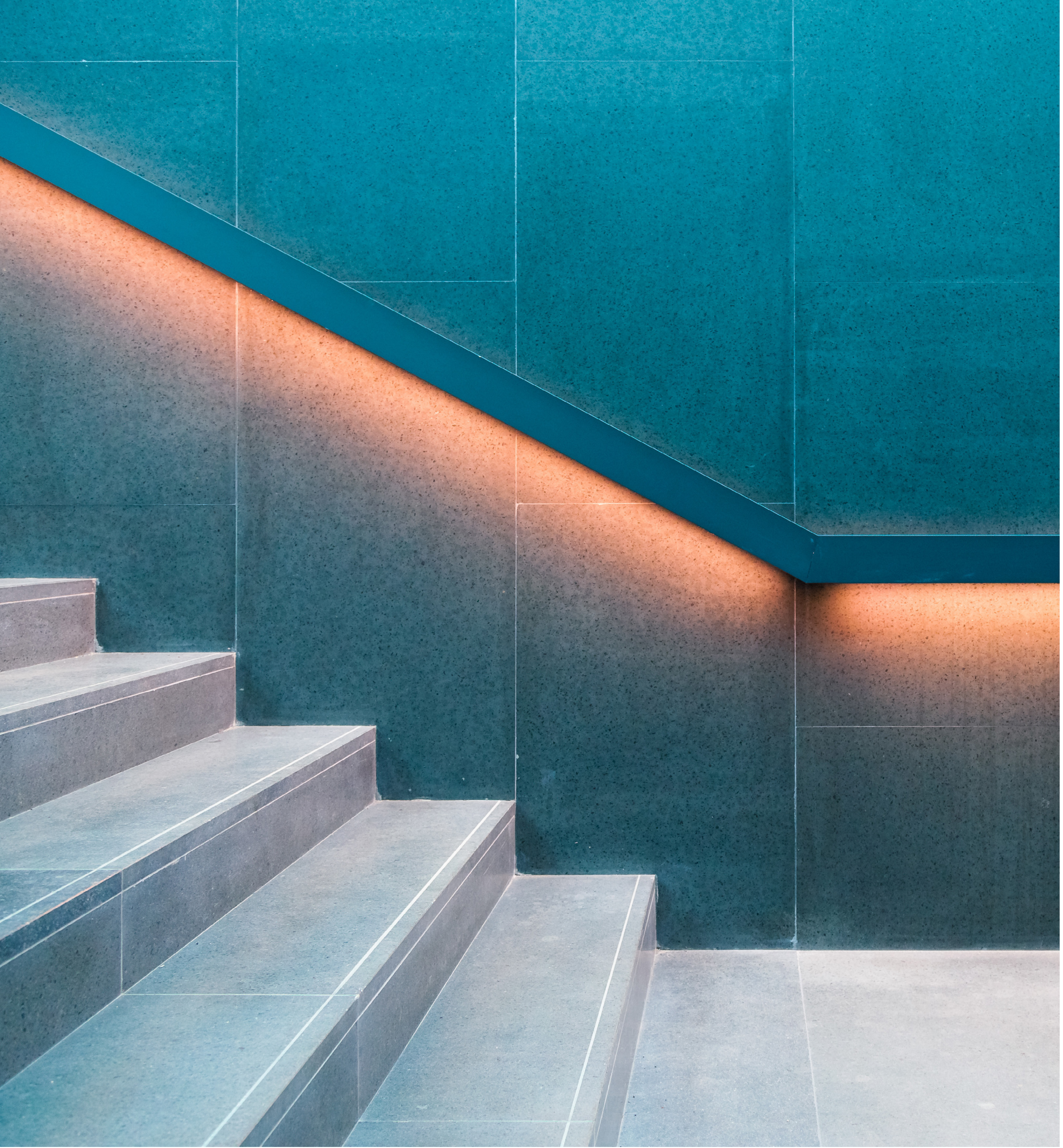
POWERFACTS EUROPE 2019



Enabling the energy transition

Europe's energy transition is a flagship project, set to deliver an integrated market, a clean energy system and a high level of security of supply for more than 500 million citizens. The European Clean Energy Package frames the next decade for energy policy and puts the EU on a path towards at least a 40% reduction in greenhouse gas emissions, a 32.5 % energy efficiency increase and a binding target for renewable energy (32%) all by 2030. Furthermore, the historic Paris Climate Agreement in 2015 highlighted the need for stepping up efforts on climate action. Europe is keen to play a leading role here.

ENTSO-E is the association of European Transmission System Operators (TSOs) and was established ten years ago by the Third Energy Package. The organisation is assigned with important legal mandates, which reflect that TSO cooperation is essential in achieving the energy and climate targets set by European leaders. This is due to TSOs pivotal role as market facilitators, drivers of innovation and operators of a large interconnected energy system with high reliability.

Europe's energy transition involves an unprecedented shift in the way markets, networks, technology and policy interplay with one another. Understanding and highlighting those dynamics is an important part of enabling the energy transition. Robust data is essential in setting out a clear picture and aiding future choices. TSOs process large amounts of data as regulated entities with strict requirements in terms of transparency. PowerFacts Europe is gathering this public data in a single place complementing it when needed by other reference sources.

> ENTSO-E PowerFacts Europe sheds light on key areas of the European energy transition.
>
> It aims to cut through complexity and presents this transformation in a clear and concise fashion, informing the debate on the energy transition.

Paris Agreement

- Sets a common goal to keep global warming well below 2°C and to target 1.5°C this century.
- Every five years: Parties to prepare, communicate and maintain a nationally determined contribution (NDC).
- Parties to reach global peaking of greenhouse gas emissions as soon as possible.

The Clean Energy for all Europeans Package

This package includes important updates to renewables and energy efficiency targets which have been adopted as of December 2018. The changes included in the package are intended to facilitate the transition by increasing interconnection targets and putting customers at the centre, amongst other key elements. This framework is needed to achieve the Energy Union and deliver on the EU's Paris Agreement commitments.

2020

CLIMATE & ENERGY PACKAGE

- 20% improvement in energy efficency
- 20% of energy from renewables
- 10% electricity interconnection target
- 20% reduction in GHGs

2030

CLEAN ENERGY PACKAGE TARGETS

- 32.5% improvement in energy efficency
- 32% of energy from renewables
- 15% electricity interconnection target

Expected to deliver a 45% reduction in GHGs

2050

ENERGY STRATEGY

- 80-95% reduction in GHGs by decarbonising the entire energy system

The 2050 Energy Roadmap explores the scope of available opportunities e.g. energy efficiency, nuclear energy, renewable energy and carbon capture and storage.

About the PowerFacts Europe report

The PowerFacts Europe report provides data and analysis in six key areas combining the traditional 'energy trilemma' that energy observers will recognise:

1. Security of supply;
2. Sustainability;
3. Affordability (described here in terms of market integration driving affordability)

with three new areas that are emerging as key within the energy transition:

4. Customers;
5. Infrastructure development;
6. Cyber physical grid.

These six areas denominate the main energy transition challenges. For each area, relevant data points have been included showing the width of issues related to the electricity system transformation.

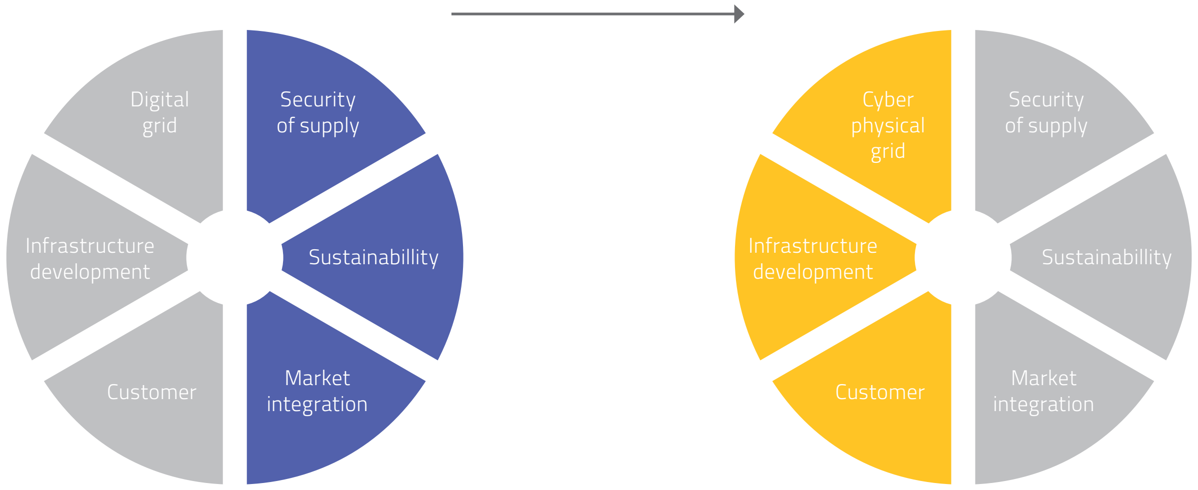
In addition to using ENTSO-E's own datapoints as the main data source, the PowerFacts Europe report also draws on additional external data to provide a complete and authoritative picture that will enrich the discussion on progress towards the energy transition.

Combining...

Traditional dimensions

...with

new ones



Summary of findings

1. Security of supply

Europe enjoys one of the world's most reliable power grid, and the prime objective is to maintain this, as new challenges arise over time. Innovation, cooperation and transparent information-sharing will be needed to cost-effectively manage operations. A new variability paradigm resulting from solar and wind generation deployment highlights a greater focus on flexibility in the system across Europe.

CHAPTER HIGHLIGHT: In 2017, only two minor incidents were registered on the transmission grid and both took place in isolated systems (islands).

2. Sustainability

European leaders have committed to ambitious decarbonisation targets. As of December 2018, new 2030 targets have been adopted which set a renewable energy target of 32%, and energy efficiency improvements at 32.5% alongside the existing 40% greenhouse gas emission target. The Paris Agreement and the Commission's 2050 long-term strategy lead towards near to full decarbonisation of the power system.

CHAPTER HIGHLIGHT: TSOs have facilitated the integration of 54 GWs of additional variable Renewable Energy Sources (RES) (wind and solar) capacity since 2015. This is nearly double the wind and solar capacity added in the US since 2015[1].

3. Market Integration

Market integration delivers welfare to European citizens, enables the integration of larger quantities of variable renewables, and helps maintain security of supply through the creation of larger, more liquid and efficient energy markets.

TSOs and NEMOs (Nominated Electricity Market Operator) have made good progress in coupling day-ahead and intraday markets, delivering the regulatory alignment needed to allow for optimal matching of bids and offers between zones. However, cross-zonal capacity challenges remain an important area for further collaboration in 2019. Here, market network codes will continue to play a crucial role in harmonising regulations to deliver fair, efficient and safe trading outcomes across Europe.

CHAPTER HIGHLIGHT: 26 countries have coupled their day-ahead electricity markets – together these countries account for over 90% of European electricity consumption and this brings together over 400 million people. This progress has been reflected in an increase in the efficiency of interconnector use for day-ahead trades. Welfare gains are also significant when one considers the integration of balancing markets with an average of 400 million euros per year.

4. Customers

The power system should be opened up to greater customer participation. Initial progress has been made in encouraging industrial and household customers to offer energy services, but more should be done to establish the products, incentives and market-conditions needed to expand participation and help customers become solution providers.

Whilst the benefits of the energy transition are increasingly evident, it is important that the 50+ million Europeans in energy poverty are not left behind.

CHAPTER HIGHLIGHT: Markets are opening to new participants and services. The reported volume of demand side response in balancing markets increased by 260% in France, 112% in Finland, and 143% in Belgium from 2016 to 2017.

[1] Source: EPA Electric Power Annual table 04_02. US solar and wind capacity increased by 28GW between 2015-2017.

5. Infrastructure Development

In its 2040 No Grid scenario, ENTSO-E illustrated that a lack of investment in the transmission system would increase marginal prices by 3%-29% depending on regions, increase the curtailment of renewable electricity, and harm security of supply. Whilst the development of physical infrastructure is only one part of the wider solution, it is fundamental to delivering a cost-effective energy transition. For Europe to maintain resource adequacy, infrastructure will need to allow system operators to address variable patterns of consumption and demand, couple sectors, and integrate increasing volumes of renewable energy.

Among others, a combination of new transmission and storage projects will be needed to enable a secure and cost-effective transition to a low-emission electricity system. Accurate assessment of system needs will be crucial in providing a solid ground for future infrastructure investment.

