Vision on Market Design and System Operation towards 2030

European Network of
Transmission System Operators
for Electricity

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Executive summary

In 2017, ENTSO-E decided to investigate what are the forthcoming challenges and opportunities for the electricity system from an operational and market perspective in two projects: One System Vision and Market Design 2030. This document brings together their findings and aims at starting a discussion with stakeholders on forward-looking solutions that can facilitate European society's goal of a secure, clean and affordable energy future.

ENTSO-E welcomes the Clean Energy Package as an important step in this direction and proposes a complementary, longer-term vision which entails the following key messages:

1. The Clean Energy Package is an important milestone for Europe's green energy transition. Its timely implementation is the priority for ENTSO-E and TSOs;

2. Europe's energy sector is shifting from a fossil fuel dominated and supply-centric model to a clean, digitalised and electrified consumer centric system with many distributed resources. ENTSO-E's Vision aims to contribute to this overarching goal;

3. Future system operations will rely upon a system of systems that should work as one. They will ensure seamless integration of growing shares of decentralised resources and power electronics. They will allow for alignment with needs of all grid connected assets and be further coupled with other sectors. Innovation and cooperation will be key enablers;

4. Different but interoperable market design features could be incorporated in the current target model to allow Europe as a whole to meet the 2030 challenges, which vary across countries and market timeframes;

5. To work as one, a system of systems should build on a multilevel architecture that articulates different geographical scales and functional layers through multilateral interfaces that are interoperable with each other;

6. The governance of this pan-European system of systems will involve multiple stakeholders. In this context, TSOs will play a key facilitation role, together with DSOs, supported by RCCs, and in dialogue with stakeholders.

Major trends reshaping the power sector

The European electricity system undergoes significant changes driven by a strong climate action agenda and related development of renewable energies. These changes take place at unprecedented speed and add further complexity to system operation and electricity markets, while also offering new opportunities.

New political framework and targets

2019 could well be a landmark for climate action with civil society movements and international reports[1] fuelling a new sense of urgency to reduce global greenhouse gases emissions. This is now reflected in public discourse as **'climate crisis'** instead of 'climate change'.

The European Union (EU) has taken a leading role in the energy transition. The European Commission has proposed in 2018 a long-term strategy to achieve **climate neutrality by 2050**. Most Member States now support this objective in the run-up to the next United Nations' Climate Change Conference. The new president of the European Commission, Ursula van der Leyen, has even proposed to increase the 2030 greenhouse gas (GHG) reduction target up to 55 %, compared to the currently agreed 40 %.

The **Clean Energy for All Europeans Package** (CEP) is an important stepping stone towards a decarbonised energy system. It sets ambitious targets for 2030 related to energy efficiency (32.5 %) and renewable energy sources (32 %). The latter translates in a 57 %[2] share of renewables in the power sector provided that **National Energy and Climate Plans** will be living up to this objective. A revision clause in 2023 could further increase these targets if it is needed to meet the EU's interntional commitments for decarbonisation.

The CEP also introduces new rules and institutional arrangements to address coordination needs in an increasingly complex power system. Coordination between TSOs at regional, synchronous area and pan-EU level has historically been developed in a proactive and successful way by TSOs. The establishment of **Regional Coordination Centres** (RCC) will enhance its effectiveness and extend its scope. In parallel, the creation of an **EU DSO entity** will strengthen coordination between TSOs and DSOs to integrate large shares of distributed energy resources.

The Clean Energy Package is an important milestone for Europe's green energy transition. Its timely implementation is the priority for ENTSO-E and TSOs.

Underlying assumptions and trends

This Vision builds on scenarios co-developed with stakeholders under the **Ten-Year Network Development Plan 2018**[3] (TYNDP). All figures mentioned hereafter are based on 2030 assumptions for the Distributed Generation scenario but all scenarios point to the same fundamental trends.

The advent of renewables is central in all underlying scenarios. Wind and solar energy will play a major role in the system by the end of the next decade with a total installed capacity of almost 500 GW for solar PV and more than 300 GW for onshore and offshore wind. Therefore, electricity flows are expected to increase and becoming more variable, requiring network development and efficient congestion management. Also, in most countries, the largest share

1 Intergovernmental Panel on Climate Change (IPPC), Special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, 2019. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), Global assessment report on biodiversity and ecosystem services, 2019

2 Agora Energiewende, European Energy Transition 2030: The Big Picture, 2019

3 2018 scenarios do not include the new targets in the Clean Energy Package as they were finalised beforehand. TYNDP 2020 scenarios will address this.

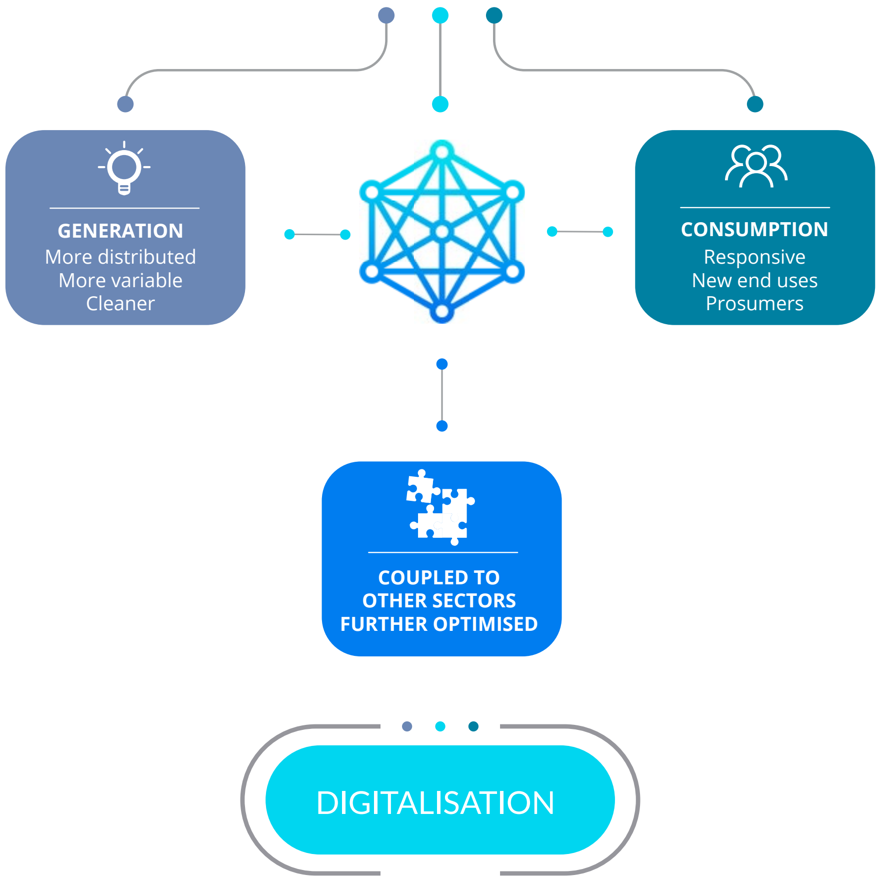

Figure 1: Major trends in the power system

of new renewable installations will be connected to the distribution network[4] which stresses the need for a proper coordination between TSOs and DSOs to integrate these resources in efficient and safe conditions.

