity (NCCS) entered into force on 13 June 2024. It establishes sector-specific rules to enhance the cybersecurity of cross-border electricity flows across the EU. ENTSO-E, in coordination with TSOs and key stakeholders, delivered core documentation as required by the Network Code schedule. This included:

- The provisional Electricity Cybersecurity Impact Index (ECII)
- Provisional list of Union-wide high-impact and critical-impact processes

Stakeholder engagement with the European Commission, ENISA, ACER, the EU DSO Entity, and others continued throughout the year. In 2025, work will focus on delivering:

- Proposal for Cybersecurity Risk Assessment Methodologies
- Proposal for Cyber-Attack Classification Scale Methodology

These deliverables form the first legally binding cybersecurity methodologies under NCCS. Additionally, a list of provisional European cybersecurity standards and controls will be published in 2025.

Collaboration and exercises

ENTSO-E's IT Security Team, together with the Steering Group ICT Security, participated in the ENISA Cyber Europe 2024 exercise, focused on managing large-scale cybersecurity incidents across European critical infrastructure.

Further activities included:

- Cyber risk assessments for TSOs
- Cybersecurity planning as part of the Baltic synchronisation process

> By combining resilient ICT with innovation, ENTSO-E strengthens Europe's energy transition, delivering secure, sustainable solutions for a connected future.

Radek Hartman,
Chair of the ENTSO-E Information and Communication Technologies Committee

4 Appendix

Appendix 1

Staff

Sonya Twohig
Secretary-General

Evelyne Driane
Head of People, Talent & Culture Section

Bruno Gouverneur
Head of Operations Section

Zoltan Gyulay
Head of Business Planning Section

Edwin Haesen
Head of System Development Section

Edwin Haesen
Head of Innovation Section ad-interim

Bertrand Macabeo
Head of Corporate Services Section

Cara McLaughlin
Head of Member Relations and Association Policy Section

Florence Melchior
Head of General Counsel Section

Nicolas Richet
Head of ICT Section

Ivan Taleski
Head of Legal Section

Christelle Verstraeten
Head of Policy, Communications and Stakeholder Management Section

Appendix 2

Network Codes and Clean Energy Package: Focus on Implementation

The Network Codes and Guidelines, the Clean Energy Package (CEP) and the Electricity Market Design (EMD) reform represent a large part of the legislative framework under which ENTSO-E operates. The implementation of the Network Codes and Guidelines, the CEP and the EMD represents a substantial effort which ENTSO-E is prioritising.

Beside the Network Code on Demand Response (NC DR), the recast of the Capacity Allocation and Congestion Management (CACM) Guideline (so-called CACM 2.0), and the Connection Network Codes 2.0, all codes and guidelines have entered into force, and ENTSO-E is now focused on their implementation and monitoring.

What is ENTSO-E's role in the implementation?

The implementation of European legislation occurs on national, regional and pan-European levels, frequently in combination. TSOs, DSOs, market participants and regulators at the EU, regional and national levels are also involved in various ways. In some cases, Network Codes, Guidelines or primary legislation define clear and detailed roles for specific bodies or entities; while in others, legal provisions are less detailed and require an additional layer of text to define roles and processes.

Implementation responsibility in network codes and guidelines

Task attributed to …	Responsibility	Approval[1]
ENTSO-E	ENTSO-E tasks	ACER
Pan-European "All TSOs"[2]	All TSOs	ACER
Regional "All TSOs"[2]	TSOs in the region	NRAs in the region. ACER makes the final decision if NRAs cannot agree[3]
National	Depending on national legislation (TSO, DSO …) (ENTSO-E may provide supporting documents and guidance)	National NRAs

Table 3 – Entities responsible for pan-European, regional and national tasks

1 In accordance with the CEP provisions of Electricity Regulation 2019/943.

2 "All TSOs" refer to the TSOs of all EU countries (pan-European "All TSOs"), or the TSOs of a specific EU region (regional "All TSOs").

3 In accordance with Article 5(3) of ACER Regulation 2019/942.

Monitoring the implementation

ENTSO-E is responsible for monitoring the implementation of Network Codes and Guidelines as defined by the legal provisions of the latter. To fulfil this obligation, ENTSO-E adds to monitoring plans and publishes reports. It also collects data (termed 'lists of information') and designs and implements interfaces for data collection. Based on new provisions under Regulation (EU) 2019/943, ENTSO-E will further cooperate with the EU DSO Entity to monitor the implementation of Network Codes and Guidelines. These will be adopted pursuant to this Regulation and are relevant to the operation and planning of distribution grids and the coordinated operation of the transmission and distribution networks.