CHAPTER HIGHLIGHT: ENTSO-E's Ten-Year Network Development Plan (TYNDP) envisages €114bn worth of grid projects to be invested in by 2040. TSOs are already delivering infrastructure today, with 59% of active Projects of Common Interest (PCIs) delivered either on-time or ahead of schedule. However, 25% of the projects are delayed, mainly due to a lack of public acceptance. Not developing grids in time translates to high costs for European customers. Without investment in grid infrastructure, the ENTSO-E European Power System 2040 'No Grid' scenario foresees extra system costs of €43bn per year by 2040.

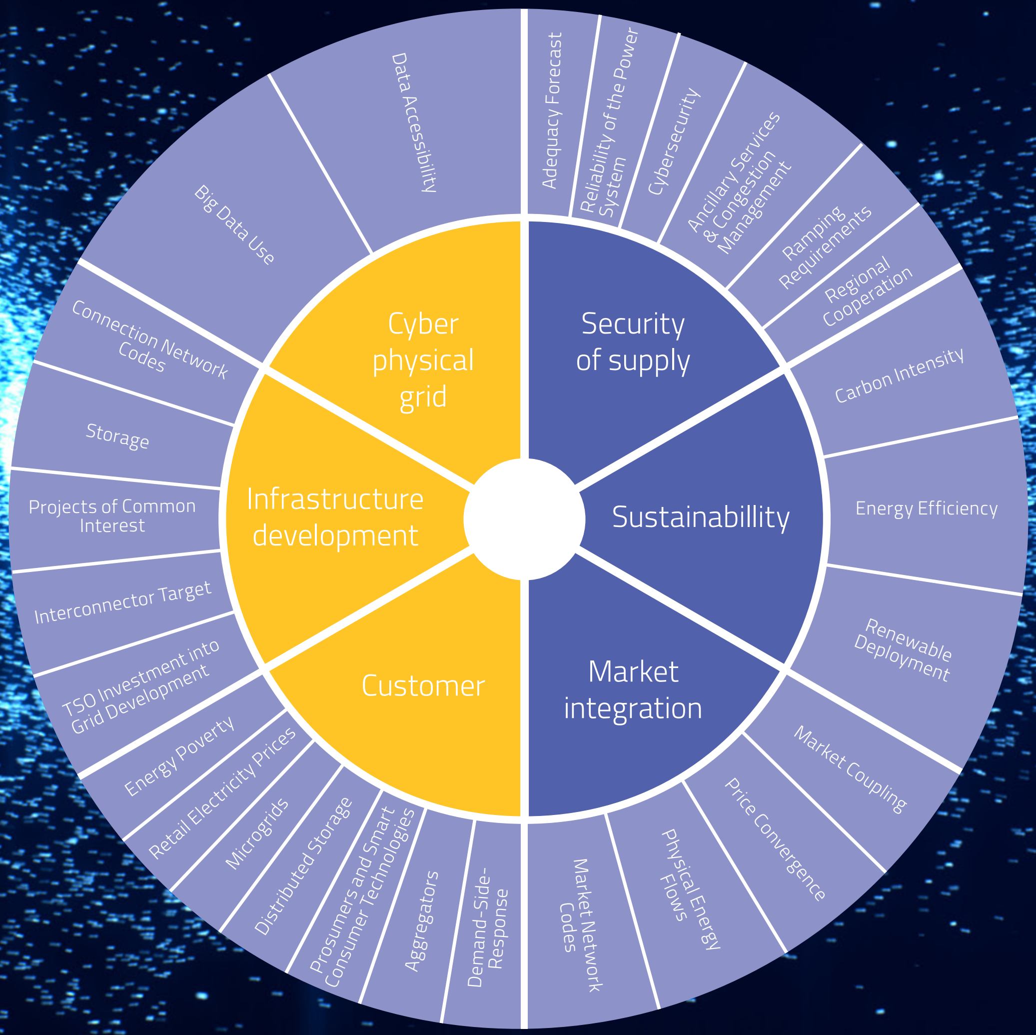
6. Cyber physical Grid

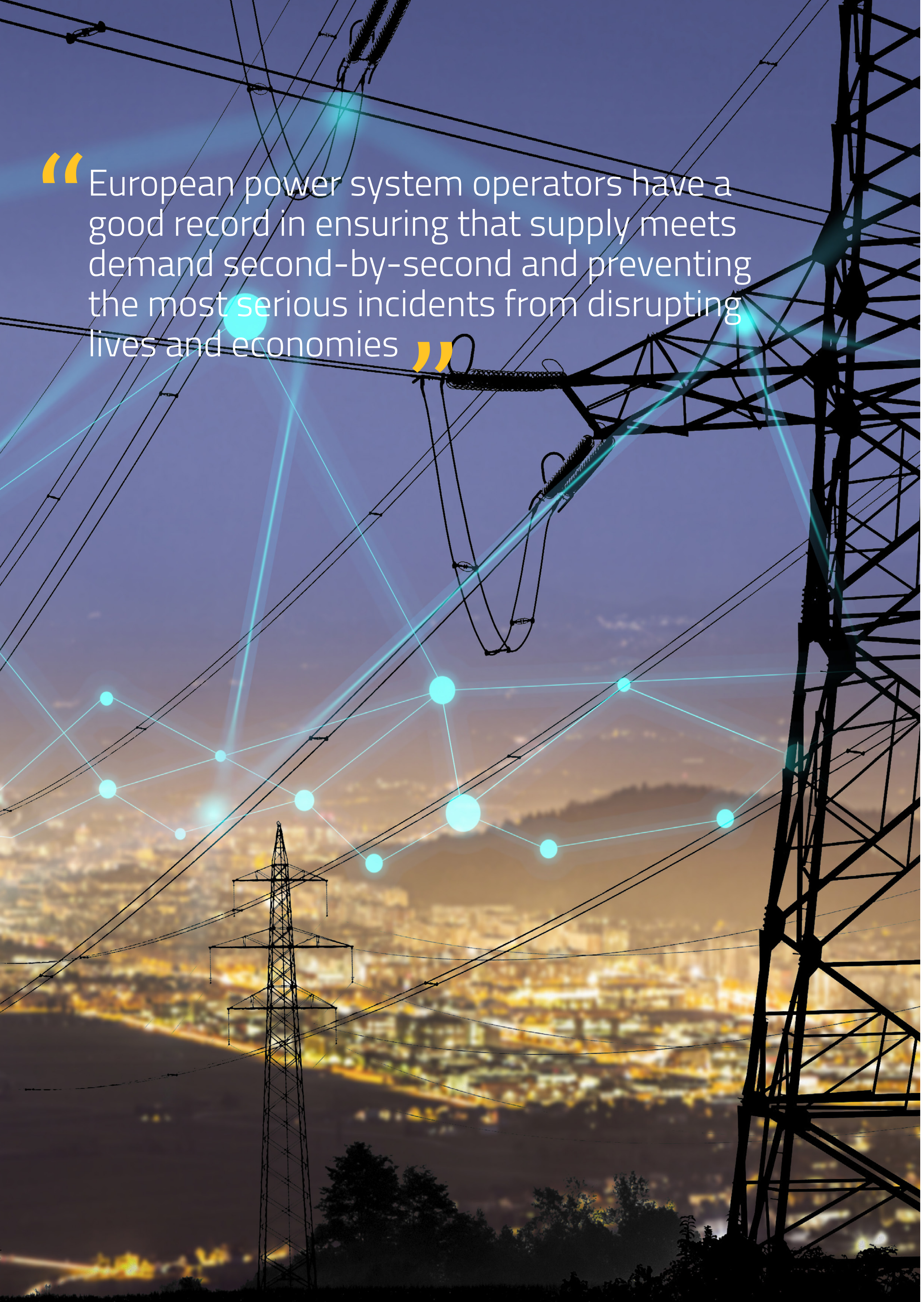
Digitalisation means the increased use of information and communication technology (ICT) and enables the timely and transparent transfer of large amounts of data with extremely low transaction costs. These signals – to market participants and system operators – create the opportunity to optimise the energy market, supported by new service propositions, increased system flexibility and secure grid operation. This emerging digital layer – sitting atop existing physical grid infrastructure – will support new services and empower customers.

Open and transparent data availability is key to enabling the digital grid. ENTSO-E is already enabling these developments through the publication of data on the ENTSO-E Transparency Platform, and the coordination of big data research and innovation projects. Additionally, progress made by TSOs in establishing the Common Grid Model (CGM) will define an agreed dataset for harmonised simulation of the power system.

CHAPTER HIGHLIGHT: The number of registered users on ENTSO-E's Transparency Platform increased from 6,700 in 2016 to 12,000 in 2017. More open data facilitates informed and efficient decision-making from all market participants, increasing trust, and creating the foundations for the development of new services and solutions. TSOs have agreed to a Common Grid Model, creating a consistent methodology for forecasting which improves coordination across regions.

PowerFacts Europe 2019 chapters and subchapters





> “European power system operators have a good record in ensuring that supply meets demand second-by-second and preventing the most serious incidents from disrupting lives and economies”

CHAPTER 1 - Security of Supply

Even with a rapidly changing energy system, Europeans continue to enjoy a high level of security of supply. As this chapter will show, Europe has an excellent record in delivering reliable power, with demand curtailments[2] being an extremely rare event (1.1 Reliability of the power system). In addition, ENTSO-E has developed advanced modelling methodology to assess risk of loss of load expectation– a security of supply indicator- in the coming decade (1.2 Adequacy forecast). Monitoring is key to ensure that these high security of supply levels can be maintained.

System operators are developing new tools and solutions from regional cooperation to digitalisation. The aim is to connect the dots between different sectors of the economy, markets, and systems; between the actors of the power system. countries and regions.

Digitisation empowers customers and enables new energy services. Such services can support flexible demand-response to variable generation (1.6 Ramping needs) and allow more effective maintenance and operation of the network (e.g. 6.1 Big data). The Internet of Energy brings new challenges such as risks of cyberattacks (1.3 Cybersecurity).

PowerFacts Europe tracks these developments and provides readers with an overview of key datapoints and trends.

1.1 Reliability of the Power System

Context

European power system operators have a good record in ensuring that supply meets demand second-by-second and preventing the most serious incidents - blackouts - from disrupting lives and economies. History illustrates the potential impact of such incidents. For instance, in 2006 an incident on the North German transmission grid led to a split of the interconnected power system of Continental Europe, leading to 15 million households experiencing power supply disruption across 20 countries[3] .

Fortunately, such blackouts are increasingly rare. Other minor network-related incidents are more likely to take place despite the best efforts to make the power system as resilient as possible. Whilst it is unreasonable or uneconomic to build resilience to very extreme events, it is crucial to monitor such incidents and base investment decisions on data-led analysis. It is therefore important to collect information, take learnings and develop coordinated responses as stakeholders in an interlinked European electricity system.

This subchapter provides open information on the number and characteristics of network incidents that occurred in Europe during 2017. More detailed information can be found in ENTSO-E's 2018 report (see sources).

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[2] Moments in time when demand for electricity cannot or is not met by supply, it is therefore curtailed.

[3] https://www.entsoe.eu/fileadmin/user_upload/_library/publications/ce/otherreports/Final-Report-20070130.pdf

Figure 1 - Network incident classification scale

Scale 0 Anomaly		Scale 1 Noteworthy incidents		Scale 2 Extensive incidents		Scale 3 Major or widespread incidents	
Priority / Short definition		Priority / Short definition		Priority / Short definition		Short definition	
#17	Incidents leading to frequency degradation (F0)	#9	Incidents on load (L1)	#2	Incidents on load (L2)	#1	Blackout (OB3)
#18	Incidents on transmission network elements (T0)	#10	Incidents leading to frequency degradation (F1)	#3	Incidents leading to frequency degradation (F2)		
#19	Incidents on power generating facilities (G0)	#11	Incidents on transmission network elements (T1)	#4	Incidents on transmission network elements (T2)		
#20	Violation of standards on voltage (OV0)	#12	Incidents on power generating facilities (G1)	#5	Incidents on power generating facilities (G2)		
#21	Lack of reserve (OR0)	#13	N-1 violation (ON1)	#6	N violation (ON2)		
		#14	Violation of standards on voltage (OV1)	#7	Separation from the grid (RS2)		
		#15	Lack of reserve (OR1)	#8	Loss of tools and facilities (LT2)		
		#16	Loss of tools and facilities (LT1)				

Trends
All ENTSO-E members monitor and report incidents using a consistent methodology and classification scale based on severity (see Figure 1). The following analysis is the result of examining each of these reports and provides a summarised view of the number and severity of incidents across Europe over recent years.

A total of 1,072 incidents were reported by TSOs in 2017, 13% more than in 2016. Despite this increase, more than 60% of the incidents were characterised as anomalies (scale 0). These are the least serious incidents recorded by European TSOs. During these events the system remains within operational security limits and returns to a normal state after the incident.