Higher renewables' penetration and underlying decrease of carbon intensity of power generation goes along with further **electrification** of applications in industry, transport, and heating and cooling. Electricity demand will increase by almost 20 %[5] compared to 2018 driven by the market uptake of technologies such as electric vehicles and heat pumps, and in spite of huge increase in energy efficiency.

These developments will lead to an increased **decentralisation** of energy resources. Residential consumers will become more active in the market, for instance as 'prosumers' or via aggregators. Innovative business models such as local energy communities will develop and the large-scale deployment of smart meters, connected devices and battery storage[6] will magnify this trend, making coordination between system operators crucial e.g. for exchange of grid and system services.

Digitalisation will help to unleash the potential of distributed flexibilities. The electricity system evolves towards a cyber-physical system where the development of an Information and Communication Technologies layer will enhance physical grid utilisation and provide an architecture that can manage the complexity of a system integrating different geographical scales, functional processes and technologies[7]. This 'Digital Grid' already translates today into pan-EU IT platforms that foster coordination between TSOs.

Sector coupling of end-use sectors and supply networks via the conversion of electricity in other energy carriers and vice-versa[8] could also provide flexibility to the electricity system on a large scale and at different timeframes. For instance, vehicle-to-grid solutions can deliver peak shaving or frequency support within hours, minutes or seconds, while district heating networks equipped with electric boilers or heat pumps can offer storage capacity to convert wind energy into heat when demand is low.

A recent survey of 26 CEOs of European TSOs confirms that most of these trends are critical uncertainties and action priorities for their companies[9].

Europe's energy sector is shifting from a fossil fuel dominated and supply-centric model to a clean, digitalised and electrified consumer centric system with many distributed resources. ENTSO-E's Vision aims to contribute to this overarching goal.

4 50 % of average of total installed renewables capacity in 16 countries of Continental Europe expected in 2030.
5 Many third-party studies foresee a sharp increase of electrification towards 2050: 53 % for the European Commission (A Clean Planet for all, 2018), 60 % for Eurelectric (Decarbonisation pathways for the European economy, 2018)
6 DG scenario shows that in 2030 battery storage capacity (utility scale) is expected to reach almost 18 GW in Continental Europe.
7 For more details, you can refer to ENTSO-E, Cyberphysical grid, 2019
8 e.g. power-to-gas, power-to-heat, power-to-hydrogen
9 World Energy Issues Monitor – Europe – TSO, World Energy Council, 2019

Reconcile markets and physics

Today's current market design in Europe has been successful in enabling a vast increase of electricity exchanges across countries, stimulating competition and increasing liquidity in wholesale markets. However, **several limitations** start to be visible for various reasons: increasing loop flows, increasing redispatching costs to relieve congestions in the grid, limited information available on the electricity system flexibility and increasing investment uncertainty to ensure resource adequacy.

In addition, following structural trends will impact on the way the power system operates:

- **Massive technology changes** induce the deployment of new energy resources that will complexify system operation;
- **The roles in the system are evolving**, requiring the development of new rules to unleash the value they offer to the system, in particular active consumers;
- **The speed of upgrading the network is slower than necessary**. For instance, it may not always match the pace of renewables development.

These aspects are closely intertwined. The aforementioned limitations will exarbate towards 2030 unless efficient and secure system operation can rely on adequate market design that properly accounts for system physics and relevant technical constraints.

A comprehensive view on future system operation

The evolution of the electricity system presents challenges as well as opportunities for system operation. The organisation model suited to adapt to these changes is a system of systems that work as one (see part 3). The following major drivers for future system operation were identified.

A high amount of the resources needed to operate the system are expected to be connected to distribution networks: generation, storage, smart grids and prosumers. Unlocking these **'distributed flexibilities'** will require new operational tools and processes to improve their forecasting and visibility. It will also imply the development of new products in dialogue with market players as well as coordinated market processes and related data exchanges between various stakeholders. This will ensure an optimal use of these flexibilities for trading as well as for fulfilling grid and system needs.

