European Network of Transmission System Operators for Electricity

Power System Vision and Action Paper

22 August 2014

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1. Executive summary

The European energy policy induces responsibilities and roles for the different stakeholders involved in the power system, in order to achieve the energy targets in an efficient way. In this respect, ENTSO-E is in charge of a multifaceted work programme, contributing into many work streams with a diversity of stakeholders. To achieve them efficiently the needs of users must be anticipated and resulting changes to the power system, for its development and operation, over a variety of time horizons, from the short (1 up to 5 years), medium (5 up to 15 years) to long term (15+years) must be identified.

The paper aims at providing to the stakeholders a clear vision of the challenges that the European power system is likely to face in the future years. Additionally, it shows how ENTSO-E actions answer these challenges through work products and their interrelationships.

2. Introduction

Today, the electricity landscape is changing faster than ever before. The fight against climate change together with the achievement of a competitive Europe via the Internal Electricity Market (IEM) requires new rules, new technologies, and new ways of operating the power system. The recent global recession, the potential of shale gas, and energy security of supply, reinforces this need for a proactive and fast adaptation of the energy sector.

Closer cooperation among all players, be it generators, consumers, Distribution System Operators (DSOs), power exchanges, power suppliers or technology providers is key to the optimization of the overall system. Transmission System Operators (TSOs) manage the backbone of the electricity supply for the benefit of the society. The importance of this role has been widely recognized in the Third Energy Package of the EU.
ENTSO-E, as the association of European electricity TSOs with key legal mandates, is the body where TSOs are cooperating for the reliable operation, optimal management, well-functioning markets, system adequacy and sound technical evolution of the European electricity transmission system, going beyond the borders of the European Union.

ENTSO-E works closely with stakeholders to ensure a secure and reliable power supply for every electricity consumer, the ability for developers to connect their facilities to the grid, especially Renewable Energy Sources (RES), the non-discriminatory, transparent and cost effective functioning of the market for market parties, policy makers and regulators, and, last but not least takes into account the general public views on new grid infrastructure. This document shows the way ENTSO-E is interacting with its surroundings, how ENTSO-E interprets the challenges and how it translates them into actions.

The long-term European energy vision requires a paradigm shift that must be addressed at the pan-European level. Uncertainties derive from large amount of RES to be integrated including offshore generation, new types of consumption, inclusion of Demand Side Response (DSR) and energy storage. It creates a set of possible scenarios which, in turn, lay the foundations for novel infrastructure planning approaches and increasingly coordinated system operation at the pan-European level, supported by well adapted market design.

3. EU Energy policy and the role of ENTSO-E

Established objectives of European energy policy

European energy policy is driven by three overarching objectives:

- Security of supply for the European economy and the consumers;
- Affordability ensured through competitiveness in the IEM; and
- Sustainability in the sense of a CO_2 neutral energy system through the integration of RES, as set out in the 20-20-20 targets.

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The targets for RES integration are a key determinate of challenges that ENTSO-E and its members must respond to. All three objectives interact and can easily become contradictory. Therefore, the emphasis placed on each one, from a legislative perspective, can drive a change in the scale and priority and shape of the ENTSO-E response.

Third Energy Package

The Third Energy Package reshapes the electricity system landscape through consolidation of the unbundling model and formalisation of TSO cooperation across Europe by establishing ENTSO-E[1]. The establishment of the roles of ENTSO-E and the Agency for the Co-operation of Energy Regulators (ACER),[2] together with the European Commission has set the framework for managing and developing the future European power system.

Energy Policy and power system implications

The European policy objective of achieving at least 80 % decarbonisation of the electricity generation sector by 2050[3] sets the longest term and most far reaching objective of European policy, with intermediary targets for 2020 and 2030[4]. Other legislation supports, promotes and provides a number of stages in the evolution of electricity generation, market design and network development.

The latest agreement on new targets for the reduction of CO_2, whilst certainly driving an increase in RES production, does not specify new binding RES targets directly. New targets are expected to be nationally specified at a later date. Earlier 2020 targets were more specific and formed a foundation assumption by ENTSO-E in its activities; the new targets are structured differently and will require assumptions to be made and subsequently updated when increases in RES are determined by national governments in future years. Having a clear picture of the national plans for emission reductions and shares of RES is a key input to the development of TSOs' responses to contribute to enabling the transition in the most affordable and secure way.