At the other end of the scale, there were no major or widespread blackout incidents, scale 3 events during 2017. Figure 5 provides an overview of the distribution between incident types in 2017.

As shown in Figure 2, at the synchronous area level, Continental Europe reported the highest number of incidents (largely scale 0 and 1) followed by Great Britain.

Isolated systems and the Nordic area were the only synchronous areas to report a higher number of scale 1 incidents compared with scale 0 incidents. This was due to incidents on High Voltage Direct Current (HVDC) interconnectors leading to reductions in cross-border exchange capacities.

Most incidents occurred on transmission network elements (73% of all incidents) with all synchronous areas reporting this at scale 0. Incidents at power generation facilities at scale 1 occurred only in isolated systems. Isolated system – islands (Cyprus and Iceland) – were the only areas to report a scale 2 incident which involves the power system entering an emergency state after the event with one or more of the operational security limits being breached (see Table 1).

Figure 2 - 2017 network-related incidents classified by severity

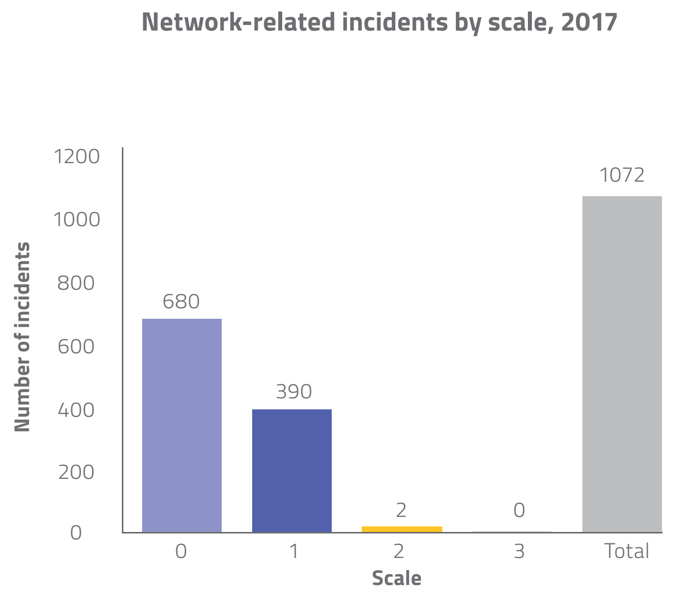


Figure 3 - 2017 network-related incidents by synchronous area

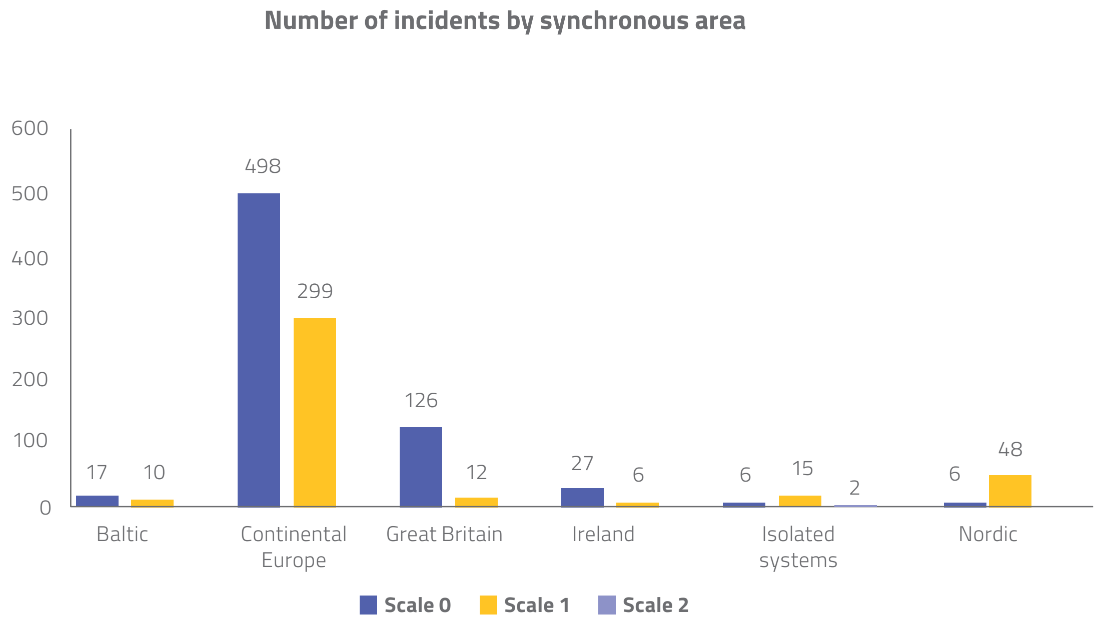


Table 1 - Summary of 2017 network incidents by scale and synchronous area

		Baltic	Continental Europe	Great Britain	Ireland	Isolated systems	Nordic	Total
Scale 0	Lack of reserve		1					1
	Incidents on power generation facilities		84	2	24	1		111
	Violation of standards on voltage		27					27
	Incidents on transmission network elements	17	375	124	3	5	6	530
	Disturbance leading to frequency degradation		11					11
Scale 1	Loss of tools and facilities		18	2	2		2	24
	Lack of reserve		12					12
	Violation of standards on voltage		21					21
	N-1 violation		66					66
	Incidents on power generation facilities					2		2
	Incidents on transmission network elements	10	181	8	6	6	44	211
	Events on load		1			7	2	52
Scale 2	Events on load					2		2
	Total	27	797	136	35	23	54	1072

Both scale 2 events involved a momentary loss of load. The first - caused by tripping during maintenance work on a power plant - led to the loss of 690 MW in generation and a loss of load of approximately 614 MW. The second incident was caused by a transmission line fault which resulted in a 5-minute frequency deviation and subsequent loss of generation (229 MW) and load disconnection (96 MW).

Higher severity incidents (scale 2 and 3) have been negligible in absolute numbers and as a proportion of overall incidents over time. Scale 0 incidents have been generally decreasing from just over 80% in 2013 to 63% in 2017. However, they still account for the highest proportion of overall incidents. This decrease has been offset by a rise in scale 1 incidents which have increased from 15% in 2013 to 36% in 2017.

Sources:
ENTSO-E (2018) *2017 Incident Classification Scale Annual Report 2017.*
Available from: https://docstore.entsoe.eu/Documents/SOC%20documents/Incident_Classification_Scale/180925_ICS_report_2017.pdf

Royal Academy of Engineering (2014) *Counting the cost: the economic and social costs of electricity shortfalls in the UK.*
Available from: https://www.raeng.org.uk/publications/reports/counting-the-cost

European Commission (2007) *Blackout of November 2006: important lessons to be drawn.*
Available from: http://europa.eu/rapid/press-release_IP-07-110_en.htm?locale=en

1.2 Adequacy forecast

Context

A secure and reliable supply of electricity is a necessary requirement of a well-functioning economy. Reducing the likelihood of system disturbances or, in the extreme, load (demand) shedding is a fundamental objective of European energy policy. The data in figure 4 from the World Bank compares the proportion of companies experiencing electrical outages in some parts of the world. It shows the Euro area outperforms the OECD country average.

This will remain a key consideration as the energy system transitions rapidly over the coming years. The integration of new forms of generation - diverse in location and operation profile – as well as rapidly changing demand from new consumer technologies powered by breakthroughs in technology, poses a different set of challenges for grid operators.

Trends

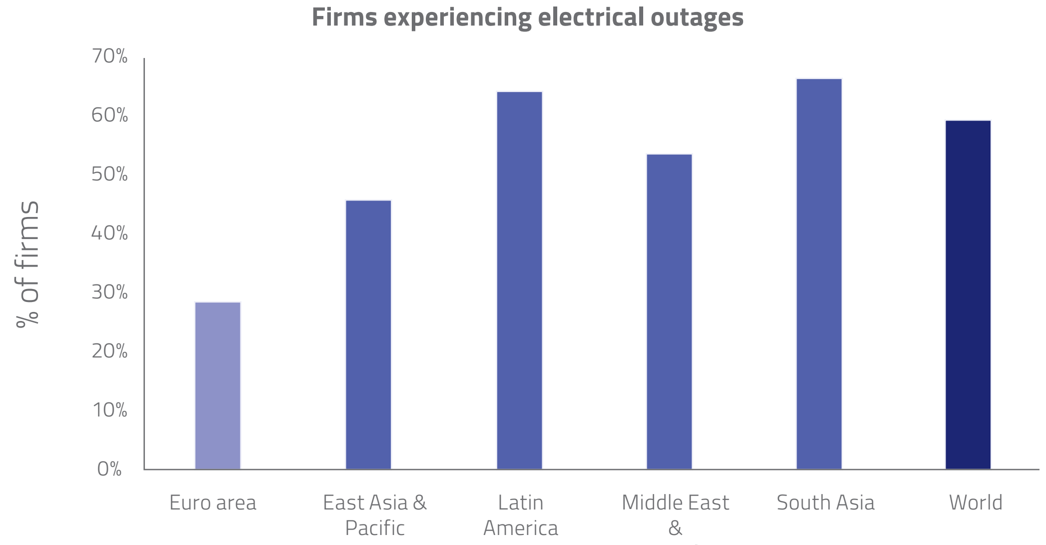
ENTSO-E's analysis provides deep insight into the relative likelihood of network disruption in European countries. The Mid-term Adequacy Forecast (MAF), assesses the adequacy of available supply resources to meet simulated demand scenarios across Europe. This annual exercise provides an overview of the state-of-play across a ten-year time frame. Ten years is usually the time frame during which policy makers, investors and market participants make strategic decisions so as to allow the power system to deliver a targeted level of adequacy. Under the Clean Energy Package, the new EU legislative package for electricity, a pan-European resource adequacy assessment developed by ENTSO-E, with an extended scope compared to the current MAF, shall in the future complement and challenge national assessments.

Such forecasting exercises focus on the likelihood of unusual events disrupting supply. The results are derived from many simulations providing a probabilistic interpretation of the likelihood of lack of supply.
One such metric explored in the MAF is loss-of-load expectation (LOLE). Simply put, it is the average number of hours per year in which it is statistically expected that there is not sufficient power supply in the market to cover demand. Note that this is not translated in a blackout as the analysis keeps security margin for unforeseen events near real time. Again, it is a probabilistic assessment based on models, and as mentioned earlier, figures show that Europe has a relatively good record in ensuring security of supply.

Crucially, such assessments are based on the best available estimates of generation, storage, transmission and demand-side data. Pertinently for all electricity market operators, LOLE is therefore influenced by any expected change in the whole system, (e.g. available generation and storage, demand profile, grid infrastructure…). That's why a yearly updated edition of the MAF is important to support monitoring European security of supply.

The MAF 2017 identified potential challenges in Poland, Finland and Sicily, with relatively high LOLE simulation results for 2025. The MAF 2018 shows less adequacy risks for most European countries and power system zones, including Poland, Finland and Sicily.

Figure 4 - Firms experiencing electrical outages by region, 2017



Source: World Bank

Figure 5 shows the base case LOLE figures for 2025 from the MAF 2018 simulations. The larger dots signify higher estimates and suggest potential challenges in peripheral countries.

Note that many countries have either very small or no dots at all. This signifies that the expected loss of load in best estimate 2025 in these Member States is very low – i.e. the security of supply outlook is positive in the MAF 2018 edition. Each edition is a last update of the best estimate, so any investment by market actors (either in new resource or decommissioning) would change the outlook. Therefore, the MAF has a role of watchdog for European security of supply for a decade ahead.

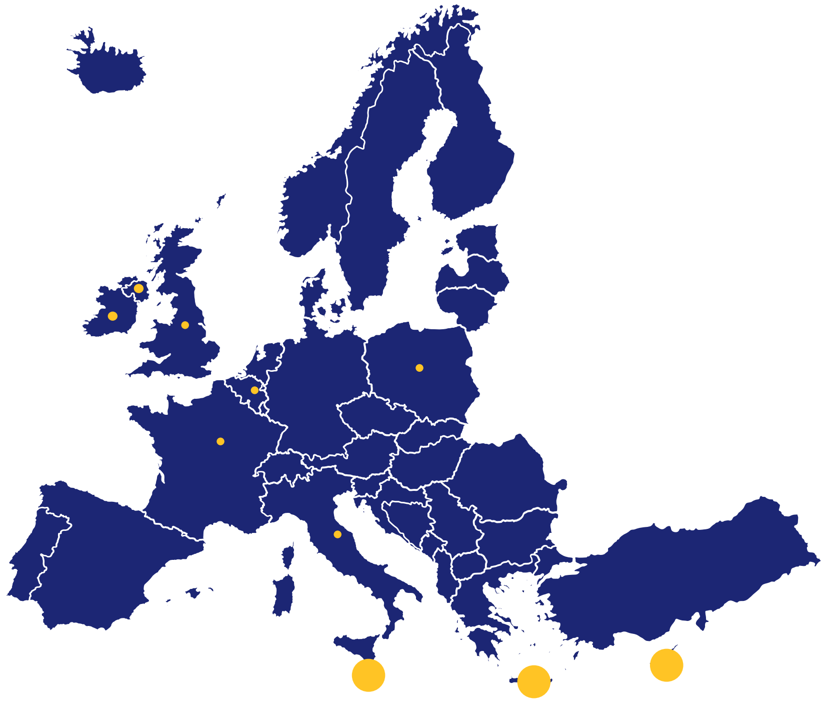
In the MAF 2018, a low-carbon sensitivity scenario considers some of the potential changes, specifically the thermal generators at risk of being closed over the next seven years due to environmental policies. This is a stress-test and considers 'what if' an estimated number of thermal units at risk of shutting down are not replaced by other resources. Figure 5 illustrates the results and shows increased LOLE in this low-carbon scenario as expected and highlights the need for other resources to be developed (DSR, storage, generation and interconnection). More detailed analysis is available in the MAF 2018.