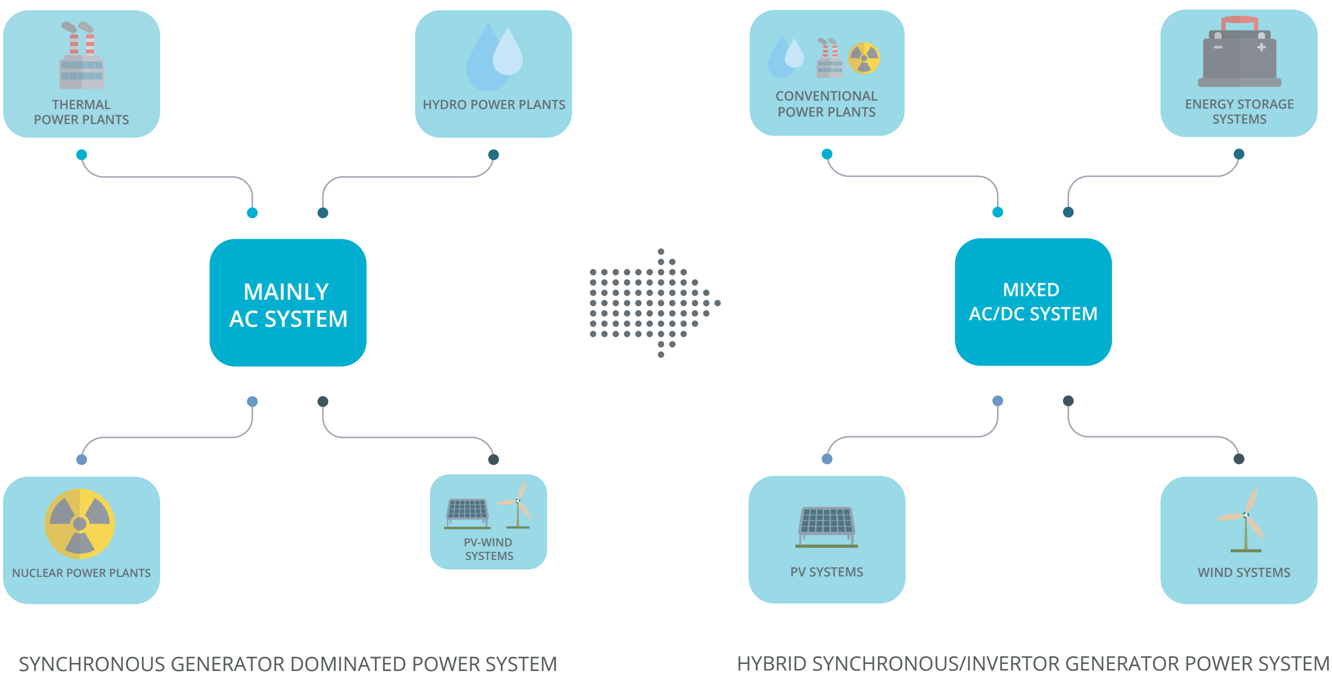

Figure 2: Transition towards a mixed AC/DC system

Furthermore, the European network was designed to operate in alternating current (AC) but it will have to accommodate an increasing part of resources and appliances using direct current (DC). These require **power electronics** to convert and control the electricity flow. For instance, power inverters transform energy produced by PV panels and wind turbines from DC to AC to feed into the grid at a constant frequency despite variable solar and wind conditions. Converters are also used to convert electrical energy from high voltage alternating current to high-voltage direct current (HVDC), or vice versa, to transport electricity subsea or over long distances with minimal losses. Integrating these solutions into the system goes along with technological and operational challenges, requiring close coordination with relevant stakeholders.

Bringing markets and physics closer together is a third driver, as the gap between market outcomes and the physical reality of the grid is widening. To bridge this gap and maintain security of supply, the main requirements for system operation are:

- Ensuring availability of resources and their technical capability for system operation before real-time and after a contingency;
- Efficient grid operation, including the ability to use cost-efficient measures to the largest extent possible;
- Access to flexibilities at distribution level in coordination with Distribution System Operators (DSOs).

Responding to a more dynamic and complex system, operational processes and tools will evolve to face new **operational challenges**: preventing and managing threats in a context of greater dependency on cooperation with other parties and neighbours for management of those risks[10], complex forecasting and integration of possible automation and decision support technologies (digitalisation). This evolution will be even more needed as the political drive for an integrated approach across energy sectors, so-called **sector coupling**, becomes stronger.

Future system operations will rely upon a system of systems that should work as one. They will ensure seamless integration of growing shares of decentralised resources and power electronics. They will allow for alignment with needs of all grid connected assets and be further coupled with other sectors. Innovation and cooperation will be key enablers.

10 A non-exhaustive list of which: natural hazards, cyber-attacks, terrorism etc.

Seamless integration of fit-for-purpose market design solutions

TSOs are committed to **complete an efficient and well-functioning Internal Energy Market** (IEM), where efficient trade across borders is a key feature that benefits all European consumers. The full implementation of the IEM and related Target Model is therefore the priority. But, as mentioned previously, the aforementioned drivers challenge today's market design.

ENTSO-E started to identify and analyse **several options for long-term evolution of market designs**, ranging from evolutionary solutions to models requiring more fundamental changes (including innovative "hybrid" options). The aim was to look beyond existing design and planned implementation of CEP requirements to further improve market design in light of challenges emerging towards 2030 and beyond.

These market design options pursue the same goals: supporting system security, market efficiency, reliability and adequacy, while delivering adequate price signals and trading possibilities for all market players, including consumers, on all geographical scales as well as in all timeframes.

The market design options explored can vary across a combination of different parameters (see figure 6 in Focus Paper Market Design for 2030 on page 17), while sharing **common fundamental principles**:

- a **better reflection of grid constraints** in market operation and resulting price signals;
- an **increasing importance of close-to-real-time markets** and of products with shorter duration and smaller size, enabling participation of consumers and of new actors; and
- a **closer coordination between TSOs and DSOs** to facilitate efficient and effective access to distributed flexibilities.

Based on our analysis, **ENTSO-E concludes that a radical market design change in the whole of Europe is neither necessary nor desirable**. Nevertheless, further improvements will be needed – at least in some market time-frames - to make markets fit for purpose in 2030 and beyond. As countries face different challenges and have different policy priorities, such market design improvements could be designed depending on the specific associated costs and implementation benefits (economic, social, environmental). **Some countries might thus consider more sophisticated market design solutions or specific features**, for instance with a higher degree of coordination between balancing and congestion management.

The introduction of any specific market design features should be preceded by thorough analysis and result from a close cooperation of policymakers, regulators and relevant stakeholders at both national and European level.

Whichever market design option is chosen, it should not only have benefits exceeding implementation costs, **but ensure that the integrated European electricity markets seamlessly work together**.

Fit-for-purpose market design solutions may be needed to further improve the current target model, allowing Europe as a whole to meet the 2030 challenges, which vary across countries and market timeframes. Any evolution should fully preserve the benefits of the internal energy market.

Towards a system of systems

Today's electricity system will shift towards a system of systems which points to an **adequate architecture of responsibilities on different geographical and functional levels** requiring an efficient interaction between the different stakeholders.

Different scales and layers of integration

The evolution of the electricity system will require at the same time:

– **Stronger cross-border cooperation to address the challenges that will be regional and pan-European in nature:**
  - › enhanced and optimised operational processes through shared rules and platforms,
  - › market designs closer to the physical reality of the grid,
  - › extended observability and forecasts of generation infeed, demand and congestions,
  - › prevention and management of threats that may span over several countries or globally,
  - › pan-European development of new grid technologies.

– **Stronger adaptation to local needs to live up to the promises of new technologies while achieving the same fundamental objectives:**
  - › integration of any flexibility service providers from small-scale to aggregation,
  - › introduction of locational signals and/or locational information in markets,
  - › consideration of local components in forecasting,
  - › integration of decision support technologies that adapt to local constraints.