It is a European priority to finalise the establishment of the IEM. This priority is led by the European Commission and reconfirmed by the Council in a recent announcement on further development of the framework for a new European Energy Policy.[5] Transparency, non-discrimination and free trade of goods should eliminate barriers on the path of the already established regulation[6] in order to deliver appropriate price signals to investors and operators.

Recently an increased focus has been put on European energy security strategy[7]. The well-functioning of the electricity internal market and the acceleration of the construction of interconnectors represent key elements of energy security strategy. The reduction of EU energy dependence is another objective which requires diversification of supply options accompanied by an optimisation of energy network infrastructures to maximise the benefit from this diversification. This has to be supported by investments in research and innovation including new technologies to optimise the management of the grid. These efforts will be coordinated through the Horizon 2020 Framework programme for Research and Innovation and the associated Integrated Roadmap[8].

Furthermore, the Energy Efficiency Directive (EED)[9] will drive increased efficiency of many electrical demand devices or the purposes to which they are applied (for example insulation impacts on space

[1] Regulation (EC) No 714/2009
[2] Regulation (EC) 713/2009

[3] COM(2011) 112 A Roadmap for moving to a competitive low carbon economy in 2050
[4] COM (2014) 15 A policy framework for climate and energy in the period from 2020 to 2030
[5] The European Council, Conclusions 20-21 March 2014

[6] Refer to Directives 2004/39/EC and 2006/73/EC (MIFID), as well as Regulation No 1227/2011 (REMIT)
[7] COM(2014) 330 European Energy Security Strategy

[8] COM (2013 /253) Energy Technologies and Innovation

[9] Refer to DIRECTIVE 2012/27/EU on energy efficiency

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heating), consequently changing the nature of demand and fostering new trends in generation. This will change the portfolio of the grid users.

Maintaining and Enhancing the Networks

Many of the EU Environmental Regulations and Directives[10] create restrictions on not only geographical areas but also on the technology and materials liable to be used to develop and operate power networks. The Energy Infrastructure Package (EIP)[11] has recognized that "adequate, integrated and reliable energy networks are a crucial prerequisite not only for Union energy policy goals, but also for the Union's economic strategy". Substantial effort has been made by the Commission on providing a sound environment for achieving the necessary grid development. The EIP gives the basis subject to the appropriate criteria for benefitting from the Connecting Europe Facility instrument, created to enable financing of identified priority energy corridors, and to facilitate permitting procedures. Permitting procedures are currently one of the hardest obstacles to ensuring grid development. Delivering simplified authorization procedures with the required transparency and public participation should improve infrastructure acceptance and accelerate delivery.

Other EU legislative areas (such as environmental and financial) are highly influential in the development of networks. The relationship between the European legislation and related national implementations may affect the way TSOs exercise their responsibilities to achieve the necessary grid development.

Consequences for ENTSO-E activities

There is a steady flow of new EU energy policies arriving as additions or alteration to the IEM (model) and these will affect planning and operation of the European power system. Substantial change will also come from investment projects prioritized as Projects of Common Interest (PCI), network codes implementation, the integration of DSR into ancillary services market design, the interface with DSOs, and guidelines or legislation on energy storage both at local and large scale. Faced with a fast changing energy landscape ENTSO-E has established an adaptive approach to product development to ensure it can respond within shorter timeframes. None-the-less TSOs in their role to operate the power system securely must be continuously aware of future challenges and robust against uncertainties, namely:

1. Will EU Energy policy be adjusted over the period to the low-carbon EU by 2050 and continue its focus on sustainability, competition, and security of supply?
2. What impacts will there be from the global environment influencing fuel type and prices and security of supply?

