EU transition in power sector

How RES affects the design and operations of transmission power systems

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***Abstract* - In the past, much of Europe's electricity grid network has been designed in consideration of the locations of conventional generation plants. However, a large share of today's renewables production - notably variable wind and solar – does not correspond to this grid architecture. Interconnectors, in addition to internal infrastructure, are key to creating new electricity corridors to connect areas of surplus to areas of scarcity. In this context, in 2014 the European Council, in recognizing that a fundamental role of transmission infrastructure is to enable the integration of areas of high renewable energy potential with main consumption areas, endorsed the proposal by the European Commission to extend the current 10% electricity interconnection target to 15%. In this way, more available interconnection capacity would enable the grid to accommodate such increasing levels of variable renewable generation in a secure and cost-effective way.**

The previously described changes in interconnected system operating conditions, resulting in potential occurrences of unforeseen serious disturbances – most notably the well-known system split observed in the continental synchronous area on 04 November 2006 – have led to create the first Regional Security Coordination Initiatives (RSCIs now RSCs) and establishment of Coreso and TSC back in 2008. These entities have allowed TSOs to further coordinate not only system operations but also network planning, system adequacy analysis, market setups, etc.

However, given the challenges faced by the electricity industry in Europe, one may wonder whether the pace of developments in regulation and market design, system operations and system planning can keep up with the pace of change in the electricity system. In response to this concern, the present paper focuses on a central question: how the electricity system that is today primarily organized in a centralized, top-down manner will be reshuffled in the future?

The structure of the paper is as follow. The authors begin by describing the changes that are occurring in the power system and market sector, together with their drivers and underpinning regulation. Then the paper presents the challenges in the Eu-wide planning process, starting from TYNDP and PCI and then proceeding also to technical aspects of cost-benefit analysis, interconnection targets and the Union's financing mechanisms.

Keywords - Aggregator, Ancillary Services, Distributed Energy Resource (DER), Variable Renewable Energy Source (VRES), Demand Response (DR), Demand-Side Management (DSM), Energy Efficiency, Electrical Energy Storage (ESS), Electric Vehicle (EV), Internal Electricity Market (IEM), Photovoltaic (PV), Regional Security Coordinator (RSC).

Abbreviations (in order of apparison)

RSC – Regional Security Coordination

TSO – Transmission System Operator

TYNDP – Ten Year Network Development Plan

DER – Distributed Energy Resource

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

IEM – Internal Electricity Market

CACM -Capacity Allocation and Congestion Management

FCA - Forward Capacity Allocation

EB - Electricity Balancing

ER – Emergency and Restoration

DC - Demand Connection

RfG - Requirements for Generators

HVDC - High-Voltage Direct Current

SGU - Significant Grid Users

ACER – Agency for the cooperation of Energy Regulators

RAM - Remaining Available Margin

UNFCCC - United Nations Framework Convention on Climate Change

ESS - Electrical Energy Storage

MRC - Multi-Regional Coupling

PCI - Projects of Common Interest

1. INTRODUCTION

Electric power systems in Europe, and in many other parts of the world are experiencing an unprecedented set of changes driven by the combination of several key trends: the increasing decentralization of power systems, uptake of and the growing penetration of distributed generation (and more recently, energy storage) and more active and price-responsive energy "consumers"; a proliferation of information and communications technologies (ICTs) that enable energy to be produced, transmitted, and consumed more intelligently and efficiently by agents of any size; the growth of variable renewable energy sources such as wind and solar energy; the dramatic cost decline in a number of technologies; the decarbonization of the energy system as part of global climate change mitigation efforts; and the increased interlink of electric system with other critical infrastructure - for instance transportation, gas sector and water cycle - which enhances the importance of electricity in modern economies. [1]

At the same time, today's network regulations, system operations and the business models deployed by electric utilities were built on assumptions developed in the 20th century. These assumptions - that power flows are unidirectional, that electricity demand is price-inelastic and will grow indefinitely, that synergies and dependencies in terms of decision-making under different time frames for system operation are low, and that new assets are the only tools for relieving network congestions - are unfit for today's reality. [2-3]

To address these challenges, TSOs, who have a long history of cooperation, have voluntary coordinated their operational planning processes through Regional Security Coordination Initiatives in areas where this coordination was the most necessary:

1. Regional outage coordination;
2. Regional adequacy assessment (short-term, namely weekly ahead to intra-day);
3. Regional operational security coordination;
4. Coordination of capacity calculation within capacity calculation region;
5. Building of common grid model.

In light of these developments, the cornerstone of the redesign of the electricity market – e.g. the Commission's Network Codes and legislative proposals of the clean energy package – shall be as innovative as the businesses to which they are applied. Specifically, they need to account for the new options for service delivery created by DERs while maximizing the incentives for operating and building infrastructure in an efficient manner, managing the increasing uncertainty in network usage, and incentivizing the development and adoption of innovative solutions that lower cost in the near and long term. [3]

A well-integrated energy market is considered a fundamental prerequisite to achieve the EU energy and climate objectives in a cost-effective way. Interconnectors are therefore a vital physical component of Europe's energy transition as they make capacity available for energy trade.

The socio-economic value of electricity interconnectors comes from their ability to increase the efficiency of the individual electricity systems by reducing the costs of meeting electricity demand and in parallel improving security of supply and facilitating the cost-effective integration of the growing share of renewable energy sources. In fact, the benefits from spatial aggregation by means of statistical balancing and more efficient use of resources in the energy market have been one of the main reasons to create large interconnected electricity systems. [4-8]

Before the late 1990's, when previously national electricity markets began to open up across borders, interconnections between Member States largely served security of supply needs, and were developed to enable electricity trade in the form of long-term contracts. Due to the then regional balancing of load and generation degree, these cross-border flows were considerably lower than the levels we see today. [9-12]

The original electricity interconnection target of 10% of import capacity over installed generation capacity per Member State was set in 2002, when the process of creating the internal market to enhance competitiveness had just started. Interconnectors were one important way to enable competition in markets that were largely a national monopoly; the competition mainly had to come from abroad. At that time, there was little penetration of variable renewables in electricity generation. [13]

The situation on the electricity market has changed fundamentally since 2002. Today, the most important reasons behind the investments in interconnection capacity are still related to security of supply and competitiveness, thought energy and climate objectives and sustainability have now become much more important drivers. [14,15]

In fact, in order for Europe to advance with its ambitious roadmap to cut greenhouse gas emissions, new transmission assets including interconnectors, and their efficient use, are needed to transmit renewable electricity from remote and isolated generation areas to consumption centers and storage sites and to connect regions with complementary characteristics of renewable generation, thus enabling the consumption of clean energy by European citizens.

However, the TSOs also recognize that many transmission infrastructure projects have had important public acceptance problems to deal with because of opposition on grounds of perceived risks to health or intrusiveness of infrastructure in the landscape and impact on nature. As a result, in some cases public disputes led to significant delays or redesign of some projects, such as for instance the re-conductoring of current lines, or changing them from alternating current to direct current technology to enable better use of these lines (for example partial undergrounding in sensitive areas).

2. A Policy and Regulatory Toolkit for the Future Power System

2.1 Network Codes

The "Third legislative Package" [16,17] generalizes efforts to develop further coordination between TSOs, with e.g. the creation of the "European network of transmission system operators for electricity" (ENTSO-E) and the establishment of common rules for the IEM. Between 2009 and March 2017, eight network codes or guidelines[1] were drafted by ENTSO-E and are now turned into binding EU regulation through the comitology process. The full implementation of these guidelines will take place over the next few years –probably going beyond 2020 for balancing – and is expected to deliver substantial benefits for the IEM. Figure 1 reports the three layers network codes/guidelines for policies and regulations.

More precisely, the codes belong to one of three families:

- **Market codes**. Market codes – e.g. the Capacity Allocation and Congestion Management Regulation (CACM), the Forward Capacity Allocation Regulation (FCA) and the Electricity Balancing (EB) guidelines - move market integration forward, for more competition, resource optimization and social welfare. They set rules for capacity calculation, day-ahead and intraday markets, forward markets and balancing procurement.
- **System Operations Codes**. Operational codes – e.g. the System Operation Guideline (SO) guideline and the Emergency and Restoration (ER) network code - reinforce the reliability of the system through state-of-the-art and harmonized rules for operating the grid. They cover system operations across a number of time frames - from long term to short term and real-time, regional cooperation, security of supply and emergency procedures.
- **Connection codes** – e.g. the Demand Connection (DC), the Requirements for Generators (RfG) and the High-Voltage Direct Current connections (HVDC) network codes - set the EU-wide conditions for linking all actors safely to the grid, including renewables and smart consumption Significant Grid Users (SGU).

[1] Whereas both, network codes and guidelines are binding EU law (once passed through Parliament), the difference lies in the character of provisions: in the network codes these must be final, in the guidelines it is possible to amend the initial ones with further detailed items like methodologies or other specifications after the guideline is legally endorsed.

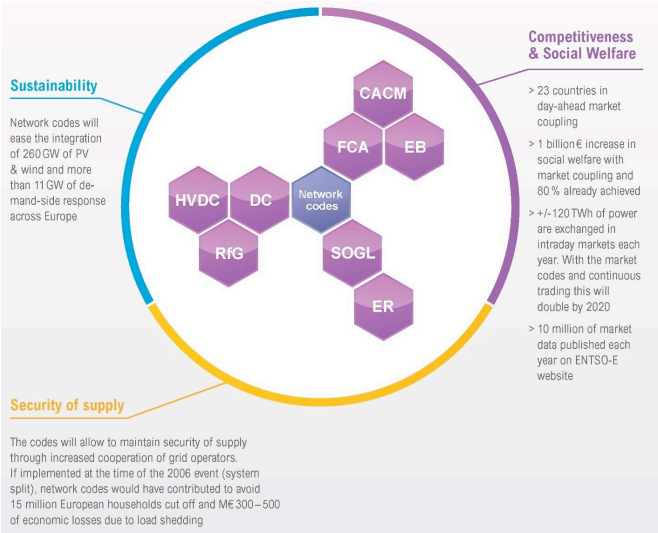

Figure 1: Three layers network codes/ guidelines for policies and regulations. [Source: Statnett.no]

2.2 Clean Energy Package

The recent initiative on the Energy Union has given a new impetus to the construction of the IEM, which is a strategy built on five pillars: (i) ensuring security of supply; (ii) building a single internal energy market; (iii) improving energy efficiency; (iv) decarbonising national economies; and (v) promoting research and innovation. In this context, the European Commission (EC) has worked on a package of proposals aiming to address some of the issues associated with energy security and the IEM (the so called "Winter Package" published on 30 November 2016), willing to facilitate the transition to a low-carbon economy by addressing factors such as increasing inflows of renewables, subsidy schemes, network access rights, storage solutions and regional cooperation.