Beyond geographical scales, the system of systems also contains **different functional layers**, which should interact with each other: physical grid, system operation processes,

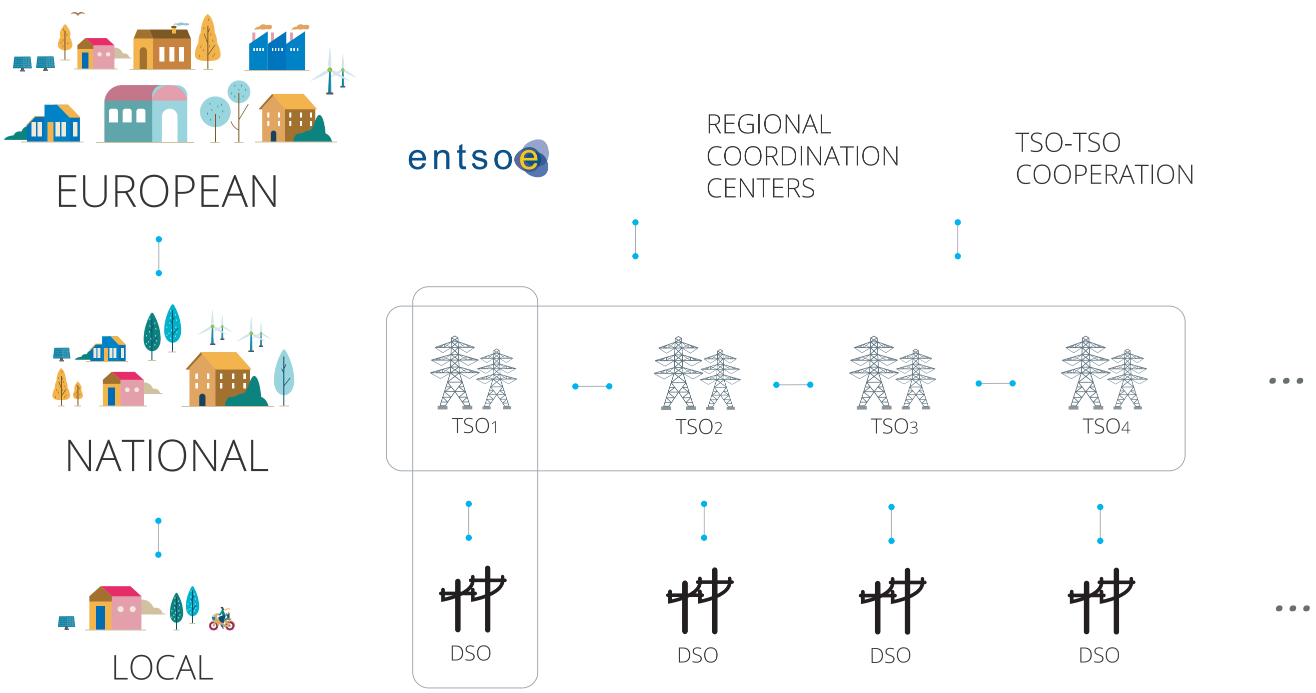

Figure 3: Different functional layers interacting with one another

market processes, interlinkages with other sectors and the digital layer. It implies a shift from bilateral to a **network of multilateral interfaces** that are coordinated with each other and connected to the digital layer on top of the physical infrastructure. This shift has already started today e.g. for market optimisation and operational coordination. Research, **innovation** and development, and therefore appropriate **incentives**, are needed to expand their development to new areas.

In such a multilevel architecture, **interoperability** is key. Common format and standardised rules to exchange data will ensure that diverse mechanisms work together, on different scales, different timeframes and different sectors. Transparency and dialogue on operational rules for the different processes are fundamental prerequisites to ensure proper coordination and efficiency.

To work as one, a system of systems should build on a multilevel architecture that articulates different geographical scales and functional layers through multilateral interfaces that are interoperable with each other.

The role of TSOs in a collaborative governance

The realisation of this Vision requires intense and trustful dialogue with all the stakeholders of the energy sector, **each one having defined roles and responsibilities**: TSOs, DSOs, regulators, policymakers, market players including energy service providers, technology providers, platform operators including power exchanges, and – with increasing importance – stakeholders from coupled sectors.

In this system of systems, **TSOs will strengthen their facilitation role**. They will enable the functioning and interoperability of this complex architecture as to ensure secure operation based on economic efficiency and market mechanisms. Within this role, ENTSO-E and all European TSOs commit to:

- Support and deliver the means for increased cross-border integration through multilateral cooperation within the Regional Coordination Centres and ENTSO-E;
- Enhance the articulation of the local, national and European needs, in close partnership with DSOs, with the aim to contribute to the Internal Energy Market, while ensuring secure and efficient operation;
- Develop knowledge and transparency on the electricity system through their local footprint and close relationships with institutions, system users, shareholders and the public at large.

The governance of this pan-European system of systems will involve multiple stakeholders. In this context, TSOs will play a key facilitation role, together with Distribution System Operators, supported by Regional Coordination Centres, and in dialogue with stakeholders.

Focus paper – One System Vision for 2030

Background

Operating the European power system is the core responsibility and mission of Transmission System Operators (TSOs). This mission is fulfilled by each TSO in its geographical responsibility area, and all TSOs together for the whole European Power System, through common rules described in the network codes and the system operation guidelines, which are developed through TSOs' common association ENTSO-E.

System Operation in Europe has been a clear success: together TSOs have managed to facilitate the creation of the common market for electricity, while maintaining a very high level of security of supply. There have been a number of challenges and drawbacks along the way, but TSOs have succeeded in finding common solutions that are efficient and consistent. One of the best examples of this approach has been the creation of the Regional Security Coordinators (RSCs): a proposal by the TSO community to better coordinate system operation between countries, put in place voluntarily and subsequently integrated into EU regulations – becoming Regional Coordination Centres after the Clean Energy Package.

Within this background, ENTSO-E has worked with its member TSOs to develop their vision on the future of the European Power System, and this document is a summary of the result of this work.

One System Vision for the year 2030

In this analysis, main drivers and evolutions expected to impact system operation for the next 10 years are identified.

Assumptions and data that form the basis of this vision stem from the scenarios and forecasts used to build our Ten Years Network Development Plan (TYNDP), as well as expert inputs from the TSO community. There are two main trends that arise clearly from this analysis:

1. The continued and significant growth of decentralised resources (generation, storage, etc.) that will be connected to distribution networks. In average terms it can be assumed that at least 50 % of all new RES will be connected to distribution networks, and for instance the 2030 expected amount of distribution network connected battery storage will approach 20 GW for Continental Europe alone.