The ENTSO-E MAF provides a detailed and state-of-the-art analysis of security of supply from the pan-European point of view. It is complemented by further studies at regional and national levels.

The Clean Energy Package reinforces the role of the MAF and methodologies between pan-European, regional and national assessments will need to be streamlined.

Sources:
ENTSO-E (2018) *Mid-term adequacy forecast 2018.* Available from: https://www.entsoe.eu/outlooks/midterm/
ENTSO-E (2017) *Mid-term adequacy forecast 2017.* Available from: https://www.entsoe.eu/outlooks/midterm/
World Bank (2018) *Firms experiencing electrical outages (% of firms).* Available from: https://data.worldbank.org/indicator/IC.ELC.OUTG.ZS

Figure 5 - Comparison of 2025 LOLE from the base case and low-carbon sensitivity scenarios in the 2018 MAF



LOLE (h) - Base Case 2025

LOLE (h) - Low-Carbon Sensitivity 2025

1.3 Cybersecurity

Context
The increasing digitalisation of systems and assets within the energy network offers economic benefits and is crucially tied to the success of the energy transition. The development of the digital grid on top of an extended and adapted physical grid will be key to Europe's energy transition.

The cyber-physical grid will rely increasingly on power platforms that connect the dots within the power system vertically and horizontally, and between other sectors of the economy and energy vectors (e.g. the gas-grid, heat and transport). The cybersecurity risks associated with such digital platforms and devices need to be equally well understood if Europe is to ensure that the power system remains resilient to attacks.

Indeed, business surveys suggest that the energy industry has some of the highest annual costs of cybercrime (see Figure 6). Energy companies are increasingly aware that cybersecurity is a risk to key infrastructure and business operations.

Trends
The European cybersecurity market is expected to have been worth a forecasted $25bn in 2018, up 72% on the 2012 level. This spending is on products and services (70% of total expenditure) which are designed to protect organisations from cyberattacks. Increasingly, much of these services are outsourced and procured externally via managed security offerings.

The European power grid is becoming more and more interconnected and is relying on interoperability of the national high, medium and low voltage grids and operational processes. TSOs are connected bilaterally, regionally (in RSCs) and at pan-European level (ENTSO-E). Furthermore, as market facilitators, TSOs must interact with market platforms. In the future, the IT interface between TSOs and DSOs and between TSOs and new market players will expand to enable the energy transition.

As all TSOs (and DSOs) are highly connected and therefore rely on each other on technical levels and for operational processes, incidents occurring in the IT/OT landscape of one TSO can/will have effect on other TSOs and (ultimately) on the security of supply.

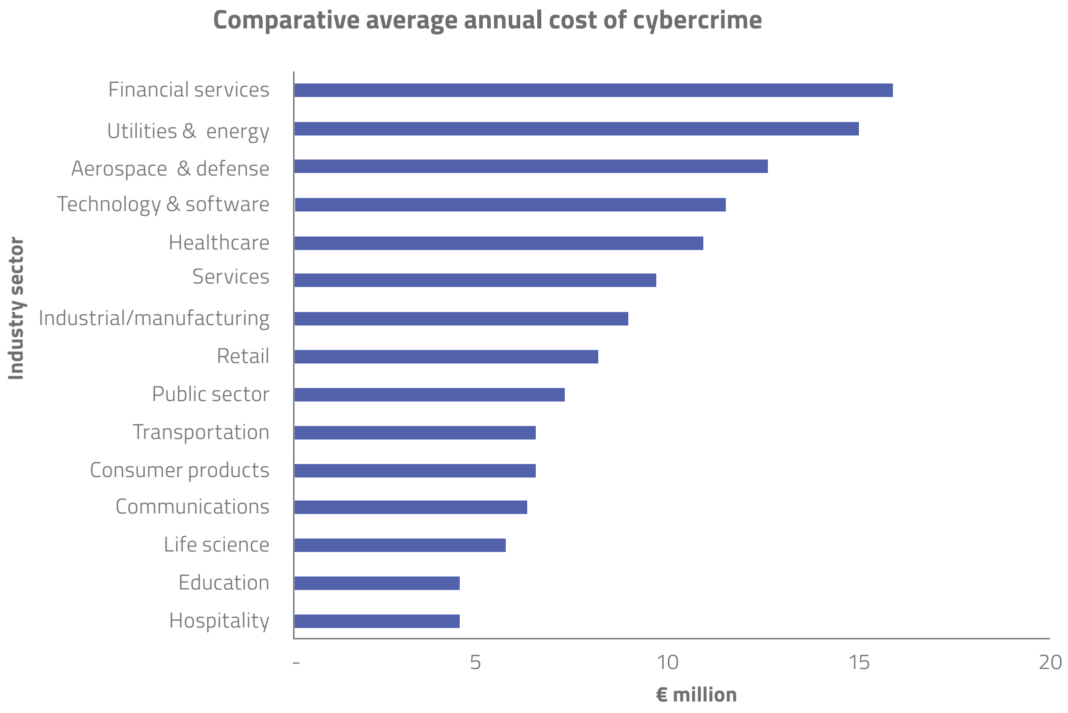
The importance of cybersecurity as an issue for all network operators across Europe has been reflected in actions taken by ENTSO-E and other pan-European partners.

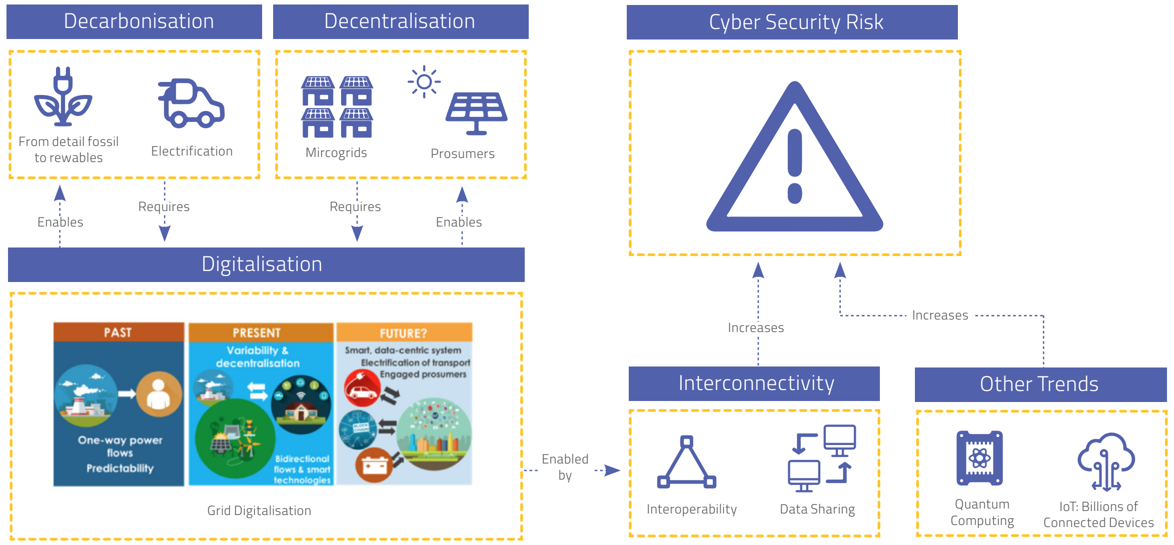
This strategy is clearly aimed at mitigating the risks specifically related to the power sector. In the same spirit, ENTSO-E is cooperating with DSOs and notably the European association E.DSO on cybersecurity and organising dedicated events and workshops. ENTSO-E has also signed a memorandum of understanding with the European Network for Cyber Security (ENCS) to support the development of cybersecurity good practices and standards.

Since 2017, ENTSO-E is actively participating to the European Commission Smart Grids Task Force (SGTF) dedicated working group on cybersecurity. This group gathers expert members from TSOs, DSOs, vendors, aggregators and manufacturers and produces regular reports.

In the future, there is scope for European institutions to decide to develop a dedicated European network code on cybersecurity if the need is identified.

Figure 6 - Comparative annual costs of cybercrime by industry (source: Accenture)





Sources:
Accenture (2017) *Cost of Cybercrime study: Insights on the security investments that make the difference.*
Available from: https://www.accenture.com/t20170926T072837Z__w__/us-en/_acnmedia/PDF-61/Accenture-2017-CostCyberCrimeStudy.pdf
Smart Grids Task Force – Expert Group 2, Cybersecurity (2018) *2nd Interim Report.*
Available from: https://ec.europa.eu/energy/sites/ener/files/sgtf_eg2_2nd_interim_report_final.pdf

1.4 Ancillary Services and Congestion Management

Context
Ancillary services and congestion management are typically linked to market facilitation activities of the TSOs.

This report is including these activities under the Security of Supply chapter for the purpose of highlighting the nature of the operational challenges that the TSOs face in a system with an increasing share of variable renewables. This is to raise awareness also on the need to develop solutions to meet these challenges being in market design, innovation, efficiency, demand response, infrastructure development and upgrading, and storage.

Ancillary services

Ancillary services help system operators maintain and restore the balance between supply and demand of electricity after the (wholesale) market has closed. They play an important role in ensuring that the electricity system is balanced second by second and can respond flexibly to sudden changes in supply or demand. These services include Frequency Containment Reserve (FCR), Automatic Frequency Restoration Reserve (aFRR) and Manual Frequency Restoration Reserve (mFRR) which maintain the system's frequency with very rapid responses to changes in supply or demand, Replacement Reserve (RR) which restores the required level of FRR given imbalance, black-start capability in the event of blackout and others.

A broadening pool of market participants – including aggregators and demand response providers - participate in the ancillary services market. Whilst these markets are evolving and differ between member states, Figure 7 provides a typical representation of the timescales in which the different products are activated and procured. Demand side response (4.1) and storage (5.4) are important parts to the ancillary services equation.

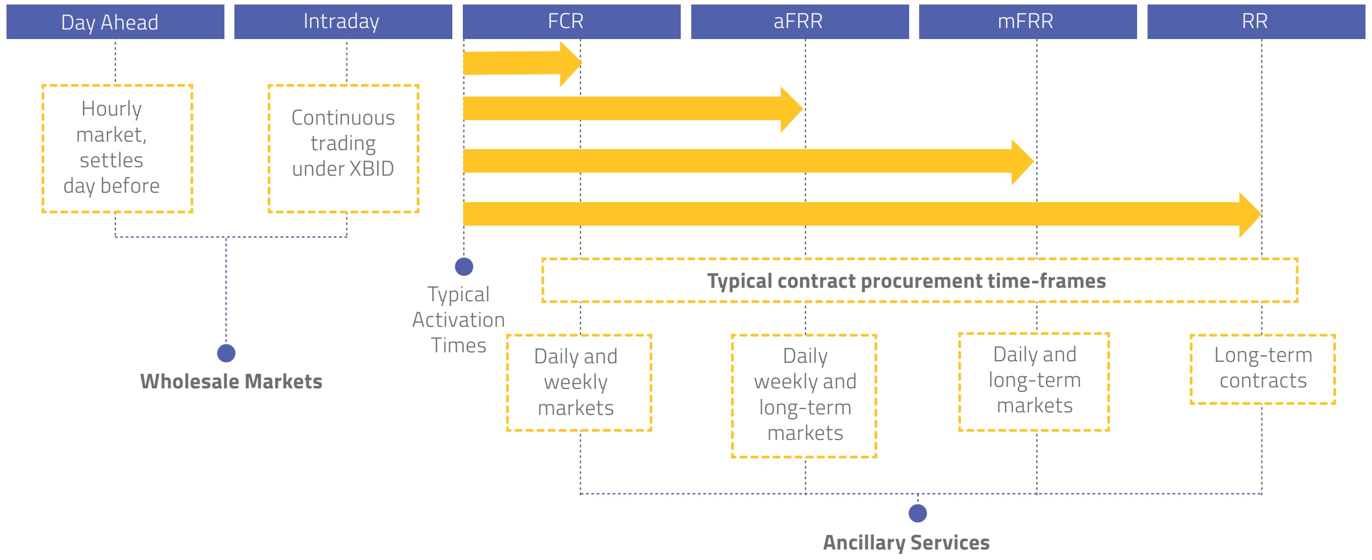
Remedial actions

TSOs manage congestions so as to maintain the security of the system. Congestions appear when there is a mismatch between the outcome of the markets and the physical limitations of the grid.