4. Challenges

The present and future energy policies are inducing a substantial transformation in the whole European energy system and pose a number of significant challenges to the electricity transmission system. Generation is becoming more stochastic, correlated to weather conditions, and widely dispersed throughout the power network; large and small scale storage contributing to maintain the security of supply are necessary. Increased cross border flows as the result of merging energy markets will also increase the system complexity. Consequently demand shall become more flexible, and the call for competitive electricity prices and a reliable system becomes even more essential. This in turn is impacting in all areas of system planning and operation and will require major changes in the market organisation and the market products.

[10] For example refer to Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment

[11] Regulation (EU) No 347/2013

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Challenges induced by generation: a quantitative assessment

The electricity system has been designed until recently based on a key assumption that electricity is produced by fully controllable centralized generators, while consumption comprises a fully stochastic set of consumers located in distributed areas.

Figure 1 shows the load profile at European level for winter time 2013 (16.01.2013). In order to ensure adequacy with the demand, the generation sources must match with the load variations at any time. These variations can be quick and being able to respond to these changes is vital to security of supply. As an example, Figure 1 shows the quick rise of the demand which can occur in Europe today: +120 GW (+25%) in 4 hours.

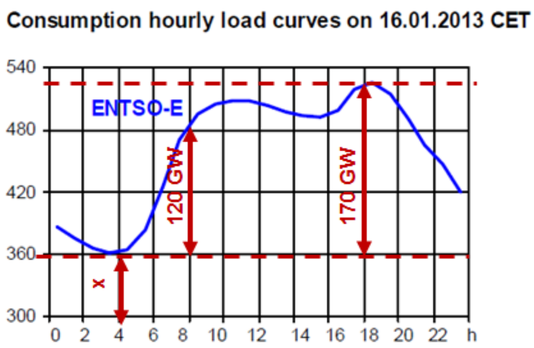

Figure 1.

Today this requirement is met mainly with controllable, non-intermittent generation sources and to a limited extent from available storage (mostly large scale hydro pumped storage). With the development of RES, predominantly based on intermittent sources, the power system should be ready to face additional variation of generation due to the weather conditions, and the daily solar cycle.

Figure 2 shows the variation of renewable in Germany for a typical week of 2014. Variations of almost 30 GW in 4 hours can be observed for an installed capacity of 60GW.

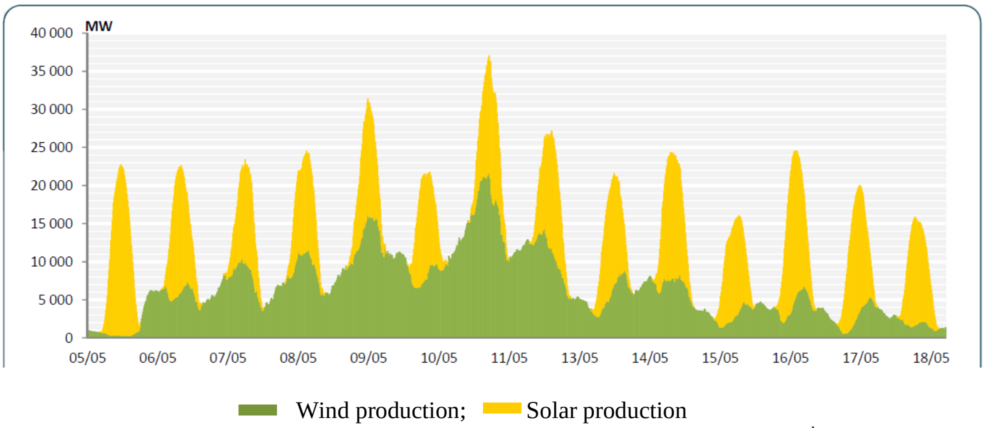

Figure 2. Renewable Generation in Germany for two weeks from the 5th May 2014

What about the future?

One of the principal challenges that ENTSO-E must respond to is the preparation of the network through its development and that of market and operational practice to meet future requirements. As typical individual network reinforcements can take in excess of 10 years from conception to completion TSOs must think in terms of decades into the future.

The four visions developed in the TYNDP (Ten Year Network Development Plan) 2014 provide a picture of the energy mix possible in the long-term perspective (2030). The scenarios developed in the European

Commission Roadmap 2050 and also in the e-Highway2050 project[12] explore an even longer term perspective, and provide a longer term and more extended view of the increasing challenges.