2. The growing share of direct current generation and transmission: the ratio of non-synchronous (power electronics) generation to total generation in 2030 will vary from 25 % for the Nordic area to around 50 % for Continental Europe, the Baltic area, Great Britain and Ireland.

Following these trends, the first clear driver for the ENTSO-E electricity system operation vision is the efficient use of **Distributed flexibilities**, as it is clear that in the future a significant part of the means to operate the system will be located in the distribution networks. Taking also into account the **need to integrate new distributed resources in a non-discriminatory, secure and efficient way**, ENTSO-E proposes mechanisms for accessing flexibility services through shared market mechanisms and a strong cooperation between TSOs and DSOs. The main areas covered by this vision are congestion management and its link with balancing, mainly based on the common TSO-DSO report on Active System Management[11], with also a short analysis of voltage control, stability and inertia.

Distributed resources raise challenges to the grid and system, but they can also provide new services to the system operators: this will be part of the solution. Needs from system operation and grid management should be identified and shared with stakeholders. Then, flexibility products can be defined and valued, and rules to access these services can be developed, just as it has been done for balancing services. Cooperation between TSO and DSO is key in the process, as the same resource could be used by both actors. The impact of using a resource for one or the other purpose

11 https://www.entsoe.eu/news/2019/04/16/a-toolbox-for-tsos-and-dsos-to-make-use-of-new-system-and-grid-services/

should be taken into account, with different implementation solutions from simple coordination to full integration of different market processes. Demand side response through aggregator services and customer participation should be properly considered.

The vision for 2030 should ensure that any market participant can support the energy transition regardless of its location in the grid and in the electricity value chain: a co-operation between TSOs and DSOs to allow any flexibility provider to value its contribution in One System, integrating different scales and actors.

A second clear driver is **Power Electronics**. The large penetration of power electronic interfaced distributed generation and high voltage direct current transmission systems will result in a hybrid AC-DC power system. Such a transition in the generation mix will have a significant impact on the interconnected European system dynamic profile and eventually on how the electrical network will be operated in the future. Indeed, the transition from a power system based on conventional synchronous generators to one with Power Electronics raises different challenges related to system dynamics, for example like the decrease of system inertia, the reduced short circuit contributions from these new generators and the emergence of new types of interaction phenomena (i.e. control interactions). Coping with all the challenges, innovation, research and development in the electrical energy business is identified as a crucial step. Indeed, HVDC systems could enhance the AC transmission system performance, transforming it to an AC-DC transmission system which exhibits enhanced controllability, flexibility and resilience. TSOs propose a roadmap towards the successful realisation of such a system, focusing on system stability, observability and controllability, and integration of technology solutions in meshed HVDC systems. The common understanding of roles, the development of new technologies, the assurance of system interoperability, the common analysis tools, harmonised standards and procedures are key factors for successful realisation of future AC-DC networks. To achieve these goals, TSOs will especially need to strengthen their technical cooperation with power generators and HVDC manufacturers.

ENTSO-E's vision for the future is 'One System', where integration of AC and DC components will be achieved, supporting safe and efficient operation.

A third driver for the future of the electricity system will be the need to bring **Markets and Physics** closer together. Today's market design in Europe has been clearly successful and has brought a vast increase of electricity exchanges between countries, but it is also starting to show a number of limitations as the gap between the market mechanisms and the physical reality has become significant. An analysis of potential design options to improve today's market models is carried out in the paper "Focus: Market Design 2030". This analysis has concluded on a number of recommendations, which take into account the different local specificities.

Bringing the market mechanisms closer to the physical reality of the network is indeed a key condition for efficiency and social welfare. Hence, bridging the gap and integrating improved market designs with an operational perspective should be the key priorities for the next decade. Besides, seamless coexistence between the different market models inside the Electricity Union is of utmost importance.

ENTSO-E's vision for the future is One System, with strong integration between market mechanisms and the physical operation of the network.

A fourth driver is **Sector Coupling**: the integrated approach by all sectors (electricity, gas, heat, transport and industry) to use energy in a sector being generated in another sector, with an overall increase in efficiency. In Europe, there is a strong political drive towards coupling sectors, where technologies like power to X – X being gas, heat, transport, or products – are coming into play. Electricity and gas are both complementary in the form of flexibility exchange, as well as dependent in terms of black start capabilities.

In the figure 4 the electricity sector is linked to all other energy sectors. Further expansion is possible and TSOs could fulfil the role of systems integrators, obviously sufficiently liaising with all relevant stakeholders. ENTSO-E's vision for the future is One System of Systems, where we will need to reach out beyond the power network.

Finally, the vision also encompasses **Further Operational Challenges**: important drivers of the future that are not dealt with in the previous parts of the vision. They are clustered into three main areas:

1. Managing and coping with threats to the power system
2. Automation and decision support
3. Complex forecasting

These three areas do not cover all the challenges TSOs will face in the future, but they are considered as the most important drivers and TSOs have a clear plan to meet the challenges through innovation and cooperation, in One System.

ENTSO-E's vision for the future operation of the power system can thus be graphically represented as shown in figure 5.