TSOs can apply remedial actions to relieve congestions:

- redispatch, which means a measure activated by one or several system operators by altering the generation and/or demand pattern in order to change physical flows in the transmission system and relieve a physical congestion;

Figure 7 - Example of typical ancillary service time-frames



- countertrading means a cross zonal exchange initiated by system operators between two bidding zones to relieve physical congestion.

The utilisation of these actions is costly and ultimately paid by the customer.

Trends

Ancillary services

Between 2016 and 2017, the volumes of contracted balancing reserves increased from 3.75 TW to 4.56 TW (see Figure 8). These figures are for pre-contracted reserves made available to the TSO. The 21.4% year-on-year increase is in a large part due to the significant rise in the levels of mFRR being contracted, which more than offset decreases in FCR and RR.

Ancillary services in Europe are deployed after the day-ahead and intraday markets have closed to ensure that frequency is maintained, and reserves are kept within safe limits. They are often, however, contracted well in advance of the day-ahead markets on weekly, monthly, annual or long-term time-scales (see Figure 10).

The volumes being contracted across different durations have remained relatively stable for most categories between 2016 and 2017, apart from 'daily' contracts, which climbed significantly by 67.8% - increasing from 1.3 TW to 2.2 TW.

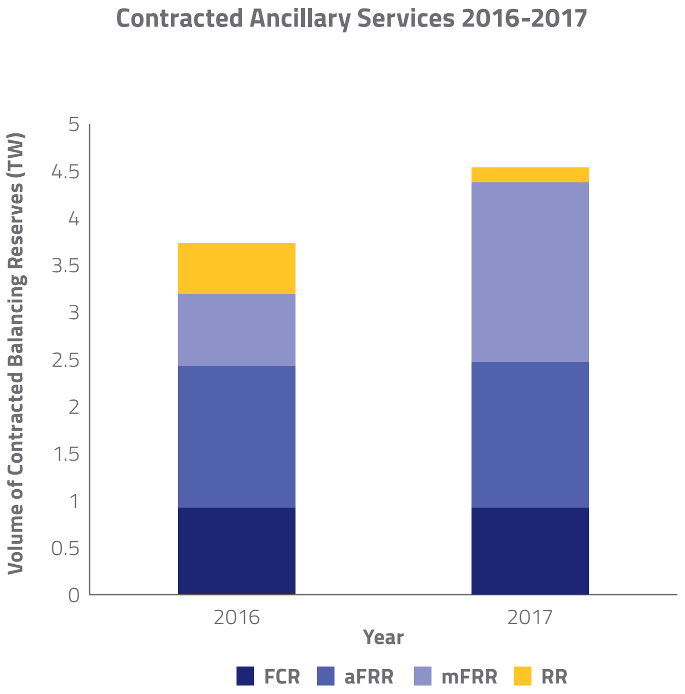
Voluntarily in cooperation projects and through the implementation of the 'Electricity Balancing Guideline', TSOs are cooperating to integrate balancing markets and deliver common European platforms. TSOs have for example established the following projects to harmonise balancing market processes across Europe (see also Figure 10):

- the International Grid Control Cooperation (IGCC) for imbalance netting process;
- the Platform for International Coordination of Automated Frequency Restoration and Stable System Operation (PICASSO) for aFRR process;
- Manually Activated Reserves Initiative (MARI) for mFRR process;
- And Trans-European Restoration Reserves Exchange (TERRE) for RR process.

Integration of European balancing markets is estimated to generate more than €400 million a year of additional social welfare benefit[4].

[4] https://ideas.repec.org/a/eee/appene/v96y2012icp316-326.html

Figure 8 - Volume of contracted ancillary services (TW) (source: ENTSO-E Transparency Platform)



Remedial actions

ENTSO-E's latest Bidding Zone Technical Report released end of 2018 gave unprecedented transparency on Europe's power grid constraints. The report shows the frequency and locations of bottlenecks, and the related costs.

It factually demonstrates that the European system has physical limitations in some areas.

The frequency and location of these constraints vary over time. In the timeframe 'Capacity calculation for the purpose of day-ahead capacity allocation', a relatively low number of congestions are reported, especially if compared to the D-1 timeframe (the timeframe between the closure of the day ahead market up to one hour before the electricity is dispatched or 'real time).

These reported congestions in the day ahead timeframe are generally on bidding zone[5] borders or in their direct vicinity. This is due to the fact that in the capacity calculation timeframe, only the grid elements with relevant sensitivity to cross-border exchanges are considered.
In the timeframe 'D-1', the report identifies congested lines detected during the operational planning process, where TSOs check the DA market outcome for feasibility against the grid's technical capability. In this timeframe, all grid elements are considered, irrespective of their cross-zonal relevance. Many lines with low frequency of congestions are reported, while high frequency congestions are reported for a relatively limited number of grid elements.

As illustrated in the chapter 'Security of Supply" the number of incidents on the transmission grid is extremely low in Europe. This shows that despite a high level of constraints on their networks and despite a system in transition, TSOs are able to keep the electricity system secure.

After market closure, the TSOs take actions to relieve congestions that could lead to security violations (remedial actions). The Bidding Zone Technical Report transparently includes figures on costly remedial actions. These costs are the highest in Germany and Great Britain. In Germany, the compensations for renewable energy producers that have to be curtailed makes up almost half of the total costs.

ENTSO-E's Transparency Platform data shows that the amount of money spent on implementing congestion management have seen an overall increase of around 25% between 2015 and 2017, from €999 million to €1.27 billion[6].

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[5] A bidding zone is the largest geographical area within which market articipants are able to exchange energy without capacity allocation.

[6] Austria, Belgium, Denmark, Estonia, France, Germany, Hungary, Italy, Norway, Poland, Portugal, Spain, Sweden and the UK.

Figure 9 - Contracted length of ancillary services, 2016-17 (source: ENTSO-E Transparency Platform, 2018)

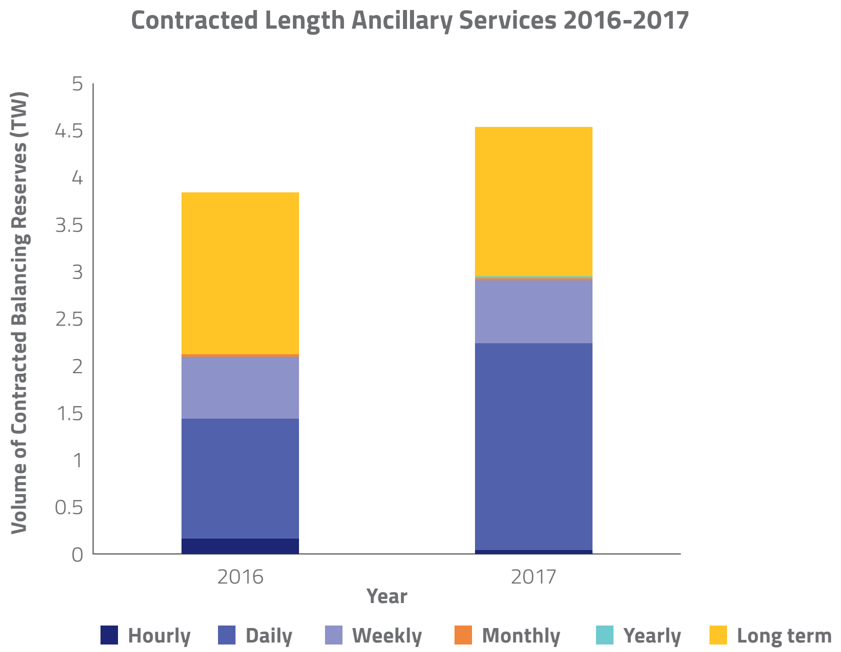
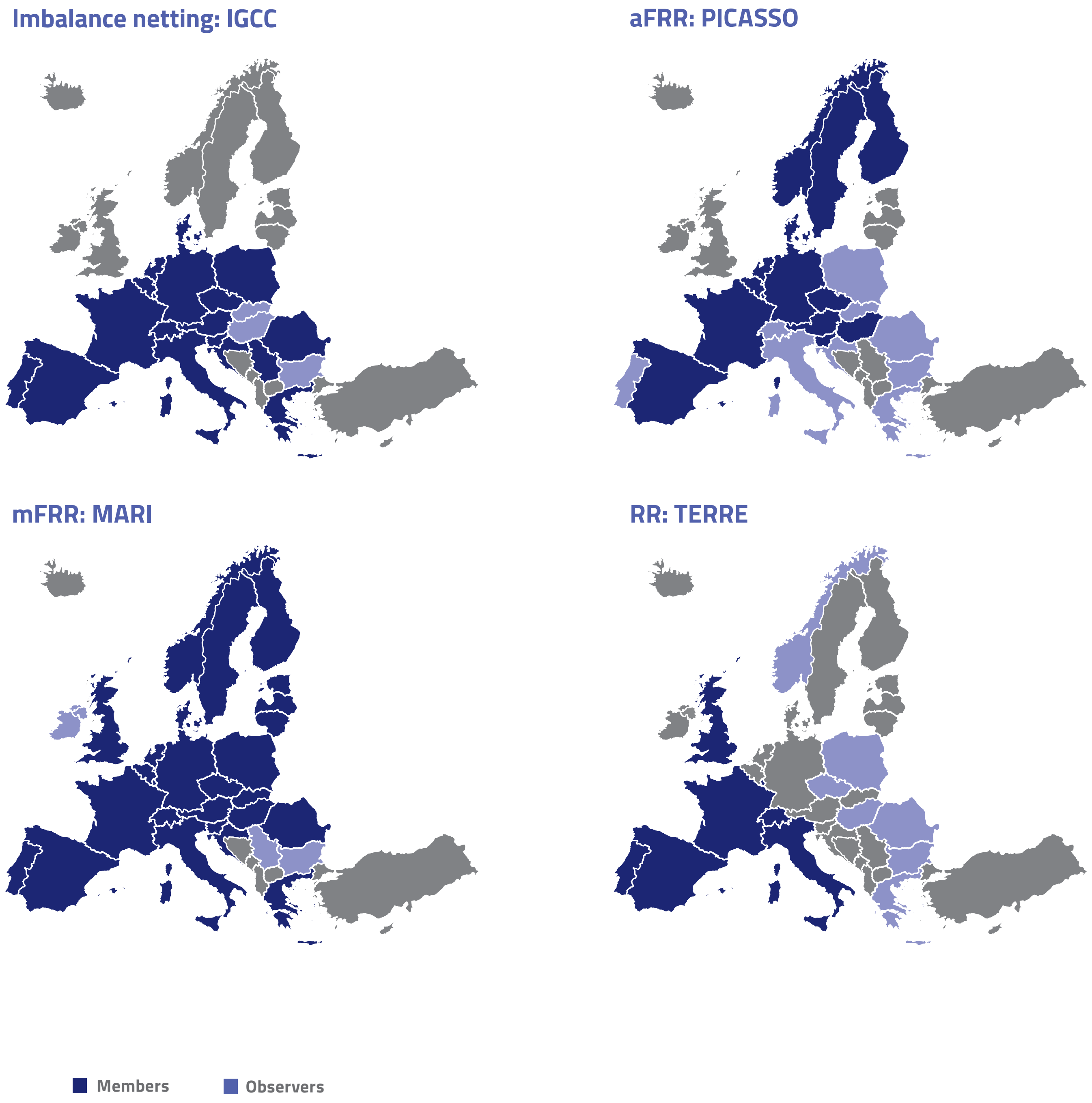


Figure 10 - European balancing implementation projects and their TSO members (as of November 2018)



Sources:
ENTSO-E (2018) *Transparency Platform: Volumes of Contracted Balancing Reserves.* Available from: https://transparency.entsoe.eu/balancing/r2/balancingVolumesReservation/show

ENTSO-E (2018) *Electricity Balancing in Europe.* Available from: https://docstore.entsoe.eu/Documents/Network%20codes%20documents/NC%20EB/entso-e_balancing_in%20_europe_report_Nov2018_web.pdf