Some of the legislative proposals contained in the package modify the internal energy market in the European Union. In addition to the revision of the regulation, there is a directive for the internal electricity market, a regulation on a European agency for cooperation between regulators of the various nations (ACER) and finally a new regulation proposal on the risk in the sector electric that identifies measures for the assessment, preparation and management of risk situations of the European electricity system and the adequacy of resources and the security of electrical supplies, repealing the current Directive 2005/89 / EC.

The Proposal reacts to the findings of the Commission that Member States take very different approaches in assessing, preventing and managing electricity crisis situations. The proposal therefore sets out, amongst others, methodologies to assess security of supply and to identify **electricity crisis scenarios** in the Member States and on a regional level, to conduct seasonal (six months ahead) and **short-term adequacy assessments** (namely monthly, week-ahead to day ahead), to establish risk- preparedness plans and to manage

crisis situations. It also provides for ex-post evaluation of crisis situations and monitoring by the Electricity Coordination Group.

The Proposal Regulation on the **Electricity Market** (recast) is based on the existing Regulation (EC) No 714/2009, which remains in force. The recast Regulation aims at setting fundamental principles for well-functioning, integrated electricity markets, which allow non-discriminatory market access for all resource providers and electricity consumers. The proposal also contains design principles for **capacity mechanisms**, ensuring, amongst others, that these do not create unnecessary market distortions or limit cross-border trade, and not go beyond what is necessary. Member States can introduce capacity mechanisms, provided they are justified by a resource adequacy concern documented in a European resource adequacy assessment conducted on the basis of a shared methodology for the medium to long-term (from 10 year-ahead to year ahead) established through ENTSO-E and ACER. When applying a capacity mechanism (to the extent allowed), Member States will have to have a **reliability standard** in place to indicate their desired level of security of supply.

Moreover, in order to support the increasingly integrated operation of electricity systems across the Union, ensuring system security and market efficiency, the proposed target model for 2025 is to erect enhanced[2] **regional coordination** (RSC+) throughout Europe in which the functions before real-time operation are centralized across larger geographic areas. The following areas of concerns are highlighted:

- *Capacity Calculation* (Art 14). TSOs not allowed to limit XB capacity below 75% of the "calculated NTC" or of the "remaining available margin" (RAM) on internal and XB critical network elements. As a result, market outcomes will be increasingly more infeasible forcing TSOs to massively employ special operational remedial measures such as costly re-dispatching of generation units. Such wide use of re-dispatching would not only lead to increased costs for end-consumers, but may also endanger system operation based on insufficient or premature utilization of the limited available remedial actions.
- *Regional scope of coordination* (Art 33). Requirement in Council GA would result in rigid assigning 1 RSC to each of the 5 system operation regions (SOR): Nordic, Baltic, CORESO, TSC and SCC-SEE, whereby more flexibility should be given to MSs in such geographical assignment taking into account the fact that (i) RSCs are service providers, (ii) interoperability requirements will ensure consistency, (iii) the large size of the CORE Region, (iv) the need to take into consideration as part of the coordination processes the interrelation with adjacent regions and (v) the need address the specificities of small regions (IE/UK, South-West Europe).
- *Tasks of regional security coordinators* (Art. 34 and Annex I), especially towards the coordination and optimization of regional restoration, the calculation of the maximum entry capacity available for the participation of foreign capacity in capacity mechanisms and the regional scope to procure balancing capacity.
- *Implementation of coordinated actions* (Art. 38.2). Binding decisions removed, but limitation to deviate from previously adopted coordinated actions only for security reasons is very concerning. The text does not recognize the time-frame in which operational decisions are made (real-time) which are different from the RSC's recommendations (day-ahead and intraday as relevant in the region). There are technical reasons why coordinated actions prepared in advanced may not to be implemented in real time. For instance, the situation could evolve and the action is not needed or effective any longer, or it is not available or a better solution is identified.

Furthermore, to increase the efficiency of the electricity system and, at the same time, ensure good cooperation with TSOs and ENTSO, the establishment of a controller for the various European DSOs ("EU DSO entity") would be appropriate. This entity should cooperate with the ENTSO for the writing and application of network codes where applicable and should also provide some guidance on the integration of distributed generation and storage in distribution networks.

Apart from the above main topics, in Art. 54 the Directive seeks also to address network operators' restriction on **storage facilities** ownership. More specifically, in the new electricity market design storage services should be market-based and competitive and consequently transmission system operators – as well as distributors - shall not be allowed to own, develop, manage or operate energy storage facilities.

On a case-by-case basis, by way of ad-hoc derogation from the Member State, TSOs may be entitled to deal with those batteries which are fully integrated in their network components provided that all of the following conditions are fulfilled:

- Such facilities are necessary to maintain the efficient, reliable and secure operation of the transmission system and they are not used to provide balancing services and to buy or sell electricity to the wholesale markets, including balancing markets;
- No other parties, following an open, transparent and non-discriminatory tendering procedure, have shown the interests to play this business; and
- The regulatory authority has assessed the necessity of such derogation and has granted its approval.

According to this procedure, the NRAs regularly perform (at the latest every five years) a public consultation for the energy

[2] Coordination between transmission system operators at regional level is jet formalized in the System Operation GuideLine (SOGL), and indirectly the Capacity Allocation and Congestion Management (CACM) guideline.

storage facilities required to understand the potential interest of the market parties to invest in such technologies.

2.3 2030 climate and energy framework & Paris agreement on climate change

At the end of 2014, the European Council agreed on the 2030 framework for climate and energy for the European Union in order to make the energy system more competitive, reliable and sustainable (Fig.2).

On the climate, it approved four important objectives, two of which are binding:

- 40% less greenhouse gas emissions by 2030 compared to 1990;
- 27% of the share of renewable energy in the gross final use of energy of the European Union in 2030;
- 27% improvement in energy efficiency in 2030;
- an existing electricity interconnection of 10% by 2020, in particular for the Baltic States and the Iberian Peninsula, and the objective of reaching a target of 15% by 2030.

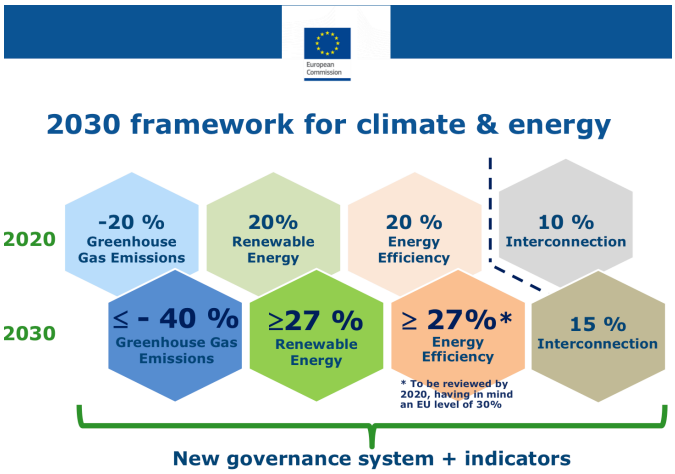

Figure 2: Agreed headline targets at the 23-24th Oct. 2014's EU council. [Source: Norden.ee]

Finally, again on the subject of energy system security, the Council has suggested strategies to reduce the energy dependence of the European Union, thereby increasing the security of electricity and gas supplies, addressing, among others, the exchange system for emission (ETS) etc ...

At the end of 2015 at COP 21, representatives of numerous parties sign the first global climate agreement in the world.

The objective, described in article 2, is to "improve the implementation" of the UNFCCC by maintaining the increase in the average global temperature well below 2 ° C to mitigate the impacts of climate change; while channeling financial flows towards a path characterized by low emissions.

The agreement was recognized as a turning point for fossil fuels.

3. Implications for the Electricity Systems of Today

In most countries, a decentralized energy system represents a relatively new approach in the energy sector. Traditionally, the architecture of the original electrical system was based on the development of large conventional power plants and the transmission of energy occurred through long lines in high voltage. On the contrary, decentralized energy systems offer opportunities to shorten the energy supply chain by ensuring the use of small-scale renewable energy sources, local and DSO, as well as for the development and expansion of prosumer participation and storage in the electricity market.

A decentralized system relies on renewable energy sources, corridors from rural and remote sites of production to the far-off centers of energy consumption, energy storage and demand response.

From an operational perspective, increasing the share of intermittent, non-dispatchable energy poses challenges like resource adequacy, the need of flexibility, control of voltage profile, minimum kinetic inertia and dynamic stability.

In the following paragraphs, the above given discussions will be boiled down to the essence, to be captured in easy-to-comprehend findings and messages that can be used for further communications on "*Regional coordination of power system operations*" and "*Seasonal Adequacy Risks*".

3.1 Resource Adequacy

The significant reduction in costs of new technological products makes some renewable sources very economical, even without government incentives. In many parts of the European Union, the construction of a new wind farm or solar plants on an industrial scale is cheaper than the management of some traditional sources (e.g. coal). On the other hand, fossil fuels do not show any downturn in prices and this leads to uncertainties about the capacity of the energy system to meet demand at all times..

Pursuant to current legal obligations of Reg. 714/2009, in order to identify the sources of possible resource adequacy concerns, ENTSO-E performs seasonal analyzes twice a year to have a good view regarding the incoming summer and winter period, the seasons in which extreme weather conditions such as extended heat waves/ cold spells affecting multiple Countries simultaneously coupled with the challenges faced in terms of generation adequacy issues (low reservoir levels, unplanned outages of power plants, outages of key nuclear units, coal and gas supplies disrupted, low wind and solar production during peak load time, etc.) and system adequacy (exceptional contingencies going beyond N-1 criteria, HVDC, NTC impacting assets, etc.) can strain the system. Accordingly, ENTSO-E publishes its Summer Outlook before 1 June and its Winter Outlook before 1

December. Additionally, ENTSO-E publishes an annual Mid-term Adequacy Forecast (MAF) that examines the system adequacy for the next ten years.

Complementing the national resource adequacy assessment performed by the ENTSO-E, Member States monitor resource adequacy within their territory and perform more granular national resource adequacy assessment to ensure that local characteristics of generation, demand flexibility and storage, the availability of primary resources and the level of interconnection are properly taken into consideration.