ENTSO-E and ACER have signed an agreement on data collection and provision to ACER. This agreement is currently being used to monitor the Capacity Allocation and Congestion Management (CACM) and should then be extended to other Network Codes and Guidelines. The Annex 3 of the Agreement has been signed by ENTSO-E and ACER. The Annex 3 focuses on the EB Regulation and has an implementation date of 15 February 2026. Data items on the Annex 3 will be reported to ACER on a monthly basis from the implementation date.

Appendix 3

Resources

Budget

ENTSO-E AISBL[4] is a not-for-profit organisation under Belgian law.

ENTSO-E's budget is covered by membership fees as well as other revenues and incomes. For 2024, the budget of ENTSO-E totalled EUR 71.6 million, funded by TSO membership fees for EUR 48.1 million and other revenues for EUR 23.5 million (H2020 grants and additional TSO funding).

Staff

Our human resources include permanent staff and secondment from TSOs. This is in addition to the numerous TSO staff members who bring their expertise to the Association via its numerous bodies (Assembly, Board, Committees and subgroups).

On 31 December 2024, ENTSO-E counted 164 employees.

4 International not-for-profit association (Association internationale sans but lucratif)

Appendix 4

Cooperation with UK TSOs

On 31 December 2020, the United Kingdom (UK) officially left the European Union (EU) with a Trade and Cooperation Agreement (TCA) signed on the same date.

The TCA foresees that:

- ENTSO-E and the UK TSOs shall prepare under the guidance of the Specialised Committee on Energy a framework for cooperation not involving, or conferring a status comparable to, membership in ENTSO-E by UK TSOs; and
- EU and UK TSOs shall prepare technical procedures once requested by the Specialised Committee on Energy.

For designing the framework for cooperation foreseen by the TCA, ENTSO-E and the UK TSOs have adopted the Working Arrangements (the WAs). The WAs provide for a dedicated cooperation platform – the Working Arrangements Coordination Meetings (WAC Meetings) – that allows both sides to address key shared priorities, including security of electricity infrastructure, expanding clean offshore energy planning like the North Sea Grid planning, and enhancing the efficient use of electricity interconnectors between the UK and Continental Europe. The WAs have been signed by both the UK TSOs and ENTSO-E and entered into effect on 2 July 2025.

Following Recommendation No. 1/2024 of 19 December 2024 issued by the Specialised Committee on Energy (SCE)1, the UK TSO's and ENTSO-E were tasked to provide a joint answer on a set of technical questions on Multi-Regional Loose Volume Coupling (MRLVC), the trading arrangement introduced by the Trade and Cooperation Agreement (TCA) between UK and EU. In particular, following the UK's Withdrawal from the EU (and consequently the Internal Energy Market), Article 312 of the TCA establishes the need for the SCE to implement a specific model to trade over EU-UK interconnectors. Annex 29 of the TCA, designates MRLVC as the market coupling arrangements to be implemented. During 2025 This report builds on previous work that was mandated by the SCE, that is a Cost Benefit Analysis (CBA) published in 20212 and a first set of answers to technical questions published in 20233 in response to the SCE Recommendation No. 1/2023 of 7 February 2023.

This report addresses the questions raised in Recommendation No. 1/2024 of the SCE. It is the result of joint work of UK TSOs and those European TSOs directly connected to the UK, with review and approval by all EU TSOs.

Abbreviations

Abbreviation	Definition
AC	Allocation Constraints
ACER	Agency for the Cooperation of Energy Regulators
aFRR	Automatic Frequency Restoration Reserves
AHC	Advanced Hybrid Coupling
AI	Artificial Intelligence
AISBL	Association Internationale Sans But Lucratif (International Not-For-Profit Association)
ALFC	Annual Load-Frequency Control
BRELL	Belarus-Russia-Estonia-Latvia-Lithuania
BSA	Border-Specific Annexes
BZR	Bidding Zones Review
CACM	Capacity Allocation and Congestion Management
CBA	Cost–Benefit Analysis
CCC	Coordinated Capacity Calculation
CCR	Capacity Calculation Region
CE	Continental Europe
CEP	Clean Energy Package
CfDs	Contracts for Difference
CGM	Common Grid Model
CGMES	Common Grid Model Exchange Standard
CID	Congestion Income Distribution
CM	Capacity Management
CMs	Capacity Mechanisms
CRDS	Congestion Revenue Distribution System
CSA	Coordinated Security Analysis
CSAM	Methodology for Coordinating Operational Security Analysis
DA	Day Ahead