Figure 11 - Congestions frequency (number of hours per year) for the purpose of Capacity Calculation for the Day Ahead in 2017

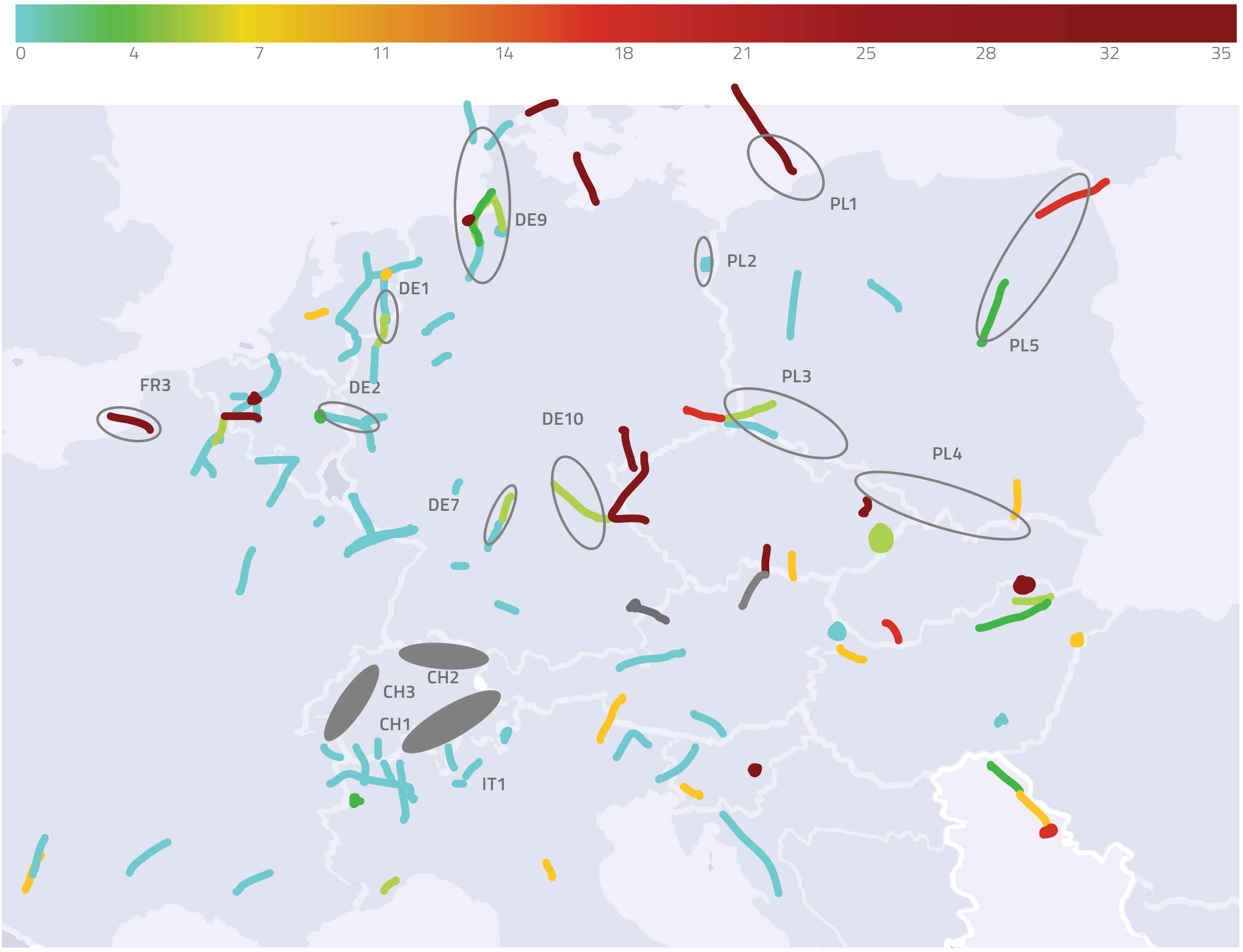
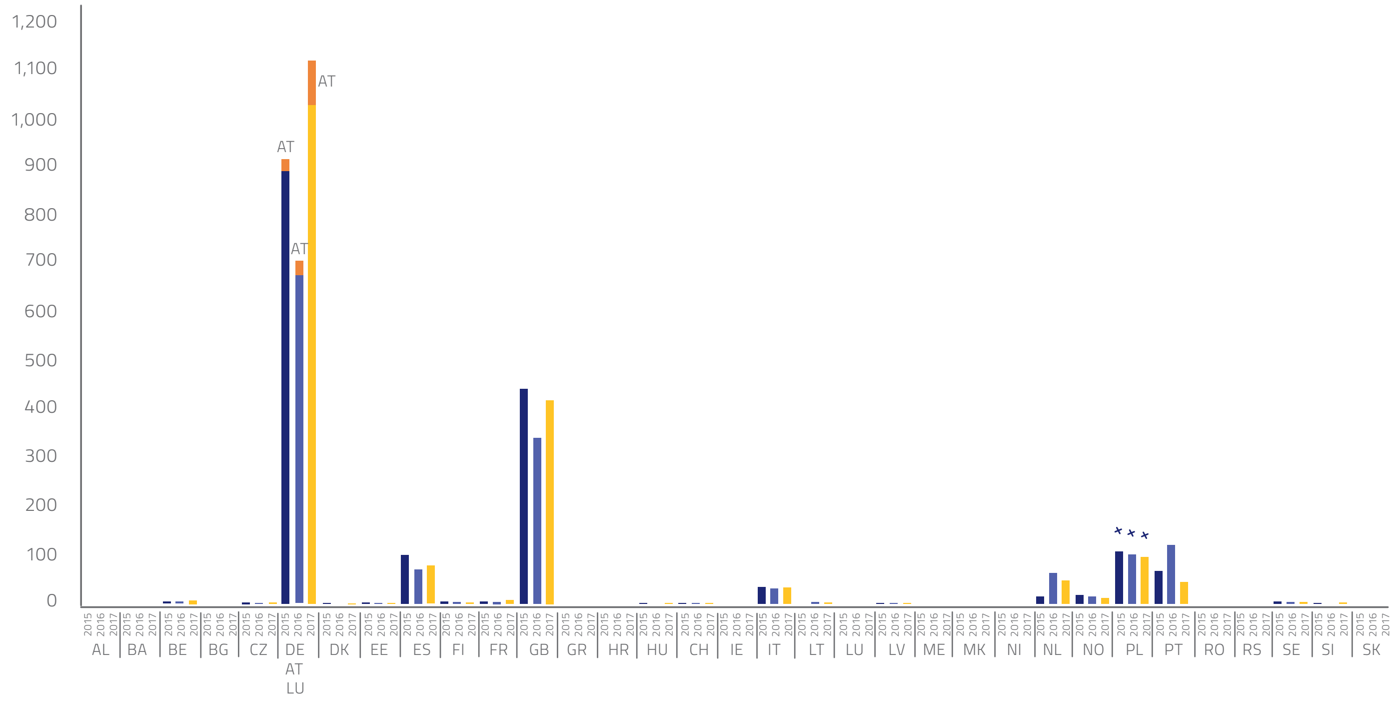


Figure 12 - Costs of remedial actions over 2015-2017



Sources:

ENTSO-E (2018) *Transparency Platform: Volumes of Contracted Balancing Reserves.* Available from: https://transparency.entsoe.eu/balancing/r2/balancingVolumesReservation/show

ENTSO-E (2018) *Electricity Balancing in Europe.* Available from: https://docstore.entsoe.eu/Documents/Network%20codes%20documents/NC%20EB/entso-e_balancing_in%20_europe_report_Nov2018_web.pdf

ENTSO-E (2018) *Transparency Platform: Congestion Costs.* Available from: https://transparency.entsoe.eu/congestion-management/r2/costs/show

ENTSO-E (2018) *Bidding Zone Configuration Technical Report 2018.* Available from: https://docstore.entsoe.eu/Documents/Events/2018/BZ_report/20181015_BZ_TR_FINAL.pdf

1.5 Ramping Needs

Context

Residual load ramping measures the required responsiveness of the electricity system to fast variations in demand and/or generation[7]. If for instance the wind stops blowing, then an electricity system with a lot of installed wind power will need to rapidly ramp up other forms of generation or ramp down demand, or use storage or other flexibility sources, and develop interconnections to balance the system and maintain frequency.

It is therefore a key indicator of the evolving flexibility requirement as Europe's energy system transitions.

In a European power system with greater penetrations of solar and wind expected, the balancing of supply and demand will, all else being equal, be increasingly influenced by weather. As network operators try to cope with greater variability in generation and potentially also in demand, the flexibility to ramp up or down resources on short notice must be maintained.

Trends

Adequacy is not only related to the total amount of capacity being installed in the system, but also to the ability of the installed capacity to adjust to the ever-increasing dynamics of dispatch events in the system. The latter is defined as flexibility adequacy and it becomes evermore important, mainly due to the increasing amount of variable renewable energy present in the power system. Several flexibility services will be required in order to ensure a smooth transition to high RES penetration.

In particular:

— Ramping needs: Notably with the growing PV penetration, flexible resources will become essential to meet the fast change of residual demand – for instance, the steep upward ramp created by the decline in solar output due to the sun setting when demand increases in the evening.

— Balancing fast reserves: The increase of variable generation along with the forecast error of wind and PV should be overcome with reserve deployment in order to secure the supply. Modelling of balancing reserves in the current MAF is performed assuming that a fixed amount of supply is kept available at any time.

Despite the considerable improvements in forecasting variable power generation, for both wind and solar, in practice, forecasting can never be perfectly accurate, with decreasing forecast errors as real-time operation approaches. Thus, forecasts are very likely to be updated hours ahead of real time, and the system will require fast starting and controllable resources (interconnectors, DSR, storage and fast response generators). Figure 13 shows the hourly residual load ramps (i.e., the hourly changes in demand minus variable renewable energy generation) that are requested from dispatchable generation units when considering each market node independently. The larger the ramps the bigger the need for flexibility.

The ramping needs must be addressed through all available means. Interconnections can contribute up to around one third of the flexibility needs in 2025. The remaining needs shall be addressed by generation, demand response and/or storage.

Recent studies in Europe and around the world confirm that flexibility is becoming a crucial point for system adequacy. Flexibility services and products are growing in importance and are progressively being integrated into the market. ENTSO-E aims to extend further insights on flexibility in future MAF reports.

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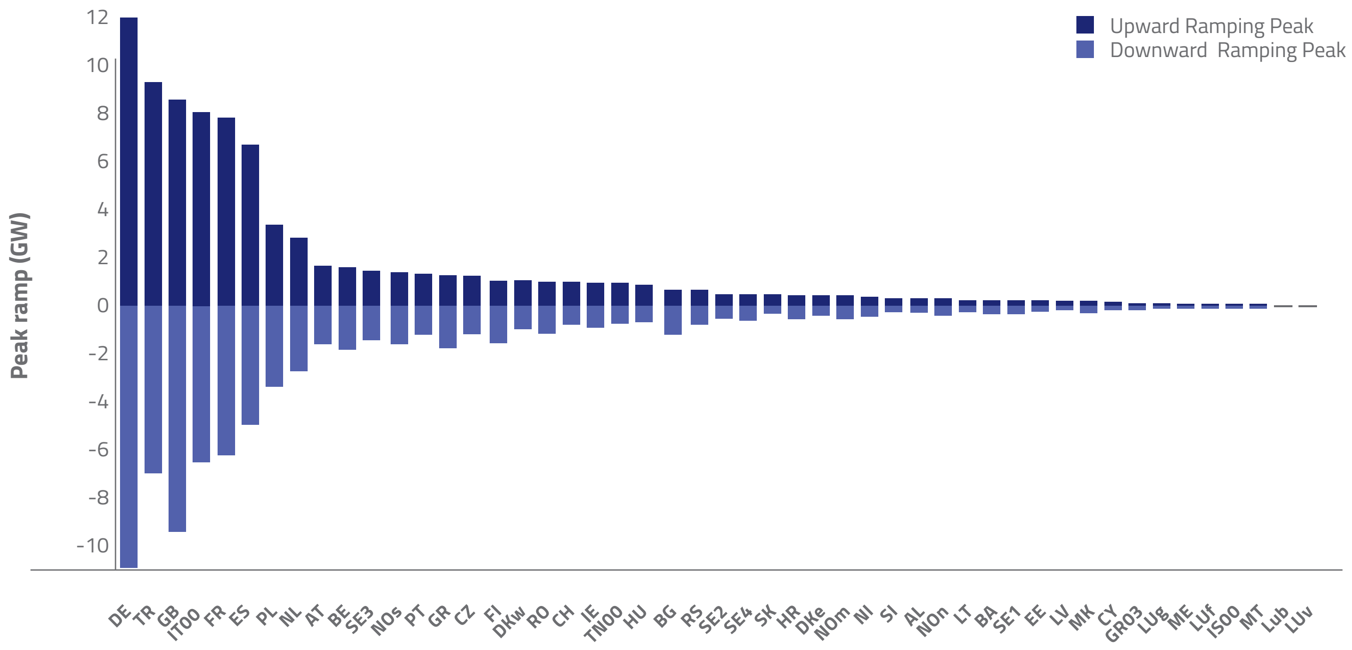
[7] Specifically, for the analysis in this chapter we define residual load as load minus the sum of wind and solar generation. Ramping requirement is the change – up or down – in residual load (MW) per hourly period.