3.2 The need of flexibility

DER technologies, particularly Variable Renewable Energy Source (VRES) technologies - such as wind and solar characterized by volatile, partially unpredictable, and mostly non-dispatchable power output with zero fuel cost - are likely to experience significant growth in coming years at both the distribution and transmission levels. (Fig.3)

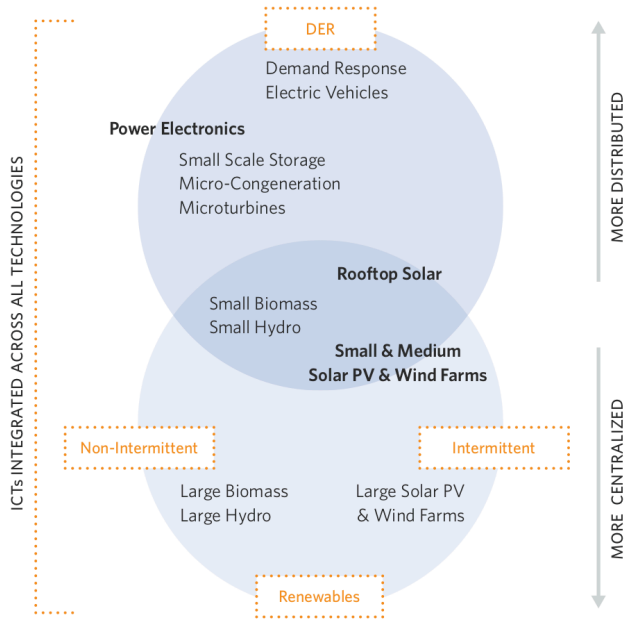

Figure 3: Conventional clusterization of Distributed Generation and Renewable Energy Sources. [Source:MIT [18]]

The central challenge of integrating VRES technologies into power systems is their intermittency, a characteristic that requires other (usually thermal) resources to rapidly adapt their power output to maintain the instantaneous balance of generation and demand. Variations in VRES power output (whether expected or unexpected) will increase the need for flexible generation capacity in power systems. The fact that a rapid change in VRES generation can sometimes be predicted does not eliminate the need for fast-ramping resources as well illustrated by power “duck curve”.

Increasing solar penetration in power system has led to a net load curve that necessitates significant ramping of thermal generators in the evening and drastic output reductions by those same generators during the daytime.

In the past, flexibility has been guaranteed on the supply side; today, this gap can be filled differently. The flexibility for short times prefers rapid response times, otherwise (for long times) the possibility of offering large storage capacities and long periods of shifting is preferred.

The system should prefer the most convenient resources and therefore these will be in competition with those already existing. Globally, there are 16 options for five categories of flexibility: supply, demand, energy storage, market design and system operations:

- Flexibility in Fossil generation
- Nuclear power plant flexibility
- Biogas power plant flexibility
- Flexibility in combined heat and power
- Active power control of renewable energy
- Demand management in industrial installations
- Demand management in services and households
- Electric vehicles
- Power to Heat
- Pumped hydro storage
- Compressed air energy storage (CAES)
- Flywheels
- Batteries
- Power to Gas
- Market options to unlock flexibility
- Network options to increase flexibility

The main options that have already reached a good maturity are found on the supply side; On the demand side, a market option is the response of large-scale industrial demand, while pumped hydropower is the leading mature storage technology. The other new resources for demand and for the accumulation of electricity are to be considered on a small scale. The development of these products is closely linked to the development of the communication infrastructure, which, due to costs, could represent a market barrier and therefore hinder its development. For example, today, with many difficulties, we are trying to develop a system of aggregators to encourage the loads that participate in the electricity market operations..

3.3 Storage

The possibility of accumulating ever larger quantities of electricity will drive the system in this transition. The storage is potentially able to provide all the useful services to the electricity system (ancillary services, power supply, etc ...), and could increase the degrees of freedom of the electricity system and, above all, postpone the need for important infrastructure investments..

This also applies to distribution, as behind-the-meter applications allow consumers to manage their bills, reducing peak demand charges and increasing “self-consumption” from

rooftop PV panels. Along with providing multiple functions and user benefits, an electricity storage project can unlock multiple revenue streams from the provision of a range of services (Figure 4).

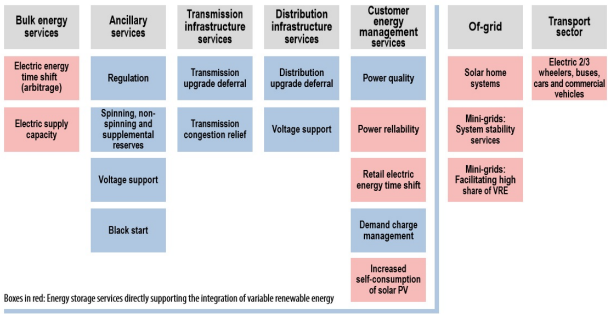

Figure 4: The range of services that can be provided by electricity storage. [Source: IRENA]

There are diverse methods for categorizing Electrical Energy Storage (ESS), depending on various key parameters such as suitable storage duration, system functionality and discharge time, among others. In the Figure 5, storage technologies are presented according to the energy form stored in the system (operating principle).

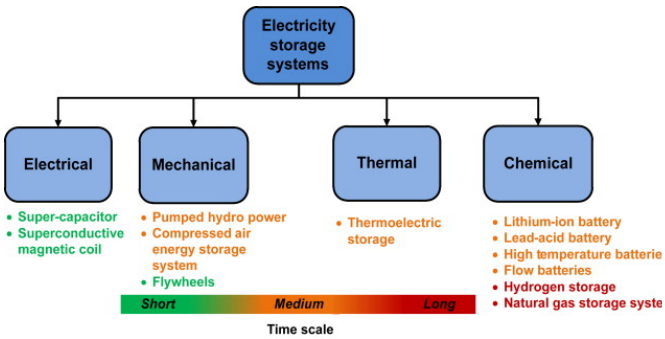

Figure 5: Electricity storage systems classification. [Source: [19]]

In 2030 significant shares of electricity generation from photovoltaic and wind sources are foreseen (for example 70-80% in some cases), and therefore the possibility of accumulating long-term energy to counteract the natural fluctuations of these sources is desirable. So in addition to the flexibility required by the system, this scenario will require low energy costs for electrical storage..

In this regards, given the complementary characteristics of the two sectors[3], from a system perspective, a potential coupling of electricity and gas infrastructures might result in a creation of a more stable system as a whole. Accordingly, Power-to-Gas (P2G) technologies - thought they are definitely not to be regarded as substitution or compensation for network development – might be considered a very promising way forward to face continuously increasing penetration of the renewables and the significant impact of their integration into the system on the financial aspects.

3.4 Demand Response

In recent years, demand response has played an ever greater role thanks to the possibility of mitigating loads and therefore reducing stress on the electrical system during emergency phases. Figure 6 reports an explicit demand response in Europe mapping the markets 2017.

The Demand Response (DR) therefore has the possibility to provide some fundamental resources that can keep the electricity grid stable and efficient, to postpone the reinforcement of the infrastructure and, above all, to offer economic benefits to the customers. [20]

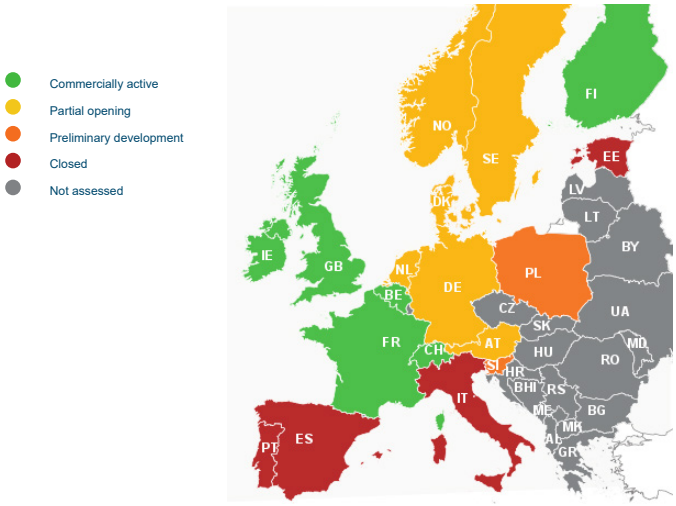

Figure 6: Explicit Demand Response in Europe Mapping the Markets 2017 [Source: SEDC [20]].

The DR operates both for short answers (seconds) and for much longer times. To facilitate the comparison between the cost and the value created by the flexibility of the loads, we proceeded to define an analytical structure that groups the DR into four main categories: Shape, Shift, Shed and Shimmy.

- **Shape** refers to demand response actions that modify the user's load profiles through response to prices or behavioral campaigns - with ample notice.

- **Shift**, on the other hand, concerns the DR which promotes the shift of energy consumption from periods of high demand to the hours of the day when there is an abundance of renewable generation.

- **Shed** covers loads that can be interrupted to help the system in emergency conditions.

[3] The electric system allows the production of large quantities of renewable energy, but it cannot provide long term storage. On the other hand, the gas system ability to produce large quantities of energy is limited, but its storage ability is considerably high. Also, the electric system is a fast real time system lacking flexibility, whereas the gas system is slow responding one but very flexible.

- **Shimmy** finally concerns the DR that involves the use of loads to alleviate short-term ramps and disturbances with times between seconds and hours.

3.5 Inertia

It is known in the literature that the inertia of an electrical system is fundamental for the stability of the frequency, thanks to the rotating masses of the others. The growing diffusion of distributed generation (photovoltaic e.g.), connected through power electronics, significantly reduces the inertia of the system, causing a greater frequency variation in the event of disturbances on the electrical system.

Depending on the size/ characteristics of a synchronous area frequency stability becomes a major concern under normal operating conditions (e.g. IE or GB) or on case of larger system disturbances (e.g. CE) already nowadays with an increasing tendency.

A measure to mitigate this trend is to emulate the transient behavior of synchronous power generating modules (determined by their inherent inertia), via i.e. the immediate response to load imbalances, by a comparable response of other system users.

Namely, virtual (synthetic) inertia is the 'product' providing a Virtual Inertial Response (VIR) by controllers that mimic synchronous connected generators natural inertial response by delivering an active power response proportional to the rate of change of frequency (RoCoF), while time delays being generated during this process.

Virtual inertia can be delivered by converter connected units (intermittent RES, relevant technical capabilities to be established by RfG requirements), biomass and hydro, storage, inter synchronous area HVDC systems (connection network codes on HVDC), or even very fast active power control through demand response (DCC).

4. Implications for the Market Systems of Today

As described in the previous section, making Europe's electricity grid fit for more renewable capacity, enabling their integration and ensuring security of supply, requires full completion of the internal energy market, in parallel with the implementation of the revised rules for rewarding ancillary services, a non-distortive combination of energy and capacity markets and for increasing the incentive for network operators to invest in new grid infrastructure. In the following paragraphs more details for market coupling, aggregators and capacity market are given.

4.1 Market coupling

Market coupling in the EU Internal Electricity Market (IEM) concerns the integration of two or more energy markets in different areas with a cross-border allocation mechanism; it certainly represents a very important tool in the vision of a single wholesale market for the European community. Fig. 7 shows a gradual implementation of the Multi-Regional Coupling (MRC).

Market coupling allows, in addition to the sale of energy, also simultaneously the sale of interconnection capacity.

In other words, instead of explicitly auctioning the cross-border transmission capacities among the market participants, market coupling makes the capacities implicitly available on the power exchanges of the various areas.