Abbreviation	Definition
DESAP	Digitalisation of Energy Action Plan
DSO	Distribution System Operator
EAS	ENTSO-E Awareness System
EB GL	Electricity Balancing Guideline
EB	Electricity Balancing Regulation
ECII	Electricity Cybersecurity Impact Index
EE	East Europe
EMD	Electricity Market Design
EnC TF	Energy Community Task Force
ENTSOG	European Network of Transmission System Operators for Gas
ERAA	European Resource Adequacy Assessment
ETIP SNET	European Technology and Innovation Platform Smart on Networks for Energy Transition
EU	European Union
FCA	Forward Capacity Allocation
GL	Guideline
HAR	Harmonised Allocation Rules
HVDC	High Voltage Direct Current
IDA	Intraday Auctions
ICS	Incident Classification Scale
ICT	Information and Communication Technology
ID	Intraday
ICS	Incident Classification Scale
IGCC	International Grid Control Cooperation
IGM	Individual Grid Model
IMM	Interoperability Maturity Model
ISMS	Information Security Management System

Abbreviation	Definition
IT–ME	Italy–Montenegro
ITC	Inter Transmission System Operator Compensation
JAO	Joint Allocation Office
LLFD	Long-Lasting Frequency Deviations
LT	Long-Term
LT-FBA	Long-Term Flow-Based Allocation
LTTR	Long-Term Transmission Rights
mFRR	manual Frequency Restoration Reserves
MRLVC	Multi-Region Loose Volume Coupling
MTU	market time unit
NCCS	Network Code on Cybersecurity
NC ER	Network Code on Electricity Emergency and Restoration
NC DR	Network Code on Demand Response
NEMO	Nominated Electricity Market Operator
NRA	National Regulatory Authorities
OBZs	Offshore Bidding Zones
ONDP	Offshore Network Development Plan
OPC	Outage Planning Coordination
OPDE	Operational Planning Data Environment
OWFs	Offshore Wind Farms
PMU	Phasor Measurement Unit
PRA	Probabilistic Risk Assessment
RCC	Regional Coordination Centre
RGCE	Regional Group Continental Europe
RDI	Research, Development and Innovation
RoCoF	Rate of Change of Frequency
RPR	Risk Preparedness Regulation
RR	Replacement Reserves
SA	Synchronous Area
SAFA	Synchronous Area Framework Agreement

Abbreviation	Definition
SAMs	Synchronous Area Monitors
SAP	Single Allocation Platform
SCADA	Supervisory Control and Data Acquisition
SDAC	Single Day-Ahead Coupling
SEC	Scheduled Exchanges Calculation
SET	Strategic Energy Technology
SEE	South-East Europe
SIDC	Single Intraday Coupling
SLA	Service-Level Agreement
SOC	System Operation Committee
SOGL	System Operation Guideline
SOR	System Operation Region
SRG	Scenarios Stakeholder Reference Group
SSDLC	Secure Software Development Lifecycle
STA	Short-Term Adequacy
TCA	Trade and Cooperation Agreement
TCMs	Terms, Conditions and Methodologies
TERRE	Trans-European Replacement Reserves Exchange
TSO	Transmission System Operator
TYNDP	Ten-Year Network Development Plan
UK	United Kingdom
WAMS	Wide Area Monitoring System

Publisher

ENTSO-E aisbl
8 Rue de Spa | 1000 Brussels | Belgium
www.entsoe.eu | info@ entsoe.eu

Design

DreiDreizehn GmbH, Berlin | www.313.de

Images

iStockphoto.com: Cover, p. 6, 10, 18, 22, 24, 37 (top), 40 (bottom), 43, 44, 47, 50, 56, 59, 64, 68. deRibaucourt: p. 14–17. François Genon: p. 15 (top left), TenneT: p. 37 (bottom), RTE: p. 40 (top). fingrid: p. 61.

Publishing date

September 2025

European Network of
Transmission System Operators
for Electricity

entsoe