Figure 13 - Hourly residual load ramps on a national basis (99.9th percentile)



Sources:

ENTSO-E (2018) *Mid Term Adequacy Forecast (MAF) 2018*. Available from: https://docstore.entsoe.eu/Documents/SDC%20documents/MAF/2018/MAF%20 2018%20Executive%20Report.pdf

1.6 Regional cooperation & System Operations Codes

Context

As cross border and variable power flows increase, the need for regional coordination across the European power system rises further. Regional coordination is however not limited to TSOs. The coordination at regulatory and policy level is equally needed and is even a pre-requisite to enhance regional cooperation of TSOs.

Indeed, TSOs have voluntarily cooperated in regions for decades. Regional Security Coordinators (RSCs) were put in place after the system split in 2006 and have been made mandatory by one of the system operations network codes, the System Operation Guideline.
System Operation codes enable state-of-the-art operational rules to be shared across Europe, these rules are also adapted to more variable and cross border flows.

- The System Operations Guideline (SOGL) outlines the steps TSOs must take in managing their grid. Key actions in-clude improving scheduling procedures and enhancing security analysis as well as regional TSO cooperation.

- The Emergency and Restoration Network Code (ER) defines agreed processes that TSOs must follow when there is an incident on the grid. This ensures that the highest standards and practices are adhered to across the European system to guarantee consumers receive the highest quality energy service. Key actions include enhancing emergency and restoration plans.

The 2006 European blackout was a major event which had widespread social and economic implications. Had some of the European network codes and notably the system operation codes already been implemented, the repercussions of the system split may have been minimised:
- 17GW of load being shed
- 15 million households being cut off from their energy supply
- €300-500 million of losses from load shedding
- 20GW of generation tripped or disconnected.

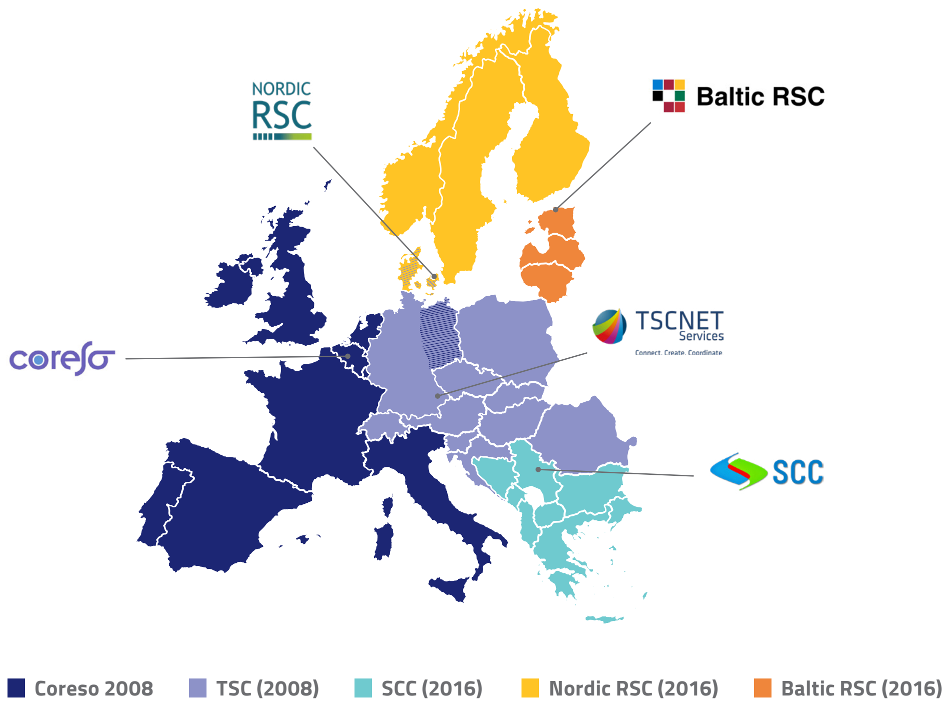
The Clean Energy for all Europeans Package amends the SOGL and adds additional service responsibilities to RSCs, who under current proposals would become Regional Coordination Centres (RCCs) after 2022. Such services include tasks to improve system operation, market operation and risk preparedness.

Enhancing regional coordination of TSOs requires closer and more systematic coordination of regulators and policymakers. ENTSO-E has proposed the concept of Regional Energy Forums gathering the policy, regulatory, technical/market layers that are all necessary for the power system to function optimally. This cooperation 'triangle' is already active at national and pan-European level but still needs developing at regional level.

Trends

By end of 2016, all five RSCs were established. RSCs provide services to TSOs, and Table 2 summarises the five core services that they are implementing. It may take up to 2022 to complete these.
Whilst it may be too soon in the implementation process for the full benefits of the TSO cooperation through RSCs to be realised, the number of coordinated actions and the lack of major incidents on the European grid can already be highlighted as signals of success.

Figure 14 - Map of RSCs



Overview of RSC services and notable actions

Regional Security Coordinators:

1. Capacity calculation
2. Security analysis
3. Common grid model
4. Adequacy forecast
5. Outage planning

Partially operational in TSCNET and CORESO

➡ **CORESO discovered 7 times more potentially critical situations in 2015 compared to 2014**

➡ **Mitigate critical grid situations**
4000 remedial actions proposed/year in CORESO
130 multilateral remedial actions coordinated by TSCNET

Table 2 - RSC tasks and associated benefits for TSOs and market participants

FIVE TASKS	BENEFIT FOR TSOS & MARKET PARTICIPANTS
Regional operational security coordination	Identify risks of operational security in areas close to national borders. Identify the most efficient remedial actions in these areas and make recommendations to the concerned TSOs without being constrained by national borders.
Regional outage coordination	Single register for all planned outages of grid assets (overhead lines, generators, etc.). Enhanced governance of asset maintenance.
Coordinated capacity calculation from CACM	Calculate available electricity transfer capacity across borders (using flow-based or net transfer capacity methodologies). Maximise the capacity offered to the market.
Regional adequacy assessment	Provide market participants with consumption, production, and grid status forecasts up to several weeks ahead.
Building of Common Grid Model	Provide a regional dynamic view of all major grid assets (generation, consumption and transmission), updated every hour.

Focus on the Common Grid Model (CGM)

A lot of services depend on the implementation of the Common Grid Model (CGM) – the first pan-European continuous grid data exchange.

TSOs model their grid in their market, operations and system development activities. The CGM compiles the individual grid model of each TSO, covering timeframes from one year to one hour before real time. TSOs' individual grid models are received by RSCs, who, following a quality assessment and pan-European alignment process, merge them into a pan-European common grid model and feed the merged CGM back into the system. The performance of the core legally mandated tasks of RSCs rely on the CGM.

The CGM, currently being developed by ENTSO-E and RSCs, will allow for a much finer representation of the network. It requires building specific hardware, software and applications. The data exchange necessary for the new CGM merging process will be supported by an information platform, ENTSO-E's Operational Planning Data Environment (OPDE). The OPDE is also the foundation of the data exchange platform needed to run the other core tasks of RSCs. The CGM is required notably by the SOGL, but also by two market network codes.

In 2016, ENTSO-E commissioned a study on the future of the regional cooperation in the power system. The study highlighted the conditions for enhanced regional cooperation in power transmission system operation:

- An initial forum of policy makers should involve member states and national energy regulators, as well as TSOs to the extent necessary. The forum would focus on cooperation at the political level and on the coordination and harmonisation of policies and regulations to facilitate market integration and improve regional efficiency. Institutions such as the European Commission or ACER could also participate in this forum.
- Consultation of stakeholders. A second group would organise the adequate consultation of all relevant stakeholders, through dedicated meetings and workshops as well as public consultations. Stakeholder engagement is needed to ensure a smooth and satisfactory implementation.
- Cooperation of TSOs. A third layer would focus on the coordination of TSOs in system and market operations and all TSO activities, for which regional coordination would be valuable. It would examine the impact of policies on system and market operation and the operational implementation of such policies, if necessary. This forum would involve RSCs and other relevant service providers or project partners (e.g. power exchanges, the Joint Allocation Office).

In addition to supporting the convergence of regulations, policy regions would also be tasked with coordinating national and regional level decisions needed for improved TSO regional cooperation.

In this concept, the allocation of responsibility is clear and the TSOs remain fully responsible for operational security. Thus, if coordination of regulations and policies is also improved, the proposed concept enables RSCs to enhance TSOs' coordination, to provide complementary analyses, and to perform new coordination services when they add value to the region. However, the allocation of responsibility and governance ensures that the TSOs can perform analysis and remain in a position of ultimate responsibility to prevent any action which could jeopardise operational security in their local network.

Economic efficiency and the maximisation of social welfare at the wider regional or European scope is the driver for this approach. The proposed framework for policy regions with effective regulatory coordination and the proposed framework for RSCs, with the evolution of governance and decision-making process specifically, aim to foster more efficient decisions and align national preferences with regional optimisation.

The approach should therefore improve economic efficiency. Moreover, the extension of RSCs' scope of activity, motivated by cost benefit analysis where relevant, also contributes to higher economic efficiency. The proposal does not require major changes in the institutional and regulatory framework as it is based on the approach set in the new regulation. However, this approach allows for the necessary evolutions in policies, regulations and market design. Finally, the concept of enhanced regional cooperation does not preclude any further evolution beyond 2030 towards other long-term solutions.

Figure 15 - Enhanced regional cooperation approach

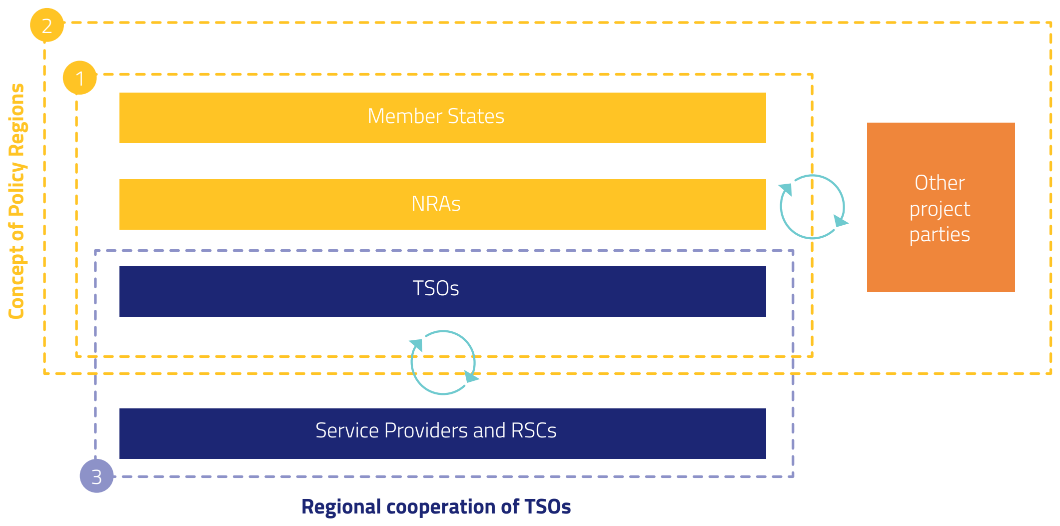
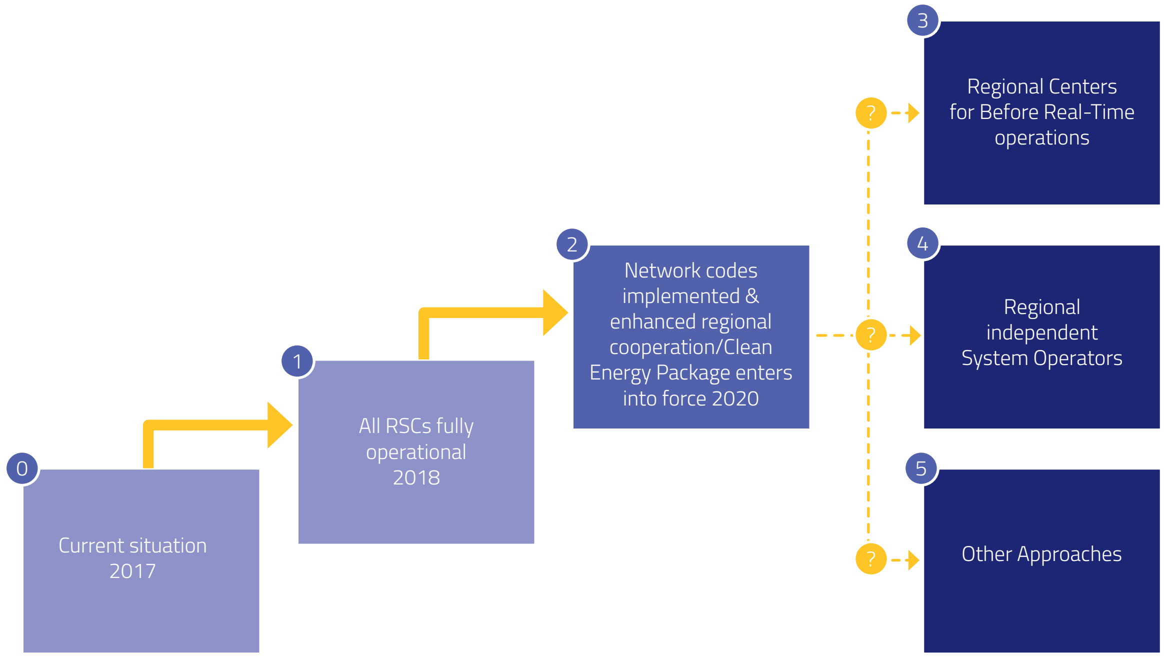