From the reading of the ACER and CEER reports on the results of internal market monitoring, referring to 2016, it emerges that inter-zonal capacity was more efficiently exploited in the intraday at times when capacity was allocated using methods implicit with explicit allocation methods.[21-27]

The role of the market coupling in integrating the wholesale electricity markets in the EU has been accentuated by the so-called Winter Energy Package of November 2016, where it is established that the Transmission System Operators (TSO) and the Electricity Market Operators appointed (NEMO) jointly organize the management of the daily and intraday integrated markets based on the mating of the market as established in the 2015/1222 regulation (CACM regulation).[28-29]

The following are the energy regions that, in 2012, applied market coupling: Central Western Europe (Spot EPEX (German-Austrian and French), Belpex (Belgium) and APX-ENDEX (Netherlands)), Nordic region (Nord Pool Spot (Norway, Sweden, Finland, Denmark, Estonia, Lithuania)), Central and Eastern Europe (OTE (Czech Republic and Slovakia) and HUPX (Hungary)), South-Western Europe (OMIE (Spain and Portugal)) and Central Europe -terminal (GME (Italy) and Borzen-BSP SouthPool (Slovenia)).

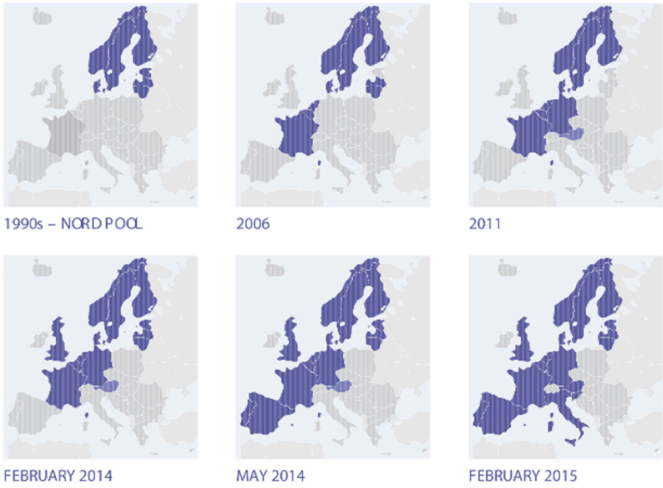

Figure 7: Stepwise implementation of the Multi-Regional Coupling (MRC) across the Union [Source: ENTSO-E]

The two market time-frames are differentiated:

- '**Single day ahead coupling**' meaning a coordinated electricity price setting and cross-zonal capacity allocation mechanism, which simultaneously matches orders from the day-ahead markets per bidding zone, respecting cross-zonal capacity and allocation constraints between bidding zones; and

- '**Single intraday coupling**' meaning an implicit cross-zonal capacity allocation mechanism which collects orders for each bidding zone from wholesale market participants and matches them continuously into contracts to deliver electricity while respecting cross-zonal capacity and allocation constraints, and is available in the intraday market timeframe once the day-ahead market allocation process has taken place (see Article 2(27) of the CACM Regulation').

As regards the day-ahead market coupling, a single European price coupling applied throughout the EU and Norway is envisaged.

Although EU rules require TSOs to resolve network congestions without limiting commercial transactions (including across borders), TSOs can under certain conditions curtail nominations to preserve system stability (see Article 16(3) of the Regulation (EC) No 714/2009 of the European Parliament and of the Council on conditions for access to the network for cross-border exchanges in electricity of 13.7.2009).

Also relevant is Article 4(3) of the Security of Electricity Supply Directive, which states that 'Member States shall not discriminate between cross-border contracts and national contracts'.

Important milestone for the development of the European market coupling was on 21 May 2015, when the Central-Western European (CWE) Region implemented flow-based capacity calculation (Flow Based Market Coupling - FBMC) for the first time in Europe. The nine parties involved include TSOs from France, Belgium, Luxembourg, Germany and the Netherlands, and two power exchanges (PXs).

The Regulation No 2015/1222 on Capacity Allocation and Congestion Management (CACM) (Fig. 8) defines the rules for a continuous intraday market that allows market participants to trade up to at least one hour before real-time. To this aim, TSOs from 12 countries, along with power exchanges (PXs), have launched the cross border Intraday (XBID) Market Project that will enable the creation of a joint integrated intraday cross-zonal market.

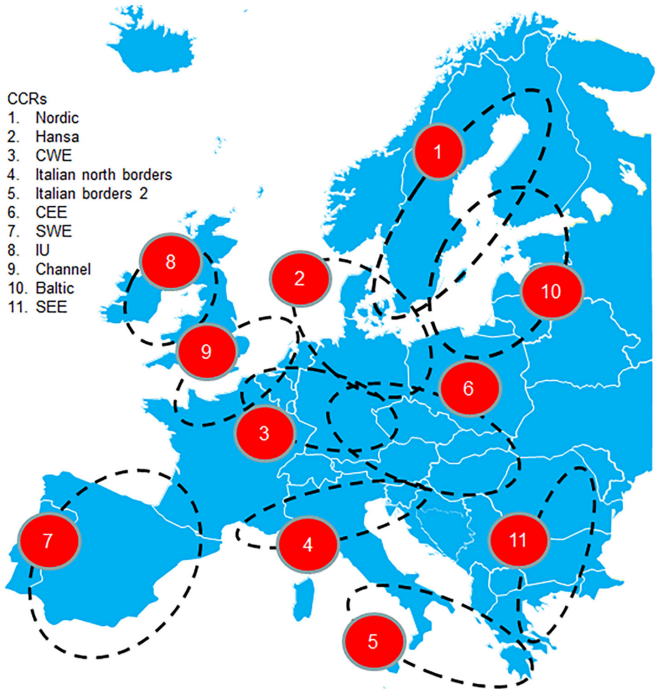

Figure 8: Capacity Calculation Regions (CCRs) in accordance with Article 15(1) of the CACM Guideline. [Source: ENTSO-E]

4.2 Reform of dispatching market (Aggregators)

The main function of aggregation is to identify and gather ("aggregate") the flexibilities of consumers and other flexible resources, such as renewables and storage. Aggregators create agreements with industrial, commercial, institutional and residential electricity consumers to aggregate their capability to adjust energy and/or shift loads on short notice. Their goal is to build up sufficient capacity of flexible resources in their portfolio to provide flexible energy products as services to the markets.

In several EU countries aggregators are entering the electrical balancing or reserve markets, and regulatory frameworks are slowly being reformed in order to better enable their market access.

In relation to the Italian context, on the 5th of May, 2017 the Italian Regulatory body (ARERA) issued the deliberation n. 300/2017 defining the criteria to allow demand, production units not yet enabled to ancillary service market (e.g. RES and DER <10 MVA) and storage plants to provide flexibility services by means of "pilot projects". These experimentations are aimed at to gather experience for an organic redesign of the national Ancillary Service Market pursuant to the European "Electricity Balancing" guideline.

The timeline encompasses as a minimum the following projects:

- Virtual load (UVAC), the minimum volume of bids submitted to the TSO shall be equal to or higher than 1 MW/ 15 min

- Virtual Power Plant (UVAP): the minimum volume of bids submitted to the TSO shall be equal to or higher than 5 MW/ 15 min

- Virtual Node (UVAM): comprising demand, generation and storage.

In 2017, Terna has launched pilot projects on both consumption[4] and production aggregated units.

Industrial and commercial consumers have in some EU countries, e.g. Germany, Austria or Italy, started to provide flexibility such as tertiary reserves.

To address these challenges the European Commission is preparing an ambitious legislative proposal to redesign the electricity market. The idea of the new CE4All legislative proposal is to increase security of supply and ensure that the electricity market will be better adapted to the green energy transition which will bring in a multitude of new producers, in particular of renewable energy sources, as well as enable full participation of consumers in the market, notably through demand response. The new electricity market design put in place by the forthcoming Regulation and Directive on the internal market for electricity will ensure that aggregators, are entitled to a dynamic price contract and are able to engage in demand response, self-generation and self-consumption of electricity.

4.3 Capacity market

There are various forms of capacity mechanisms (Fig. 9). They can be grouped into two broad categories: targeted mechanisms and market-wide mechanisms. Within these two categories, it is also possible to distinguish volume-based mechanisms and price-based mechanisms.

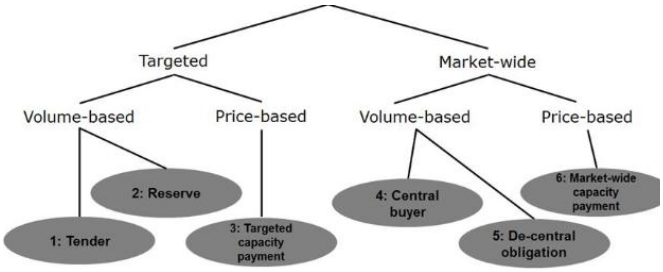

Figure 9: Taxonomy of capacity mechanism models.[Source: Europa.eu]

In 2016, the Commission's sector inquiry into capacity mechanisms has formed the basis for a close cooperation between the Commission and EU Member States to ensure that capacity mechanisms are well-designed and fit for purpose. (Fig. 10)

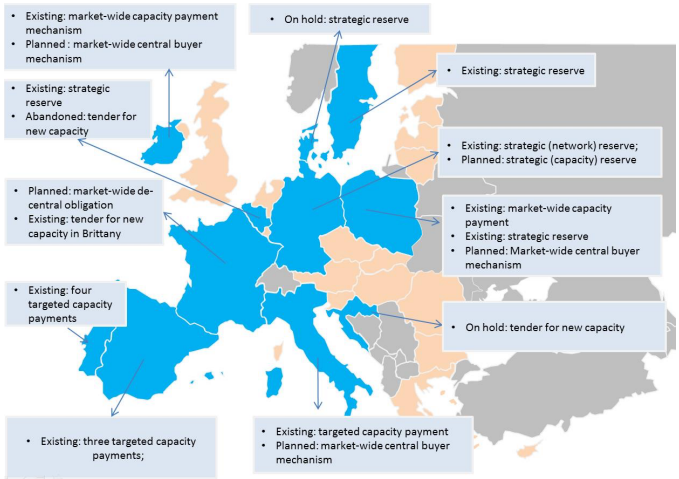

Figure 10: Capacity mechanisms (existing, planned and on hold) in the 11 Member States assessed in the sector inquiry – excluding interruptibility scheme. [Source: Europa.eu]

The sector inquiry report confirmed that capacity mechanisms can be necessary where market and regulatory failures block the price signals necessary to maintain appropriate levels of security of supply. However, the report made clear that Eu State Aid rules should be:

- Open to all types of potential capacity providers and feature a competitive price-setting process to ensure that competition minimizes the price paid for capacity,

- Designed to coexist with electricity scarcity prices to avoid unacceptable trade distortions and avoid domestic overcapacity.

- Open to explicit cross-border participation to ensure incentives for continued investment in interconnection and to reduce the long-term costs of EU security of supply.

Based on this background, on February the 7th, 2018 the European Commission has approved under EU State aid rules electricity capacity mechanisms in Belgium, France, Germany, Greece, Italy and Poland (Fig. 11).