Figure 3 below presents the installed capacities, both intermittent (mainly wind and solar sources), as well as non-intermittent (other sources) for the different time horizons, 2012, 2030 and 2050. For 2030, the value ranges represent the span of the four visions included in TYNDP 2014. The 2050 value range comes from five scenarios of the e-Highway2050 project. The figure shows the progressive shift from non-variable (not intermittent) to variable (intermittent) generation under a wide range of scenarios and planning study assumptions.

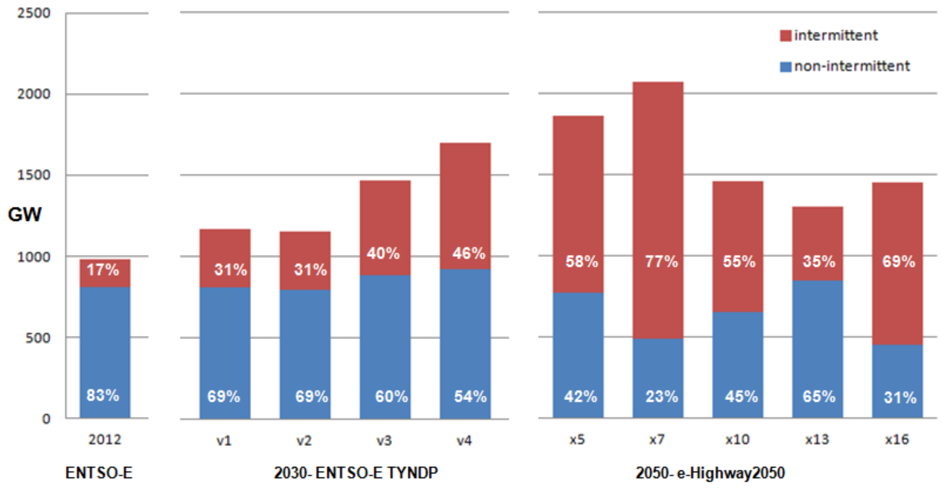

Figure 3. Installed capacities of generation for EU

This is illustrated further in Figure 4 which shows the results of some simulations performed by the e-Highway2050 project, depicting possible load patterns in October 2050 for one scenario of the study (“large scale RES”). In comparison, the figure also shows the pattern of the intermittent RES generation (wind, photovoltaic, Run-of-River hydro plants) foreseen in 2050. This example highlights the need for flexibility solutions: risk of energy ‘spillage’ up to 200 GW in some hours and the need to fill an energy gap up to 400 GW to supply the demand. These flexibility needs can be provided either by non-intermittent generation, demand side response, or storage.

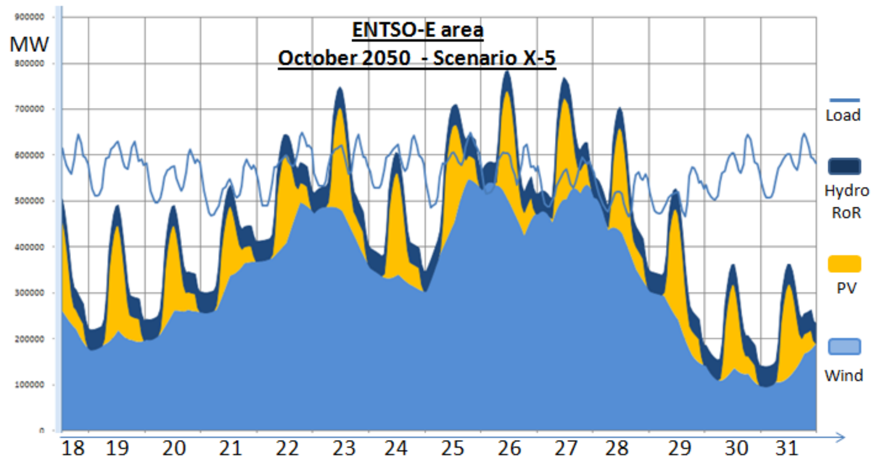

Figure 4. Period 18 October – 31 October / RES generation / ENTSO-E area

[12] For further information please refer to http://www.e-highway2050.eu/e-highway2050/

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The challenges induced by changes in demand patterns

The evolution of the nature of load demand is impacted by numerous and often antagonistic challenges. While improvements in the efficient use of electricity are assumed in decarbonisation scenarios, there is an expected additional demand for new services requiring electricity such as electric vehicles, heat pumps, and energy positive buildings. The increased consumer participation in the energy market, along with an expected long term shift to electrification of parts of the transport and heating systems, will significantly change the existing consumption patterns.