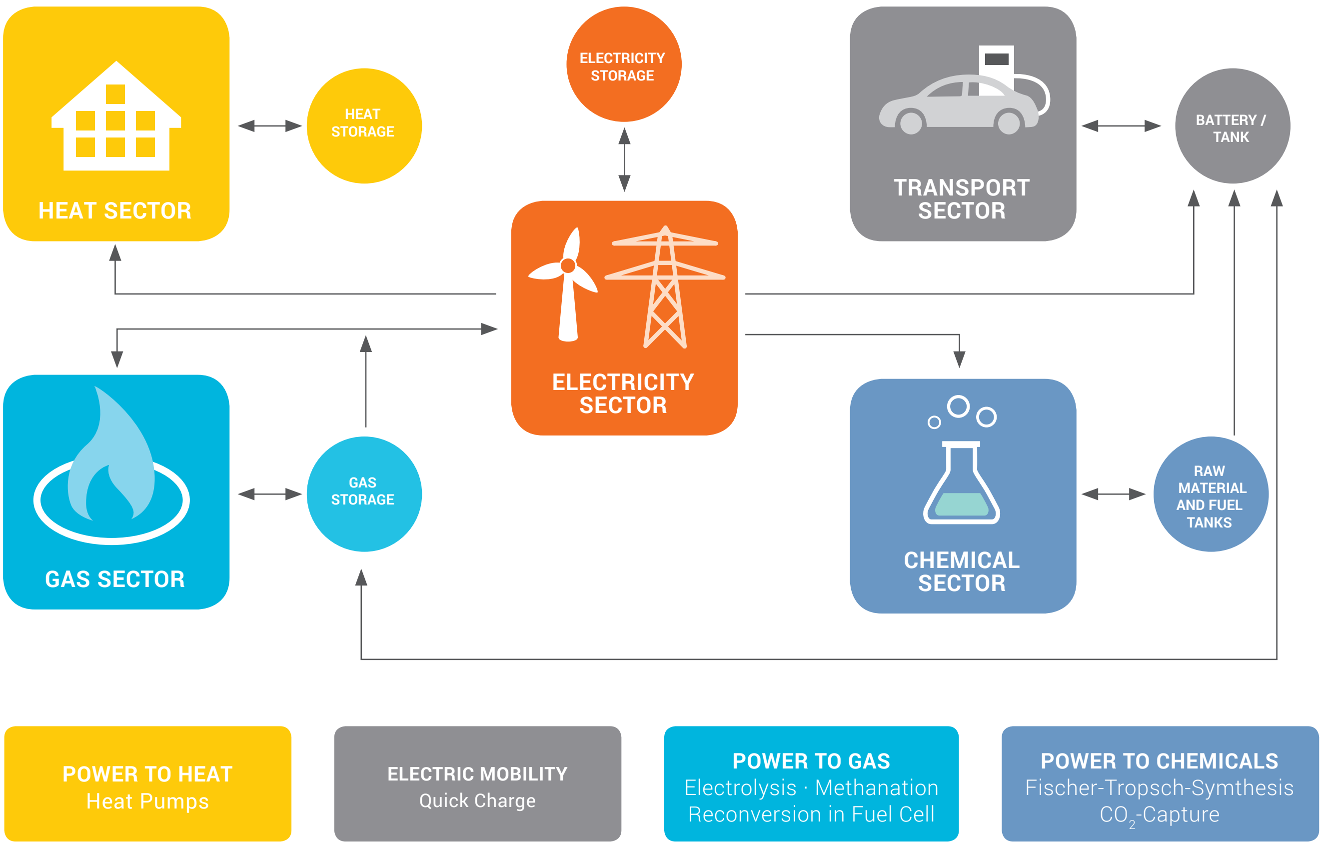

Figure 4: An illustration of sector coupling

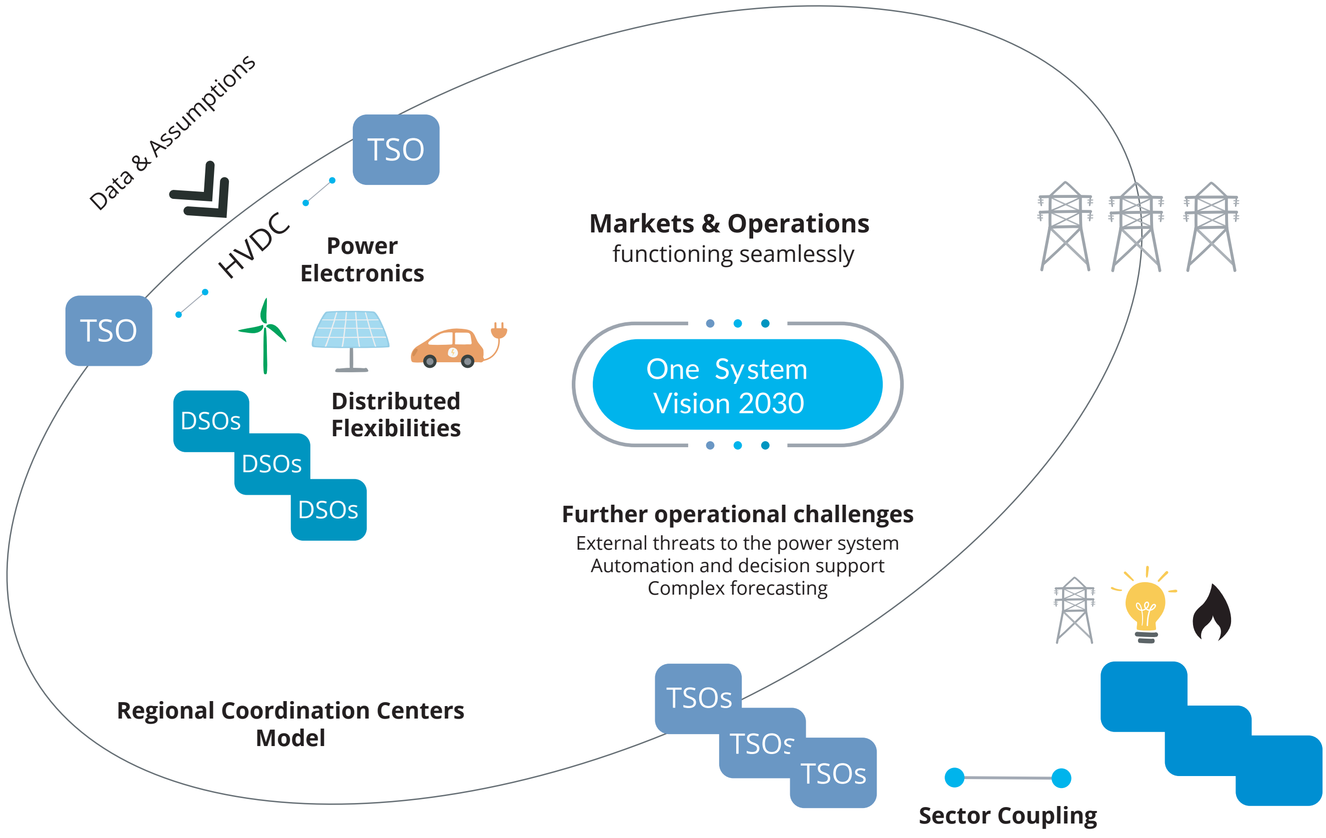

Figure 5: ENTSO-E's one system vision 2030

One System, Regional Cooperation and Local Diversity

The One System Vision shows that the drivers for the future will need at the same time stronger cross-border cooperation and stronger adaptation to local needs and constraints:

- **The system of the future will need stronger cross-border cooperation.** This is shown in our vision with the new market models that will be closer to the physical reality requiring closer operational coordination, to meet the challenges of managing threats that may span different countries, combining our resources to develop solutions for a system with high level of power electronics, and the need to include multiple countries in our forecasting.