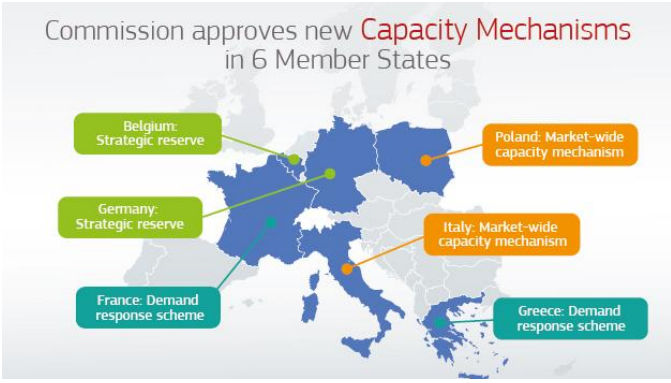

Figure 11: Six electricity capacity mechanisms approved by the Commission to ensure security of supply in Belgium, France, Germany, Greece, Italy and Poland. [Source: Europa.eu]

[4] 1st tender's average auction price was ~30k€/ MW.

In the cases of **Belgium** and **Germany**, the Commission has authorized **strategic reserves**[5]. Strategic reserves keep certain generation capacities outside the electricity market for operation only in emergencies. They can be necessary to ensure security of electricity supply when electricity markets are undergoing transitions and reforms and are meant to insure against the risk of a severe supply crisis during such transitions. Chiefly, for Belgium, the reserve is needed to mitigate the supply risks due to Belgium's high reliance on an ageing nuclear fleet, including when it comes to imported electricity. For Germany, the reserve is needed to ensure security of supply during the ongoing reform of the German electricity market and to manage the phase-out of nuclear electricity generation. The strategic reserves are procured through regular, competitive tenders open to all types of capacity providers, including demand response, to ensure effective competition and to limit costs.

In the cases of **Italy** and **Poland**, the Commission has authorized **market-wide capacity mechanisms**[6]. Under a market-wide capacity mechanism, capacity providers can obtain a payment for being available to generate electricity or, in the case of demand response operators, for being available to reduce their electricity consumption. These can be necessary where electricity markets face structural security of supply problems. In fact, Italy has demonstrated that a significant amount of capacity risks exiting the market and new investments are unlikely to take place because investors cannot earn a sufficient return from their electricity sales. Similarly, Poland has demonstrated that it is faced with market failures in the electricity market that prevent prices from incentivizing power generators to keep existing capacity in the market or to invest in new capacity.

Both mechanisms in Italy and Poland are open to all types of capacity providers, including demand response, existing and new capacities, domestic and foreign.

Both measures are temporary and support will be granted through regular, competitive tenders to allocate capacity contracts at the minimum cost. In parallel, both Italy and Poland committed to implementing reforms to the functioning of the electricity markets.

In the cases of **France** and **Greece**, the Commission has authorized capacity mechanisms specifically promoting **demand response**[7]. Demand response schemes pay customers to reduce their electricity consumption in hours when electricity is scarce; the advantage of such schemes is that demand response operators may be able to react more quickly than electricity generators. France has demonstrated that this scheme is necessary to further boost the demand response sector in the country, where extreme demand peaks during cold weather are likely to occur. In Greece, the existing scheme played an important role in managing the tight electricity situation during cold spells in December 2016 and January 2017 and the measure may be called upon again in the near future.

5. REGIONAL TSOS INITIATIVES (RSCS)

Regional Security Coordinators or RSCs are entities created by transmission system operators to assist them in their task of maintaining the operational security of the electricity system.

The first RSCs were set up on a voluntary basis by TSOs since 2008, with Coreso (based in Brussels) and TSC (Munich) as pioneers in Continental Europe. Mid-September 2017, the newly published system operation guideline (SO GL) – and indirectly the Capacity Allocation and Congestion Management (CACM) guideline - drafted under the Third Energy Package registered the RSCs into EU law.

At present, there are five operational RSCs and one additional is in the making to cover the whole of European population by end 2018 (Fig. 12).

- **Coreso** (2008) based in Brussels by the nine TSOs of 50Hz|DE, Eirgrid|IE, Elia|BE, Nationalgrid|GB, Ree|ES, Ren|PT, Rte|FR and Soni|GB and Terna|IT

- **TSC** (2008) based in Munich by thirteen TSOs of 50Hertz|DE, Amprion|DE, Apg|AT, Čeps|CZ, Eles|SI, Energinet|DK, Hops|HR, Mavir|HU, Pse|LP, Swissgrid|CH, TenneT|DE, TenneT|NL and TransnetBW|DE

- **Security Coordination Centre SCC** (2015), based in Belgrade by the South East Europe (SEE) TSOs of Ems|RS, Cges|ME and Nos BiH|BA

- **Nordic RSC** (2016), based in Copenhagen by the TSOs of Fingrid|FI, Statnett|NO, Svenska kraftnät|SW and Energinet|DK

- **Baltic RSC** (2016), based in Tallinn by the TSOs of Elering|EE, AS Augstsprieguma|LV and Litgrid|LT

- **SEE RSC** is currently being built in Thessaloniki Greece by Admie|GR, Eso|BG, Transelectrica|RO, Ost|AL, Kostt|KO*, Mepso|MK and Teias|TR

[5] 'Strategic reserve' means a capacity mechanism in which resources are only dispatched in case day-ahead and intraday markets have failed to clear, transmission system operators have exhausted their balancing resources to establish an equilibrium between demand and supply, and imbalances in the market during periods where the reserves were dispatched are settled at the value of lost load. [Ref. Commission proposal Regulation on the internal market for electricity, COM(2016)-861].

[6] This follows the Commission previous approval of market-wide capacity mechanisms in Great Britain, France and for the Irish 'all-island' market on the basis of the same criteria.

[7] This follows the Commission's approval of a specific demand response support scheme in Germany in 2016 on the basis of the same criteria.

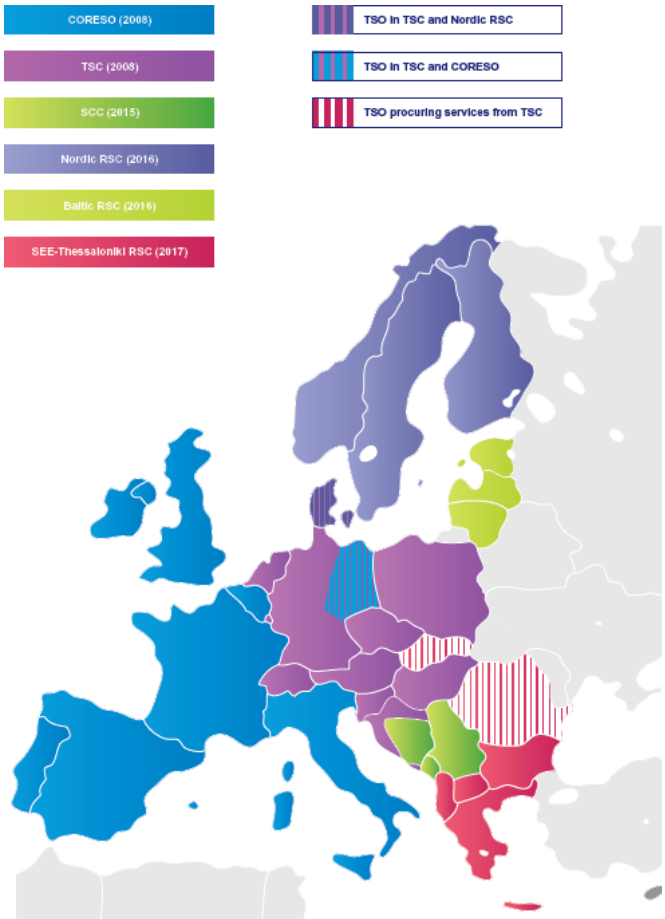

Figure 12: Coverage of the 6 Regional Security Centers (RSCs).[Source: ENTSO-E]

In December 2015, a multilateral agreement on regional operational security coordination was signed with 36 interconnected TSOs and ENTSO-E to roll out the then called Regional Security Coordination Initiatives (RSCIs) in all Europe and to have them deliver five core services to support the national TSOs' decision-making (Fig. 13).

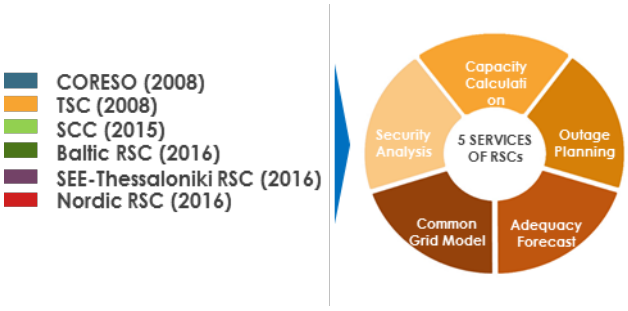

Figure 13: Mandatory services to be procured by a TSO from a RSC. [Source: ENTSO-E]

In the RSC model:

- TSOs provide data to the RSCs;
- RSCs perform analyses and provide results to TSOs until Before Real-Time operations;
- TSOs take the final decisions: full decision-making responsibility remains with the TSOs, e.g. the ultimate responsible and labile for security of supply, based on the real-time operational conditions.

Following Network Codes' full implementation beyond 2022, further regional coordination could be designed, given that a smooth and gradual deployment - based on safe evolutionary migration - is necessary in order to allow for regulatory and legal frameworks to adapt and for TSOs and RSCs to establish a new governance for system operations.[30-35]

6. TSO Cooperation Regarding the Network Development and Long Term Planning

6.1 Ten-Year Network Development Plan (TYNDP)

TYNDP reports are required on biennial basis by Regulation EC 714/2009, whereby "ENTSO-E shall adopt a non-binding Community-wide 10 ear network development plan". The formal role of the TYNDP in European electricity system development is further strengthened via Regulation (EU) 347/2013, through which the ENTSO-E TYNDP is mandated as the sole instrument for the selection of Projects of Common Interest (PCIs).

TYNDP provides a benchmark for transmission network development (scenarios, common studies, development solutions, project assessment); making use of the profound expertise of 6 Regional Groups[8], the Pan-European system development is coordinated and effectively linked with the national needs, finding synergies when relevant between European, Regional and National studies. [36-39]

As such, it provides interested parties/stakeholders – namely NRAs & MS (ACER and EC as representative of Member States), TSOs, project promoters, market players, techno providers and others (e.g. representatives of Environment-oriented Non-Governmental Organizations (NGOs), Academy and Energy research centers…) - with comprehensive support to take qualified decisions to develop the European power system in a reliable, harmonized, sustainable and connected way. Figure 14 reports a map of TYNDP 2018 project collection.

It uses a holistic approach taking into account transmission development, regulatory development and market development.

[8] RG North Sea (NS), RG Continental South West (CSW), RG Continental Central East (CCE), RG Continental Central South (CCS), RG Continental South East (CSE) and RG Baltic Sea (BS).