Furthermore, this political vision coupled with recent technological developments in the field of Smart Grids has opened up new potential to develop DSR and even storage taking advantage of the characteristics of these new applications. Making this potential a reality will require a new relationship between TSOs, DSOs, suppliers, and new entrants (e.g. aggregators). The need for consumer support to deliver both Smart Grids and DSR raises uncertainty on the timing and scale of DSR penetration in the energy market.

The challenges of storage development

In order to maintain or increase the security of supply in the European electricity system additional storage is required.

The TYNDP already includes large scale storage facilities, such as Pumped Hydro Storage (PHS) and Compressed Air Energy Storage (CAES), connected at transmission level, allowing for large amounts of energy to be stored and delivered back to the grid on a yearly to daily basis.

The restructuring of generation and the demand side combined with the slow development and difficulty in establishing interconnectors makes it essential to implement significant storage capability. Figure 4 shows the magnitude of the needs up to several hundreds GW in order to limit the spillage of RES and to contribute to filling the gap between load and generation at other periods of time.

There will also be a substantial need for balancing the power system in the shorter timescales of a few hours or even minutes. Fluctuations from wind or solar powered units has until now been balanced by spinning reserves on traditional thermal power plants. These resources are expected to decline in future years. Large or small storage capabilities of heating and cooling applications, electric vehicles and gas grids could partly compensate these lost reserves.

In future there will be a need for fast reacting storage (i.e. batteries) as well to support the power system with ancillary services and not just ensuring large energy flows. These may be sourced by either transmission connected or decentralised means connected to the distribution grid.

However, the regulatory framework for storage is not yet in place. Aspects like who should own and operate the storage facilities needs to be clarified. Is the storage facility a part of the operation of the power system or is it a fully market integrated resource with potential for use in different electricity markets?

Towards a more integrated energy system

The extension of the role of electricity or as it is known ‘electrification of the energy supply chain’, the intelligence of the new applications (in the heating, cooling, and transport sectors) as well as the possible use of gas to provide storage and balancing facilities is leading to an integrated approach to energy use for Europe. This integration shall take place on all scales: from the local (heating, cooling and transport) thanks to smart grid deployment, to pan-European applications such as the use of gas. Together with the DSOs the TSOs will need to facilitate and plan for new power system that can cope with these challenges. Further on, the work together with ENTSOG and with the stakeholders representing the storage sector will pave the way towards the development of an integrated energy system.

Consequent challenges for transmission infrastructure

a) Investment affordability and public acceptance

The transmission infrastructure should address the needs induced by the changes in demand and generation, while taking into account the increased difficulty in creating new corridors and addressing general environmental concerns - gaining the necessary permits and public acceptance for developing the infrastructure.
Another challenge to the timely delivery of transmission infrastructure is the financeability of these investments. This requires both regulatory stability and appropriate risk/reward balance to ensure the continued attractiveness of the electricity transmission business to the financial sector in comparison to other sectors.

b) New grid technologies

The increasing integration of variable energy sources together with variable loads will demand a highly flexible system in terms of operations and management. Inevitably, much of the existing infrastructure will have to be replaced or modernized and operational concepts will need to be continually improved. Power system components installed today are built to operate for the coming 30 - 40 years, the grid architecture and concepts for control as well as the requirements for different grid users' need to be specified now but allow for the future stable, reliable and economic operation of the system, even if this operation is completely different from today

New technologies must be wisely embedded into the existing infrastructure, guaranteeing interoperability. For example, high levels of power electronic based components (inverter connected generation or DC circuits) present a significant challenge for system operation to ensure continued co-ordinated action of the complex control and protection systems associated with these power electronic components. Also, reduced use of synchronous generators in the future will lead to more stringent requirements for emerging technologies to substitute their capabilities in operation of the power system.