- **The system of the future will need stronger adaptation to local needs.** This is mostly shown in our vision by the need for shared access to distributed flexibilities. This will depend on the network, institutional and economic realities of each country, with the drive for automation and decision support that will need to adapt to local constraints, culture and realities, as well as the power electronics solutions and forecasting that will have a strong localised component.

- Within this context that will be at the same time more European and more local, TSOs will be particularly well situated, as we have at the same time:

- The tools and means for increased cross-border cooperation through Regional Coordination Centres with the full range of services that they will provide, as well as with the help of our common association ENTSO-E.

- The in-depth knowledge of local constraints, through our own local footprint and close relationships with institutions, customers, shareholders and the public at large, and through our partnerships with Distribution System Operators.

In conclusion, the organisational model suited to adapt to the main drivers for the next 10 years will be:

One Power System

- For the benefit of all Europeans
- Facilitated by Transmission System Operators
- Together with Distribution System Operators
- Assisted by Regional Coordination Centres
- In Dialogue with Relevant Stakeholders

Focus paper – Market Design Vision for 2030

Introduction

ENTSO-E is fully committed to complete the implementation of the 3rd package and of the newly entered into force Clean Energy Package (CEP). We believe the CEP will accelerate the integration of European markets and further increase regional cooperation of TSOs, thereby bringing additional benefits to European consumers. Exposing more RES to wholesale price signals and facilitating participation of consumers and storage resources to all electricity markets will further improve liquidity and market efficiency.

A successful implementation of CEP requires strong contribution from TSOs, the most challenging task being to deliver increasing transmission capacity for allowing market parties to trade within and across bidding zones, while at the same time ensuring an efficient and secure system operation at all times. In order to achieve this, TSOs need to manage increasing uncertainties and complexity in shorter periods before real-time.

There is no shortage of challenges lying ahead, both during CEP implementation and beyond. Decarbonisation, digitalisation and greater decentralisation will transform the power system. Anticipating such longer-term challenges, **ENTSO-E started assessing options for further improvements to the market design in the 2030 horizon and beyond**, in particular focusing on better alignment of market operation to power system operation, as well as on better coordination of congestion management and balancing across the EU.

ENTSO-E is convinced that **the main efforts should focus on the implementation of Network Codes and of the Clean Energy Package**. At the same time, the profound changes in the way electricity is generated and consumed, as well as the foreseen developments of European power systems will trigger a debate on an enhanced market design for the 2030 time horizon.

ENTSO-E has focussed in particular on how short-term markets could ensure an efficient management of an increasing amount of congestions to cope with increasing and more volatile electricity flows, in the ultimate interests of consumers and all market parties. While this is only one of the many market design challenges, ENTSO-E believes that efficiently using the scarce transmission resources is a key one, where the TSOs play a fundamental role as market facilitators.

In addition to continued development of the grid infrastructure, so critical for efficiently accommodating variable and low carbon generation, our analysis shows that for Europe as a whole, several market design solutions exist, with various degrees of suitability for different market situations. Some of them could be integrated as evolutions of the current target market model with minimal implementation efforts, while others would require more fundamental changes with longer transitions. In any case, further in-depth analysis and discussions with stakeholders will be needed.

Improving markets to meet the 2030 challenges

Ongoing transformation of the power system, in particular increasing variable and unpredictable flows on all voltage levels, will require stepwise improvements of current models on both system operation and market design. In the current European debate, it is already acknowledged that today's market design requires evolutions to efficiently meet the future challenges of the energy transition, as well as to accommodate new actors and new technologies. One such example is moving to shorter gate closure times paired with increasing intraday volumes traded shortly before real time.

These drivers require market design solutions that decrease the gap between market outcomes and the physical reality of the grid, so to ensure system security at all times in an efficient manner.

Against this background, ENTSO-E, representing 43 TSOs from 36 European countries, elaborated the market design vision for 2030 to address the identified challenges. This vision reflects the common views of ENTSO-E members on future market design, mainly focussed at **solutions for congestion management, and on how to most efficiently and securely reconcile the market outcome with the physi-**

cal system, for the ultimate benefit of all consumers. Other market design challenges, such as investment price signals and generation adequacy, or solutions through capacity mechanisms or further active power management at the TSO-DSO interface, are not discussed in this paper but are being addressed separately in other ENTSO-E work.

Addressing the challenges and reaping the opportunities provided by the ongoing power system transformation, such as emergence of new players, more renewable energy sources and more distributed generation, will require **further market design improvements in addition to those already under implementation**, as provided for by legal requirements of Network Codes and the CEP. Irrespective of the specific features to be implemented, market design solutions for 2030 and beyond will generally need to:

- **include stronger locational signals** to incentivise that the dispatching of generation, consumption and storage is more in line with system costs and grid constraints;
- **increase the locational visibility of resources (at all voltage levels)** for system operators in order to implement actions to solve congestions timely and efficiently.
- **enhance short-term markets to allow market participants to trade closer to real-time** and in shorter time intervals, while ensuring the required time and means for TSOs to operate the system securely;
- **facilitate effective system operation and enhance system flexibilities** to ensure an efficient use of the actual and future capabilities of the grid and of flexible resources.
- **ensure a closer coordination between TSOs and DSOs**, to ensure that power flows, congestions, data, and market interactions with assets and consumers at distribution level are managed efficiently and effectively with a "one system approach";
- **facilitate provision of new ancillary services, including non-frequency ancillary services**, in line with the CEP Directive principles.