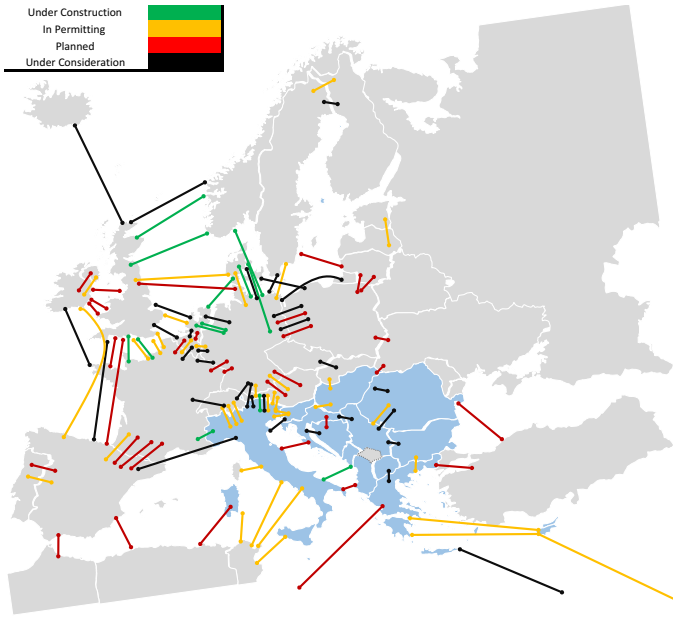

Figure 14: Map - TYNDP 2018 project collection.[Source: TYNDP 2018]

More in detail, the objectives of the TYNDP 2018 process are to deliver the four main products:

- **Scenario Report and datasets** – describe time horizons and scenarios to be used in the analysis of possible future system landscapes as well as in project assessments. The report also describes story lines, input data and Pan-European market simulation results on scenarios.

- **Pan-European system needs report** – summarizes both the approach taken to investigate possible future investment needs and the resulting investment needs on the basis of the new TYNDP 2018 long term scenarios for 2040.

- **Regional Investment Plans 2017** – present a regional focus of the future investment needs and challenges in the region – as identified by the Pan-European process and analyzed more in detail (e.g. operational aspects) in the regions. Regions can also choose to develop regional sensitivities to put an additional perspective to the previous TYNDP analysis.

- **TYNDP Report Package** – contains a number of reports and leaflets describing each project's CBA result as well as other analysis of the future system.

In November 2017, the Networks of transmission system owner for gas (ENTSO-G) and electricity (ENTSO-E) have for the first time released their joint set of scenarios. The TYNDP 2018 - Scenario Report consist of a mix of 4 bottom-up, top-down and external scenarios led by the Energy Commission, all reaching EU emission targets, as follows:

- **Sustainable transition**: this scenario, developed bottom-up[9], primarily anticipates targets are primarily reached through the combination of national regulatory incentives, emission trading schemes and subsidies. It assumes steady growth of Renewable Energy Resources, moderate economic growth, and progressive development of electrification in heating and transport sectors.

- **Distributed Generation**: this scenario, developed top-down[10], assumes targets are primarily reached through consumer/prosumer growing awareness, engagement and empowerment leading to massive penetration of small scale decentralized generation and batteries including distributed heat point allowing fuel arbitrage. It assumes high economic growth indirectly linked to the development of that new economy.

- **Global Climate Action**: this scenario, developed top-down, assumes targets are primarily reached through a strong global mobilization of government on decarbonization targets, leading to development of large scale renewables in both electricity and gas sectors, as well as string carbon price signals to the energy industry.

- **EUCO 30**: this scenario is primarily developed out of external inputs received from the Energy Commission targeting to achieve 2030 climate, energy and energy efficiency targets. This scenario combines high energy efficiency targets (30%) as well as high penetration of nuclear assets, wind and Carbon Capture and Storage mitigating coal phase out.

All these storylines imply the following general trends on generation asset portfolio:

- A reduction in **thermal generation** asset nuclear and coal (though less pronounced in the Distributed Generation scenario),

- An increase in **wind** and **solar** assets, with a different mix of centralized versus distributed assets, having impact on grid topologies

- Levels of **hydro** and **pumped storage** remain relatively constant considering the saturation of available sites

- **Biomass** and **other renewables** remain relatively constant to low levels

- Emergence of new technologies to manage grid stability whether **electrochemical energy storage**, **demand response**, **e-vehicle** or **Power to Gas**.

These scenarios (Fig.15) have the following impact on the overall European Generation and Demand technology mix:

[9] Information flow from TSOs to ENTSO-E.
[10] Information flow from ENTSO-E to TSOs.

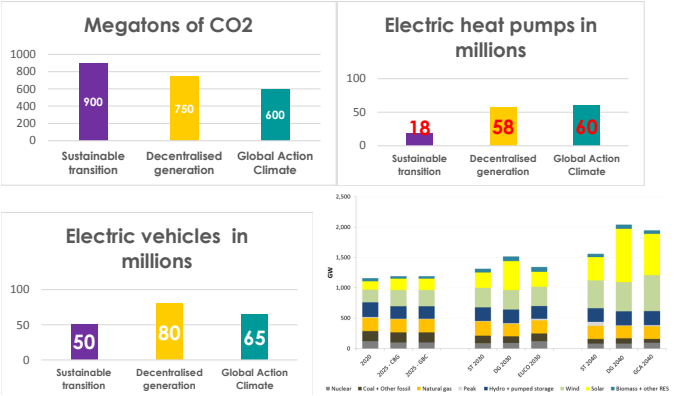

Figure 15: 2040 scenarios. Bottom right: evolution of the generation mix. [Source: IEA]

Based on these scenarios, in February 2018, ENTSO-E released of the first pan-European report "Europe Power System 2040: completing the map" providing a quantitative assessments and qualitative analysis from the transmission system operators' point of view on the hardware, software and regulatory evolutions needed by 2040, and of the costs - financial but also environmental and in terms of electricity supply - of not investing in the power networks [2].

As a result, the report concluded that, a lack of new investments by 2040 would hinder the development of the integrated energy market and would lead to a lack of competitiveness. In turn, this would increase prices on electricity markets leading to higher bills for consumers. By 2040, not reinforcing the transmission grid at borders and within countries would on average increase the total European market value by 43 billion euros per year by 2040 in an average case. This is more than three times more than the 12 billion per year Europeans need to invest to reinforce the grid according to the TYNDP 2016 [33]. At the besides, the study did also show that infrastructure's underinvesting will also affect the dynamic stability of the European grid and could, in some regions, threaten the continued access and use of renewable resources, which also has a cost for society.

6.2 *Project of Common Interest (PCI)*

The 3rd Union list of projects of common interest (PCIs) was published 24 November 2017 and replaces the 2nd list established by the Commission Delegated Regulation (EU) No 2016/89 of 18 November 2015.

The 3rd list[11] contains in total 176 PCIs including 106 electricity projects and 53 gas projects. For the first time, the list of PCIs provides for four cross-border carbon dioxide network projects.

In the case of Italy, the Commission granted/ reconfirmed the PCI status for the followings interconnections:

- Towards France, 400 Grande Ile-Piossasco (Savoie-Piemont)
- Towards Austria, Wurmlach-Somplago
- Towards Slovenia, Salgareda-Divaca
- Towards Switzerland, Thusis/Sils-Verderio Inferiore (Greenconnector) and Airolo-Baggio (San Giacomo)
- Towards Montenegro, Villanova-Lastva (within the cluster Romania aiming at to connect Italy with the Black Sea)
- Towards Corse, new entry Codrongianos-Lucciana-Suvereto (SACOI 3)
- Towards Tunisia, new entry Elmed

being, SACOI 3, Savoie-Piemont and Elmed also qualified as as "electricity highways".

Electricity PCIs are clearly identified as the most relevant projects for completing the European internal energy market, for achieving the Union's energy policy objective of affordable, secure and sustainable energy. Above all, for a project to be considered a PCI, it must be beneficial to at least two Member states, foster market integration and further competition, enhance security of supply and help reduce CO2 emissions. These projects will help Member States to comply with the 2030 climate and energy policy objectives, and the 2020 and 2030 electricity interconnection target. To easily set the above-mentioned policy pillar goals in motion, these projects benefit from (1) accelerated permit granting, increased transparency and earlier public participation, (2) improved regulatory treatment; and (3) eligibility for EU financial assistance (CEF – Connecting Europe Facility) scheduled for spring 2018.

As a member of the Cooperation Platform established by the Commission, ACER, ENTSO-G and ENTSO-E played an active role in the PCI selection process, preparing the dedicated methodologies, and developing and implementing the socio-economic and environmental cost-benefit analysis of each new interconnector.

6.3 *Cost-benefit analysis*

The Cost Benefit Analysis (CBA) methodology is developed to evaluate the benefits and costs of TYNDP projects from a pan-European perspective, providing important inputs for the selection process of PCIs. In this context, the main objective of this CBA methodology is to provide promoters (either TSOs or third parties) with a common and uniform basis for the assessment of transmission projects (including storage and its contribution in the ancillary services market, e.g. to frequency control reserve (FCR)) with regard to their value for the Socio-Economic Welfare (SEW) throughout Europe.

The Guideline for Cost Benefit Analysis of Grid Development Projects is continuously developed by the ENTSO-E in compliance with the requirements of the EU Regulation (EU) 347/2013[12]. The Regulation is intended to

[11] The list is reviewed every 2 years by the Commission and projects can be removed or added as stipulated by the PCI selection process.

[12] This is a continuously evolving process, so the ENTSO-E will review periodically the CBA methodology, in line with prudent

ensure a common framework for multi-criteria cost-benefit analysis for TYNDP projects, which are the sole base for candidate projects of common interest (PCI). Moreover, this guideline is recommended to be used as the standard guideline for project specific CBA, as required by Regulation (EU) 347/2013 Article 12(a) for the cross-border allocation of the costs process (CBCA)[13].

A detailed description of the overall assessment, including the modelling assumptions and indicators computational rulebook, is given in [1].

The cost-benefit impact assessment criteria adopted in this Guideline reflect each project's added value for society. Hence, economic and social viability are displayed in terms of **market integration** (increased capacity for trading of energy and balancing services between bidding areas), **sustainability** (RES integration, CO2 variation) and **security of supply** (secure system operations). Further benefits such as **Security of Supply** (SoS) or improvements of the **flexibility** also have to be taken into due account in the near future.

The indicators also show the effects of the project in terms of costs and environmental viability. They are calculated through an iteration of market and network studies. It should be noted that some benefits are partly, or fully, internalized within other benefits such as avoided CO2 and RES integration via socio-economic welfare, while others remain completely non-monetized (e.g. the "extra value" of transmission lines/substations regarding LOLE and "low probability, high impact events" that go beyond N-1).

The assessment of costs and benefits are undertaken using combined cost-benefit and multi-criteria approach within which both qualitative assessments and quantified, monetized assessments are included. In such a way, the full range of costs and benefits can be represented, and the overall impacts, positive as well as negative, for each project can be compared providing sufficient information to decision makers.