Consequent challenge for system operation

The general move towards a more diverse, numerous, smaller sized and a less controllable generation fleet presents major challenges to accommodate this generation on the network. The intermittency of some of this generation requires new tools and approaches in order to maintain adequate security of supply. Further, the introduction of more variable and dynamic demand, demand side response, new technologies on the power system and the increase of pan-European power flows, all add challenges in forecasting and controlling generation, demand, and storage resources, in order to maintain efficient and secure system operation.

5. Addressing the challenges: ENTSO-E's key role

At the highest level, ENTSO-E is focused on delivering its core objectives, which are directly derived from the EU energy policy, based on the principles of:

- **Security** - pursuing coordinated, reliable and secure operations of the electrical power system.
- **Adequacy** - promoting the development of the interconnected European grid and investments for a sustainable power system. Monitoring system adequacy and giving guidance to energy policy and market participants wherever Security of Supply is endangered.
- **Market** - offering a platform for the market by proposing and implementing standardized market integration and transparency frameworks that facilitate competitive and truly integrated continental-scale wholesale and retail markets.
- **Sustainability** - facilitating secure integration of new generation sources, particularly growing amounts of renewable energy and thus the achievement of the EU's greenhouse gases reduction goals.

ENTSO-E elaborates its legally mandated deliverables taking into account the above core objectives:

- Network codes development in a number of areas defined in the regulation;
- Coordinated regional network development planning and the biennial publication of the ten year network development plan (TYNDP);
- Publication of research plans;
- Common network operation tools;
- Recommendations on the coordination of technical cooperation with 3rd-country TSOs;
- An annual work programme;
- An annual report;
- Generation adequacy outlooks;
- Monitoring and analysis of TSO performance and publication of the results;
- Monitoring and analysis of the implementation of network codes and European Commission's guidelines as well as their effect on harmonisation; report the findings to ACER and include them in the annual report to the Commission.

Regulation EU/714/2009 sets out the tasks of ENTSO-E and the obligation for the TSOs to cooperate at EU and regional level, and drives many of the deliverables above. However, other duties have been determined by other pieces of legislation. For example, the EIP regulation (EU) 347/2013 requires ENTSO-E to develop methods for a cost-benefit analysis (CBA) of energy infrastructure and storage projects as well as to ensure the transparency of the data. The methods should be used in the future TYNDPs, from 2014 onwards and they will constitute the basis for prioritizing Projects of Common Interest (PCIs). At the same time the ENTSO-E Transparency Platform (Regulation (EU) 543/2013) will continue to facilitate the implementation of IEM and the creation of efficient, liquid and competitive wholesale markets.

A number of measures have or are being put in place in order to meet the challenges described above. Table 1 illustrates how a wide variety of ENTSO-E work products addresses a variety of challenges and uncertainties. Answering a given challenge often require a combination of more than one measure. To be effective and efficient ENTSO-E's measures may also respond to more than one challenge.

However, all of the ENTSO-E measures play a key role in order to achieve the EU energy policy targets. Their respective time periods and technical detail interlink to progressively develop infrastructure measures to respond to the challenges identified, first researching, then specifying and constructing the infrastructure for users' capabilities and operation. The result of these deliverables having a shared end-goal will be smarter infrastructure and investments, along with the continuous evolution and adaptation of the technical and regulatory framework and the market design, leading to a reliable, competitive and sustainable energy system.

Focusing on four of the most notable work products which should be seen as complementary, the R&D Roadmap, the Network Codes and the TYNDP.

The R&D Roadmap is the deliverable having the most overall and general view, encompassing issues across all categories of the challenges over a 20-year window. It outlines the R&D needed in order to meet the energy policy targets. The R&D Roadmap is organised into six clusters ranging from grid architecture, integration of power technologies, new tools for network operation, market designs, asset management and collaboration between TSOs and DSOs.