Design Options

Several market design options were analysed to identify solutions able to ensure the above six points. Solutions were assessed across a number of different variables, focussing in particular on short-term markets and congestion management. For instance, solutions can range from models with very large zones, based on current zonal market design, to models where congestions are priced within the wholesale electricity market with a fine locational granularity, or with longer or shorter time granularity of energy products traded (as Market Time Units (MTU) and Imbalance Settlement Periods (ISP) are expected to shorten to reflect the increased variability of new generation resources). Some of the existing models around the world are configured based on features at one end of the spectrum of possi-

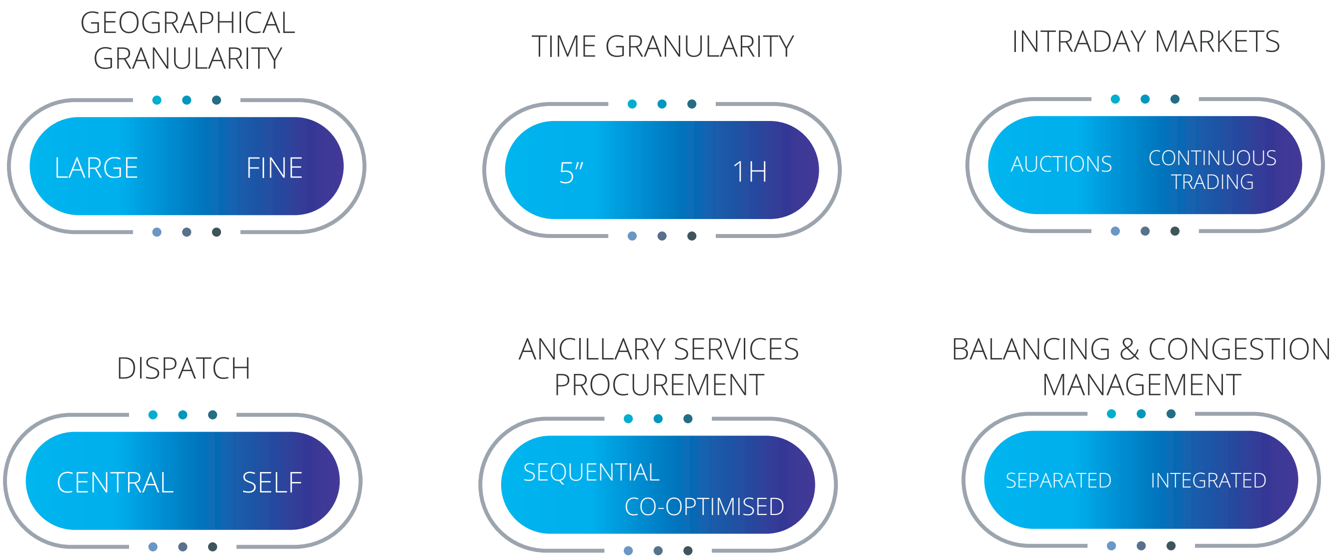

Figure 6: Examples of market design options[12] for short term markets and congestion management

12 Any solution for short-term market and congestion management should be part of a holistic market design addressing all 2030 challenges, such as investment price signals and system adequacy

ble solutions, while some are characterised by intermediate features between the 2 possible extremes (see Figure 1 below). Innovative hybrid models combining features of different existing models can also be identified, for instance by having finer geographical granularity in market timeframes closer to real-time or by introducing more degrees of flexibility in the zonal market coupling. Other important dimensions which may differentiate chosen solutions for market design, like time granularity or treatment of ancillary services, are presented on the picture below.

The analysis carried out by ENTSOE and the discussions conducted with business experts and academics leads to the conclusion, that at his point in time **ENTSO-E does not see a need for introducing new market design regulations**, especially considering the recent approval of the CEP and the entailed implementation tasks. Nevertheless, further improvements will be needed – at least in some market time-frames - to make markets fit for purpose in 2030 and beyond. One of the purposes of this paper is to contribute to the discussion about such future improvements.

As countries face different challenges and have different policy priorities, such market design improvements could be designed depending on the specific associated implementation costs and benefits (economic, social, environmental). For instance, in countries with significant congestions, some TSOs are experiencing significant challenges that are exposing limitations of their current market design, particularly in the way congestion management is treated. Such countries might thus consider more sophisticated market design solutions, with higher degree of coordination between balancing and congestion management. Therefore, **the future beyond 2030 where specific market design solutions efficiently coexist in Europe could be a realistic evolution** that deserves careful attention and further analysis.

It will however be of utmost necessity to ensure that such evolutions fully preserve the benefits of the Internal Energy Market. The main goal for Europe as a whole is to ensure an integrated and well-functioning Internal Energy Market (IEM), where efficient trade across bidding zones borders is a key feature. ENTSO-E is fully committed to realizing this goal and making sure that European consumers get maximum benefits from interconnected power system operation. There is no doubt that **regardless of the specific market design features implemented locally by particular countries, the integrated European markets must seamlessly work together**.

Recommendations

Although the Third Package, the Network Codes, and more recently the Clean Energy Package represent important steps forward for the transition to a low carbon electricity system with consumers at its centre, more challenges lie ahead to enable the full transition of the European power system. Considering the speed and complexity of this transition, the current market design may not be fully future-proof for 2030 and beyond, at least not in all market timeframes or in all European countries with their specific needs and challenges. The identified ways forward have different features and respond to different needs and priorities but they all share some fundamental general principles:

- Better reflection of grid constraints in market operation and resulting price signals;
- Increasing importance of close-to-real-time markets and products with shorter duration and smaller size, to adapt to decarbonisation, decentralisation and digitalisation, while enabling consumers' participation;
- Closer coordination between TSOs & DSOs to facilitate efficient and effective access to distributed flexibilities.

Our evaluation of different market design solutions clearly shows that no unique solution is optimal under all criteria: each has its own advantages and disadvantages. This leads to the following **recommendations**:

- To enable the transition to a low carbon electricity system with consumers at its centre **a radical market design change in the whole of Europe is neither necessary nor desirable** at this stage;
- The **overall goal must be to foster an efficient Internal European Market**, in line with the needs of European consumers and the capabilities of the European transmission and distribution grid, consistent with EU energy policy goals, and designed in close cooperation with relevant policymakers and stakeholders at national and European level.
- The **suitability of market design solutions may depend on national specificities** (market, operations, grid, etc.) and may be impacted by specific national energy and climate policies. As challenges and levels of congestion vary from country to country, different fit-for-purpose solutions may be needed. It will however be of utmost necessity to ensure that such evolutions fully preserve the benefits of the internal energy market.
- Any market design solution for short-term market and congestion management should be part of a **holistic market design addressing all facets of the 2030 challenges**, such as investment price signals and system adequacy, with the goal of a seamless European integration.

About ENTSO-E

ENTSO-E, the European Network of Transmission System Operators for Electricity, represents 43 electricity transmission system operators (TSOs) from 36 countries across Europe.

ENTSO-E was established in 2009 and was given legal mandates by the EU's Third Legislative Package for the Internal Energy Market, which aims to further liberalise the gas and electricity markets in the EU.

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