Figure 16 displays the main categories of indicators used to assess the impact of projects on the transmission grid. The indicators that report on EU 20-20-20 targets are marked in green.

planning practice and further editions of the TYNDP, or upon request (as foreseen by Article 11 of the EU Regulation 347/2013. At the moment, EC final approval of the CBA 2.0 is in progress and ENTSO-E drafting of CBA 3 is ongoing.

[13] The cross-border cost allocation decisions for electricity and gas infrastructure projects of common interest are one of the regulatory tools provided by the trans-European energy infrastructure EU Regulation to facilitate the implementation of PCIs. Apart from a few exceptions in 2014, NRAs and the Agency, based on project specific CBA showing in general net positive impacts in the hosting countries, decided in March 2017 to allocate investment costs following the "territorial principle", meaning that costs are borne by the country where the project is located. In some cases, NRAs allocated only part of the investment costs due to expected excessive increase in transmission tariffs, and relied on EU funds to fill the financing gap, thus putting heavy administrative burden and higher risk for TSOs to invest.

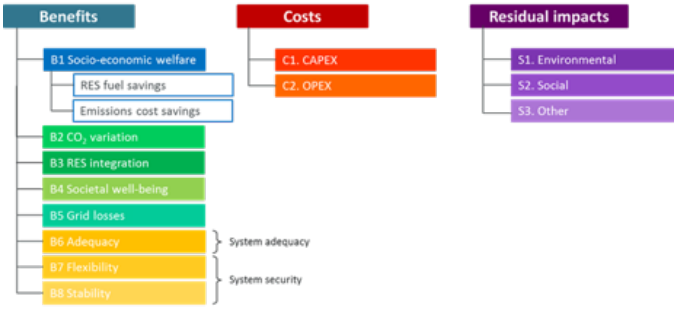

Figure 16: Main categories of the project assessment methodology.[Source: ENTSO-E]

6.4 Interconnection targets

A well interconnected and developed trans-European grids are indispensable for making the energy transition a success. To this end, The European Council of October 2014 endorsed the proposal by the European Commission of May 20142 to extend the current 10% electricity interconnection target (defined as import capacity over installed generation capacity in a Member State) to 15% by 2030 while taking into account the cost aspects and the potential of commercial exchanges in the relevant regions.

To make the 15% target operational, in March 2016 the European Commission decided to set up a Commission Expert Group on electricity interconnection targets tasked to provide specific technical advice, among others to examine if regional, country and/or border level targets to be considered. In its report delivered to Commissioner for Climate Action and Energy Miguel Arias Cañete in October 2017, the Expert Group proposes a new approach for setting interconnection targets based on the underlying principle of maximizing societal welfare.

Firstly, as a conditio sine qua non, each new interconnector must be subject to a socio-economic and environmental cost-benefit analysis and implemented only if the potential **benefits outweigh the costs**.

Secondly, new interconnectors must help exploit the benefits of market integration by enabling better prices for customers, help meet the electricity demand on the national markets and possibly offer over-supply of renewable electricity to neighboring Member States. Therefore, the development of additional interconnections should be considered if any of the following thresholds is triggered:

- **Minimizing price differentials**: Member States should aim at to achieve yearly average of price differentials as low as possible. The Expert Group recommends €2/MWh between relevant countries, regions or bidding zones as the indicative threshold to consider developing additional interconnectors;

- Ensuring that **electricity demand**, including through imports, can be met in all conditions: in countries where the nominal transmission capacity of interconnectors is below 30% of their peak load, options for further interconnectors should be urgently investigated. The proposed formula to

reflect the electricity demand and possible import need would be: nominal transmission capacity / peak load 2030.

Figure 17 and figure 18 report member states maps in relation to peak load and installed renewable generation capacity.

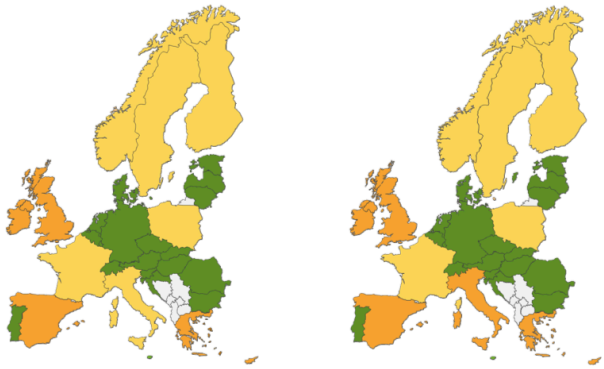

Figure 17: Member States by interconnection level as measured in relation to the peak load in vision 3 (Distributed Generation, left map) and vision 4 (Global Climate Action, right map). [Source: EC.europe.eu]

The countries in orange, Cyprus, United Kingdom, Ireland, Greece, Spain and Italy (in vision 4), have interconnection levels equal or below 30%; the countries in yellow, Italy (in vision 3), Finland, France, Poland, Norway and Sweden have interconnection levels between 30% and 60%; while the countries in green, Malta, Germany, Romania, Bulgaria, Belgium, Portugal, Czechia, Netherlands, Denmark, Estonia, Hungary, Slovakia, Lithuania, Austria, Switzerland, Croatia, Latvia, Luxembourg and Slovenia, have interconnection levels above 60%.

– Enabling **export potential** of excess renewable production: in countries where the nominal transmission capacity of interconnectors is below 30% of their renewable installed generation capacity options for further interconnectors should urgently be investigated. The proposed formula to reflect the electricity supply and the export potential would be: nominal transmission capacity / installed renewable generation capacity 2030.

The countries in orange, Cyprus, United Kingdom, Greece, Ireland, Spain, Italy, Germany, Finland (vision 3) and Romania (vision 4), have interconnection levels equal or below 30%; the countries in yellow, Romania (vision 3), Finland (vision 4), France, Portugal, Sweden, Poland and Belgium (vision 3) have interconnection levels between 30% and 60%, while the countries in green, Belgium (vision 4), Denmark, Bulgaria, Austria, Netherlands, Norway19, Switzerland, Malta20, Hungary, Latvia, Slovakia, Lithuania, Croatia, Estonia, Czechia, Luxembourg and Slovenia have interconnection levels above 60%.

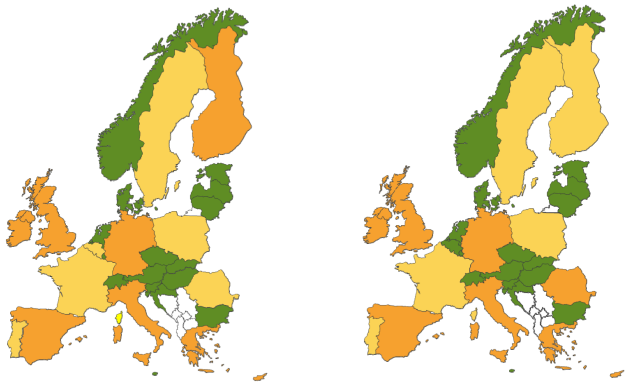

Figure 18: Member States by interconnection level as measured in relation to the installed renewable generation capacity in vision 3 (Distributed Generation, left map) and vision 4 (Global Climate Action, right map). [Source: EC.europe.eu]

While acknowledging that additional interconnection capacity is needed for the reasons given in the previous chapter, the Expert Group is of the opinion that the existing interconnectors should be used efficiently and the capacity available to the market significantly increased compared to the current utilization. The Expert Group recognizes the relevance of the ACER Recommendation on the common capacity calculation and redispatching and countertrading cost sharing methodologies issued in November 2016[14] [18]. In its Recommendation, ACER proposes to address this by establishing three principles, the first two of which are already enshrined in European legislation: 1) limitations on internal network elements' should not be considered in the cross-zonal capacity calculation methods; 2) the capacity of the cross-zonal network elements considered in the common capacity calculation methodologies should not be reduced in order to accommodate 1oop-flows, 3) the costs of remedial actions should be shared based on the 'polluter-pays principle', where the unscheduled flows over the overloaded network elements should be identified as 'polluters' and they should contribute to the costs in proportion to their contribution to the overload.

7. The Need For Grids: Risks and Challenges

7.1 Eu financing mechanisms

The **Trans-European Networks** (**TEN**) were created by the European Union by Articles 154, 155 and 156 of the Treaty of Rome - officially the Treaty establishing the European Economic Community (TEEC, 1 January 1958) – with the stated goals of the creation of an Internal Market and the reinforcement of economic and social cohesion. This

[14] ACER calculates that on average 31% of the maximal thermal capacities of the AC interconnectors for meshed and non-meshed networks is made available to the market in Continental Europe. The percentage on DC interconnectors is much higher on average – around 80% of the thermal rating.

development includes the interconnection and interoperability of national networks as well as access to such networks.

According with these objectives, the European Commission developed guidelines covering the objectives, priorities, identification of projects of common interest and broad lines of measures for the three sectors concerned:

- Trans-European Transport Networks (TEN-T)
- Trans-European Energy Networks (TEN-E)
- Trans-European Telecommunications Networks (eTEN)

The **Connecting Europe Facility (CEF)** is a European Union fund for pan-European infrastructure investment in transport, energy and digital projects which aims at a greater connectivity between European Union member states. It operates through grants, financial guarantees and project bonds. It is run by the Innovation and Networks Executive Agency.

The Trans-European Energy Networks policy and the Connecting Europe Facility (providing €5 billion to energy infrastructure for the period 2014-2020) have done a great deal to better connect and integrate Europe's gas and electricity markets. Also, the European Fund for Strategic Investments (EFSI), where the energy sector has currently the highest share, has mobilized additional €2 billion investment to the energy infrastructure, renewable energy and energy efficiency projects, including PCIs co-financed by CEF.

However, given that power sector is high risky, capital intensive and, that professional communication to the concerned local communities is useful and important to build trust and reduce public opposition, TSOs now urge a regulatory change and a reformed European Structural and Investment Funds (ESIF), EFSI and CEF to elaborate clear and comprehensive approaches for costs recovery of activities aimed at to increase investment in interconnections that bring tangible results to society and to ensure an easier sharing of costs and benefits.

7.2 Supporting regulations for the timely implementation of grid projects

Nevertheless, it is largely understood that the most efficient and cost-effective way to enable energy transition towards a fully decarbonized power sector, and to further integrate RES in the system is a timely increase of grid capacity through upgrading and expanding the grid, yet, deployment of new grid infrastructure is in several regions confronted with public opposition and thus behind schedule.

Moving forward this deadlock, the following task was given to ENTSO-E in the conclusions of the Energy Infrastructure Forum Copenhagen, 23 – 24 June 2016:

"The Forum invites the ENTSOs to set up expert groups on implementation of transmission projects in the electricity and gas sectors respectively. The experts shall examine options relevant to each sector to support the timely implementation of infrastructure projects. They shall identify, where relevant, and implement approaches that for example can help to get more acceptance from residents, that bring value locally and that facilitate political buy-in on all levels. The expert groups shall report in writing to the participants of the Forum on their findings and the progress achieved. In this context, the Forum recalls the importance of getting all stakeholders engaged to stimulating and promoting public acceptance."