The TYNDP concentrates on hardware issues such as pan-European optimized network planning utilising existing and foreseen technologies. It represents the most up-to-date and technically complete study of tomorrow's power system and storage. Its role is to ensure a greater transparency regarding the entire electricity transmission network in Europe. In this sense the plan underlines the bottlenecks within the European transmission system and presents the associated pan-European projects meant to solve them.

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Domain	Challenge	ENTSO-E measure											
		NC	TYNDP	CBA	SAF	CSO	EMFIP	LMD	MON	PP	EXT	3rd TSO	R&D
Demand	change in consumption patterns	S					S	M,L					L
	ensure quality of supply	S											M,L
	energy efficiency measures	S											
	increase of electricity									S,M			L
Generation	change of the generation mix	S,M	M,L		S			M,L					M,L
	change in the characteristics of generation	S						M,L					M,L
	change of the generation location	S	M,L					M,L					M,L
	forecast of new generation technologies		M,L		S		S						L
Infrastructure	public acceptance										S,M		M,L
	need for more flexibility of infrastructure		M,L			S							L
	adaptation to market integration	S								S,M			L
	integration of enhanced technologies	S	M,L										M,L
	uncertainties in power flows	S,M				S						S	L
	development and integration of storage		M,L			S							L
Policy and economics	different regulatory frameworks in member states	S,M								L			
	increased need for investments		M,L	S						L			
	new legislation									S,M,L			

Time periods mentioned in the document
S equates to 1 up to a 5 year period; **M** equates to a 5 up to a 15 year period; **L** refers to 15 year+ period

Measures mentioned in the document:
Cost Benefit Analysis for PCI **(CBA)**
Coordination of system operation (**CSO**)
EMFIP platform (**EMFIP**)
Relations/consultations/transparency/workshops (**EXT**)
Long term market design (**LMD**)
Monitor of NC implementation (**MON**)
Network codes **(NC)**
ENTSO-E Position papers (**PP**)
Stakeholder R&D Roadmap (**R&D**)
System Adequacy Forecasts (**SAF**)
Cooperation with third country TSOs (**3rd TSO**)
Ten Year Network Development Plan (**TYNDP**)

Table 1. Key Measures to respond to Key Challenges

ENTSO-E draft network codes set out rules on cross-border issues within operation, connection and market. They are thus the most technically detailed of the deliverables and the ones addressing the shortest time horizon. The network codes are intended to complement existing national rules by tackling cross-border issues in a systematic manner and by creating a coherent and coordinated framework.

In order to implement the above mandated deliverables an important coordination between TSOs takes place inside the association. A crucial deliverable is the on-going coordination of system operation across the entire ENTSO-E regions spanning the continent. Based on commonly agreed and regularly updated operational rules, TSOs across Europe run the transmission infrastructure together and jointly develop principles for operations design in the long term. The experiences of this real time operation form the basis to identify the needs for further development in all the areas of the system.

Other ENTSO-E products are important for the future and are linked to R&D work.
ENTSO-E has established the Transparency platform where relevant market information is made available to create a level playing field for market participants. ENTSO-E creates IT standards for market messages and measurements.

Furthermore, while the implementation of the IEM takes place within regions across the continent, the coordination within ENTSO-E ensures a common understanding of the European Target Model and helps keeping these initiatives aligned. An additional challenge will be to ensure the consistency of national capacity mechanisms into a common European concept. ENTSO-E will have a key role to play in the implementation of any new structures stemming from the extensive ongoing discussions on future market design.

As part of the development of measures, a broad representation of stakeholders is involved ensuring effective consultation with society[13]. All ENTSO-E deliverables that are identified as measures are consulted with stakeholders. ENTSO-E aims at taking these views into account. This includes financial planning for the investments required, according to the TYNDP, drafting of network codes which will become binding for a large range of 3rd parties, and development of the R&D Roadmap showing the way to meet energy policy targets. ENTSO-E is actively involved in the debate to ensure appropriate regulatory frameworks that meet the future challenges and holds regular discussions with the European Commission and ACER.

[13]For details on the the ENTSO-E consultation process see https://www.entsoe.eu/fileadmin/user_upload/ library / consultations/110628_Consultation_Process_Description.pdf

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