Pragmatically, to address public opposition in the areas concerned, efforts need to be put in place to engage with local population even more, to jointly develop approaches to address people's concerns and needs. As such, clear and robust regulatory framework is needed to enable project developers to engage with the public in a constructive and dynamic way such to jointly deliver "better projects" on the ground – which will on one hand be more expensive and, on the other hand, minimize impacts, reduce potential conflicts and risks of failure.

TSOs Community intend to address the issue that in many countries the framework to allow for the recovery of costs resulting from enhanced stakeholder's dialogue and for measures in the projects is not sufficiently developed to steer timely project implementation that brings value to society. To this end, the following approach has been initiated under the umbrella of the ENTSO-E:

- Address the question of cost recovery for enhanced stakeholders dialogue and for implementing better projects, as expressed in the "Document Supporting regulations for the timely implementation of Grid Projects" which was jointly present by RGI and ENTSO-E at the Infrastructure Forum 2017;

- A study with Florence School of regulation addressing the economic value of timely implementation of projects even if projects costs increase;

- Share of best practice examples on new technological solutions (e.g. undergrounding cables), innovative asset designs (the so-called "grid aesthetic") and successful stakeholders' engagement, that helps significantly to improve the acceptability of projects, accelerate the permitting process or creates improved nature protection and, in the end, speed the implementation of a grid development project up.

Further to the above, it must be emphasized that, since public acceptance is the single biggest obstacle to the construction of new lines, the coming regulation should specify that congestion income may be used to cover 'all costs for activities increasing, including active stakeholder participation and costs resulting from measures for public acceptance'.

7.3 Public acceptance

While there is a great consensus in society that some electricity grids are needed for the successful transition of the electricity system towards higher shares of renewables, single grid development projects often face local opposition. During the past years, many grid operators reshaped their approach

towards engaging both organized stakeholders and the public. Many governmental and non-governmental initiatives have been started to gain more support for grid development. These address all different stages of project planning and implementation – from the need definition to the approval and construction phase.

However, concerns of affected communities still remain. They regard many different aspects, including the effect new grids might have on the environment (safeguarding biodiversity, waste produced and climate change, etc.), landscape, tourism, health (in particular the effects of electric and magnetic fields and CO2 emissions), or property prices.

While it might be unrealistic to gain the consensus of all actors involved in grid development projects in the end (acceptance of final result), chances are high that people accept the outcome of a dialogue and permitting process if they consider the procedure to be transparent, participatory and fair (acceptance of procedure). This is why TSOs continuously work on improving procedures approaches towards stakeholder engagement and public participation.

7.4 Grid aesthetics

Design and technology can play a major role when seeking better solutions for the integration of grid infrastructure in the surrounding landscape. However, this requires big engineering efforts and often entails higher costs.

Some TSOs have experimented with these new design options. In successful cases, calls for new towers' silhouette is used to engage stakeholders and the public. Most frequently, this has been done via public contests or stakeholder dialogues. This way, new pylon designs can be a starting point for local discussions and increase the number of different alternatives the grid operator can offer to stakeholders. In ideal cases, the new pylons become objects of identification and attractiveness for the specific area.

Some of the wide-ranging solutions adopted by Terna include: reaching agreement with local communities on new projects before implementation; mitigating visual impact through "green masking" initiatives, using suitable vegetation or pylons designed to integrate more effectively into the surrounding landscape. Put in practice, for instance, innovative solution in Italy consist of (Fig.19):

- **Foster** supports are pylons that won the first international "Supports for the environment" competition, designed for Terna by Sir Norman Foster, from whom they take their name. He is a British designer and architect who is one of the principle exponents in high-tech architecture.

- The single pole **tubular** pylons are a significant innovation in the creation of high and extra-high voltage lines. As well as being compact, these pylons are characterized by a reduced base size (from 250 to 50 m2) and having less of a visual impact.

- The "**Germoglio**" pylons were designed by architect High Dutton (head of the project: architect Rosental). Structural functionality, high flexibility in use, industrial feasibility and accessibility for grid maintenance operations: these are the Germoglio pylons' main characteristics.

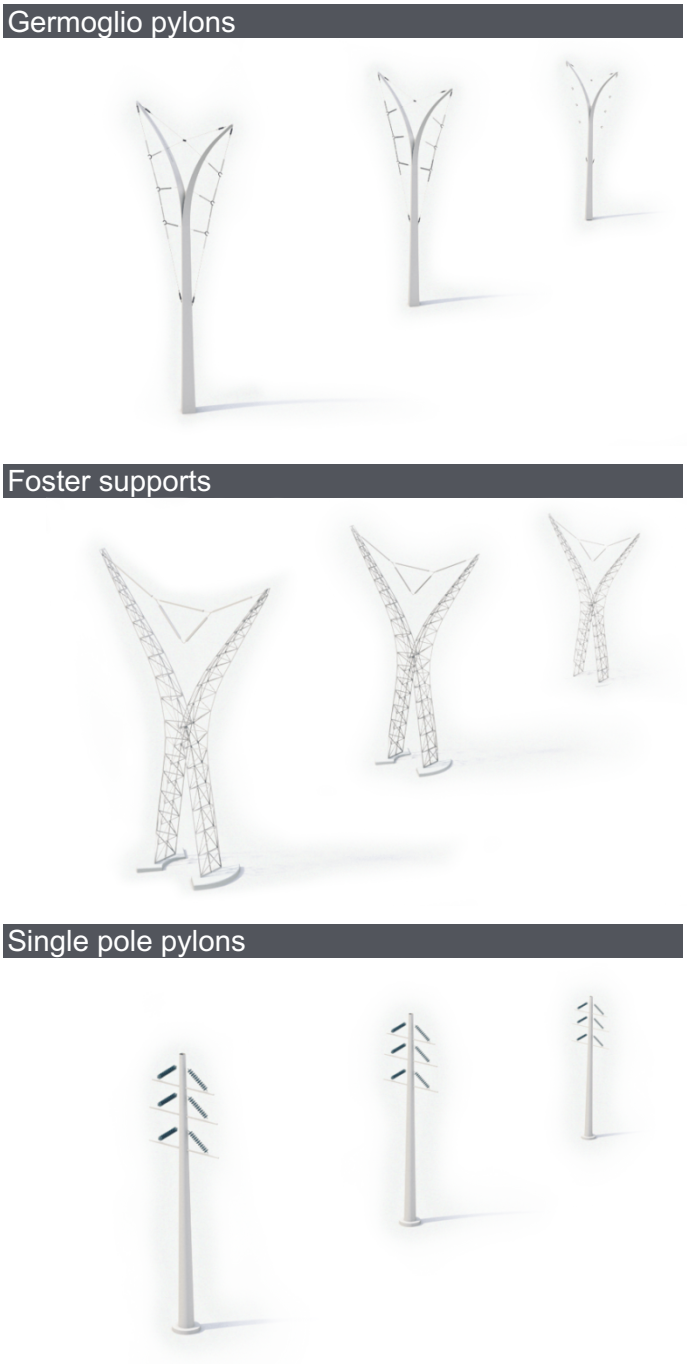

Figure 19: Innovative pylons design of Terna. [Source: TERNA]

7.5 Underground cables

Overhead lines have a range of advantages that usually make them the default option for transmission system operators: the technology is well-known and reliable; they are

easy to build and access for maintenance purposes; there is ample insight in building and operating costs that currently are estimated to be lower than those of building a cable. Cables, on the other hand, entail a reduced visual impact, which is an important argument for affected populations and local communities. Yet, laying underground cables usually requires state-of-the-art technologies and higher installation costs.

Whit this framework in place, TSOs currently aim at to determine how to evaluate the options of overhead lines vs. cables in specific natural settings, share recommendations on relevant criteria to look into, and fine-tune techniques to conveniently explain the choice of cables vs. overhead-lines to a concerned public.

According to the ENTSO-E TYNDP 2016, ~40,000 km route length of extra high voltage (EHV) power lines on land and at sea will need to be built/ refurbished by 2030. Current estimates foresee 53% of the total distance will have to be built using EHV underground and submarine cables, the majority of which being HVDC submarine cabling.

To cover this, it's paramount to figure-out how to improve the CBA to capture environmental benefits of undergrounding cables, and to quantify or monetize them in an objective manner.

7.6 Sustainability

On 25 September 2015, the 193 countries of the UN General Assembly adopted the 2030 Development Agenda titled "Transforming our world: the 2030 Agenda for Sustainable Development". Paragraph 51 of this agenda outlines the 17 Sustainable Development Goals (SDGs) - since 2017 rebranded as the 17#GlobalGoals - and the associated 169 targets. Each target has between 1 and 3 indicators used to measure progress toward reaching the targets. In total, there are 304 indicators that will measure compliance.

The SDGs cover a broad range of social and economic development issues. These include poverty, hunger, health, education, climate change, gender equality, water, sanitation, energy, environment and social justice.

For companies, this translates into a series of commitments. Terna, for example - as member of the Global Compact, the UN initiative that joins businesses in voluntarily respecting the 10 fundamental principles, and applies its own Code of ethics for establishing relations based on trust with stakeholders - is especially committed to:

- Goal 7 "Affordable and Clean Energy - Ensure access to affordable, reliable, sustainable and modern energy for all", and

- Goal 9 "Industry, Innovation and Infrastructure - Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation".

Targets for 2030 related to these goals include access to affordable and reliable energy while increasing the share of renewable energy in the global energy mix. This would involve improving energy efficiency and enhancing international cooperation to facilitate more open access to clean energy technology and investment in clean energy infrastructure. Plans call for particular attention to infrastructure support for the least developed countries, small islands and land-locked developing countries.

8. CONCLUSIONS

The electricity system in Europe is changing rapidly. While it originally was designed on the basis of centralized predictable generation ensuring steady power flows, it has progressively evolved to integrate more decentralized and variable renewable energy sources.

In the ENTSO-E's Sustainable Transition scenario, by 2030 at least 52% of the electricity consume will be generated from RES. Connecting Europe's electricity systems would allow the EU to boost its security of electricity supply and put the EU well on track to reach its climate and environmental 2030 target, being the suggested interconnection target of 15% by 2030 a powerful tool to achieved these objectives.

Renewables, particularly photovoltaics and wind onshore, have introduced new challenges for system operators in terms of infrastructure planning, innovation efforts and integration of customers as active market participants.

This paper describes the changes that are occurring in the power system and market sector, together with their drivers and underpinning regulation. At the end the paper presents the challenges in the Eu-wide planning process, starting from TYNDP and PCI and then proceeding also to technical aspects of cost-benefit analysis, interconnection targets and the Union's financing mechanisms.

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