Figure 16 - Growth of regional cooperation, suggested timeline

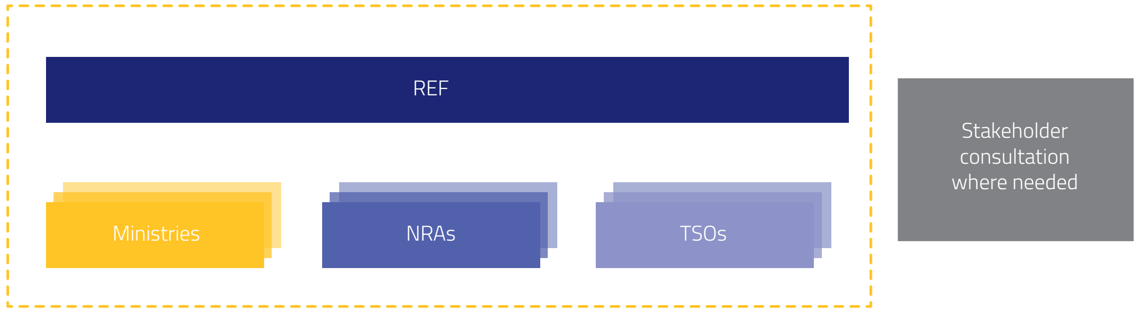


Regional Energy Forums (REF)

In 2017, ENTSO-E has issued a policy paper "Power Regions for the Energy Union: Regional Energy Forums as The Way Ahead" which argued for the creation of Regional Energy Forums (REF) - a structured and lasting cooperation between European countries, NRAs, TSOs at regional level, consulting with stakeholders where applicable.

The concept of the REF is designed to ensure that countries within a region work constructively together, develop and agree on solutions to provide common political guidance. Agreed solutions will then be implemented by the members of the Forums in line with their respective roles and powers. In doing so, they work bottom-up on solving the specific challenges of each region. REFs will contribute to the deepening of energy relations in Europe and provide a framework which allows for the best possible coordination of national efforts towards the internal energy market and the Energy Union.

Figure 17 - Regional Energy Forum concept



Sources:
ENTSO-E (2018) *Network Codes.* Available from: https://electricity.network-codes.eu/network_codes/

ENTSO-E (2018) *In the spotlight: regional coordination of electricity TSOs*

FTI- Consulting Energy/ Compass Lexecon (2016): *Options for the Future of power System regional Coordination:* Available from: https://www.fticonsulting.com/~/media/Files/us-files/intelligence/intelligence-research/entso-e-future-power-system-regional-coordination.pdf

ENTSO-E (2017), *Power Regions for the Energy Union: regional energy forums as the way ahead* Available from: https://docstore.entsoe.eu/Documents/Publications/Position%20papers%20and%20reports/1.1.1.1.Corrected-interactive-entsoe_pp_REF_print.pdf

-36%

CARBON INTENSITY OF ELECTRICITY PRODUCTION IN THE EU-28 BETWEEN 1990 AND 2014

11%

INCREASE IN NET RES GENERATION BETWEEN 2015 AND 2017

-6% CARBON INTENSITY OF THE POWER SECTOR IN EUROPE BETWEEN 2015 AND 2016

Chapter 2 - Sustainability

Europe has been at the forefront of climate change policy for decades. EU targets and Member State policies reflect the importance of sustainability, as does the region's continued support for the Paris Agreement. The Commission's 2050 Strategy is evidence of commitment to long-term decarbonisation.

As of December 2018, new renewables and energy efficiency targets for 2030 have been adopted by the European Parliament and European Council (see graphic on page 5 for more detail). If achieved, greenhouse gas emissions (GHG) are expected to decrease by 45% relative to 1990 levels. This would be in exceedance of the 40% target.

The energy efficiency target as part of the '20-20-20' targets requires attention, as it may not be met (20% reduction in primary energy consumption against projected levels by 2020.)

This chapter presents data on the evolving carbon intensity of electricity (2.1), the EU-28's energy efficiency targets (2.2), and renewables deployment (2.3). Taken together, these measures are important and complementary parts of Europe's decarbonisation drive.

2.1 Carbon intensity

Context

The EU has already agreed to an economy-wide 40% reduction target in GHG emissions by 2030 (from 1990 levels) under the Paris Agreement. The European Commission's analysis suggests that 2030 power sector emissions will likely need to fall by at least 54% against 1990 levels to allow for the economy-wide 40% reduction. ENTSO-E and ENTSOG are working on a COP21 compliant scenario, in close cooperation with numerous stakeholders and especially NGOs, through the Renewables Grid Initiative.

Trends

Whilst preliminary estimates suggest that total GHG emissions increased by 0.6% in 2017 as a result of increased energy demand from transport and industrial sectors, the carbon intensity of electricity production in the EU-28 decreased by 44% between 1990 and 2016 (from 524 to 296 gCO2/kWh). Progress has occurred during several years when the price of allowances from the EU ETS has remained relatively low. Permit prices have increased during 2018 and suggest market conditions are more conducive to investment in emission-saving technologies and measures.

Between 2015 and 2016, figures show that the carbon intensity of the power sector in Europe decreased by 6%, the second largest annual percentage fall since 1990 (see Figure 18). Indeed, much of this has been driven by increased uptake of renewable generation, and an increasing role in the production mix. In 2017 the share of electricity from renewable sources was 30%, double the share ten years ago.

> “The EU-28 has been successful at “decoupling” energy consumption and economic growth, with a reduction of energy intensity of 35% between 1995 and 2016 ”

Based on Member State projections, the European Commission estimates that total emissions are in line to fall by 26% below 1990 levels by 2030. This falls short of the estimated reduction needed (54%).

Figure 19 provides an illustration of a 54%-68% reduction in carbon intensity by 2030. This is intended as a guide to the decrease in carbon intensity which may be required given the 2030 targets (given a conservative assumption of stable electricity demand). The figure suggests that Europe has made significant progress to date in reducing the carbon intensity of electricity production, but that this rate will likely need to accelerate over the next decade – especially given the expected increase in power demand driven by the expected electrification of transport, heating and industrial sectors.

Further carbon intensity reductions will be needed to support the economy-wide targets set under the Paris Agreement – especially given structural changes in heating and transport sectors which could drive greater consumption of electricity.

But, as suggested by the trendline in Figure 19, increased uptake of renewable generation and a shift away from the most-polluting generation sources has supported a rate of carbon intensity reduction which could support Europe’s 2030 decarbonisation goal.

Figure 18 - Carbon intensity of European electricity production (sources: EEA, UNFCC, Eurostat)

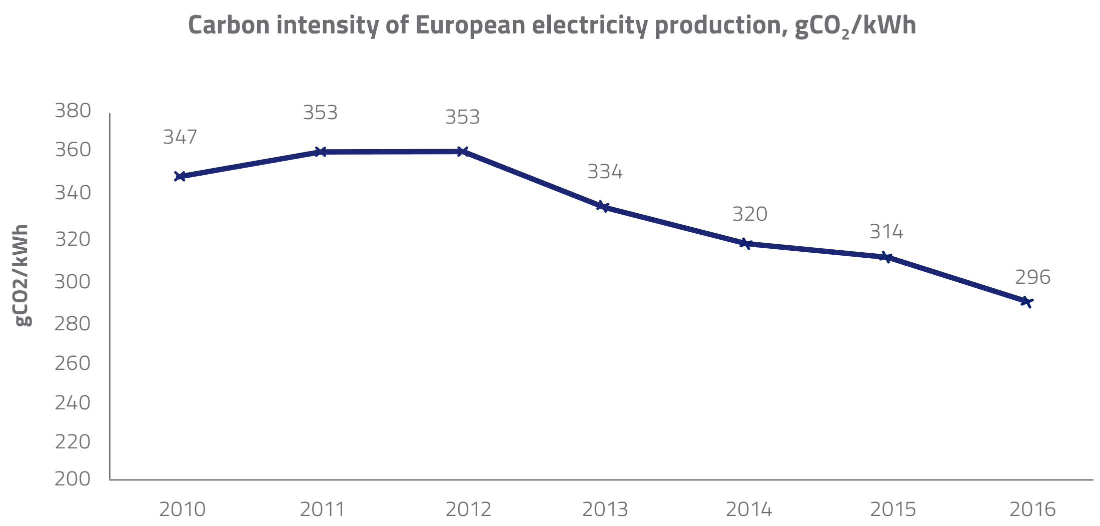
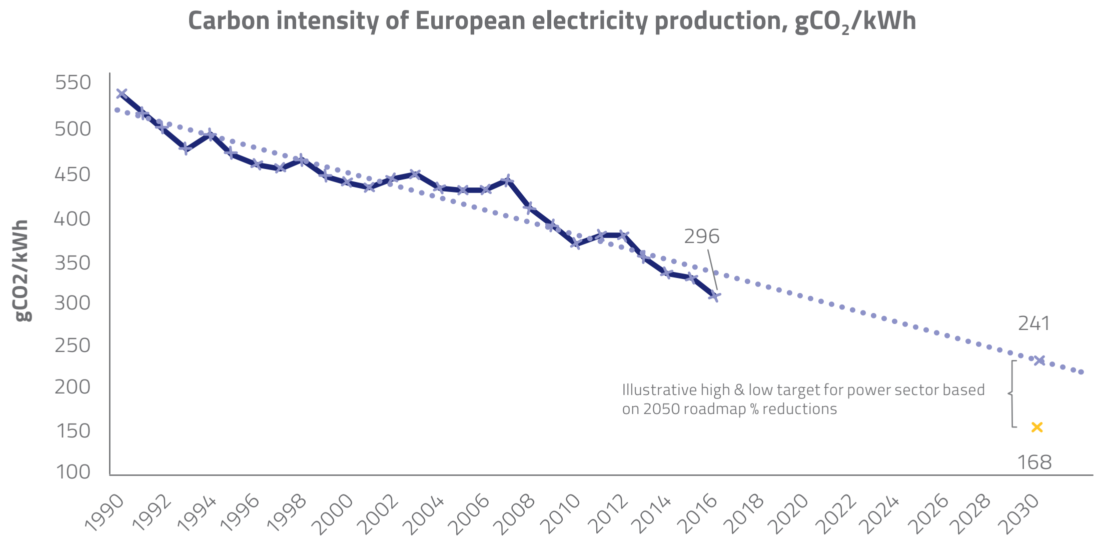


Figure 19 - Carbon intensity reduction in respect to illustrative 2030 targets



This analysis is illustrative and assumes that the carbon intensity of electricity (gCO2/kWh) will have to fall by at least the equivalent proportion as for total power sector emissions (MtCO2e). This assumption could be conservative given potential increased power demand.

Sources:

EEA (2018) *CO_2 emission intensity.* Available from: https://www.eea.europa.eu/data-and-maps/

EEA (2018) *Greenhouse gas emissions.* Available from: https://www.eea.europa.eu/airs/2018/resource-efficiency-and-low-carbon-economy/greenhouse-gas-emission

Eurostat (2018) *Supply, transformation and consumption of electricity.* Available from: https://ec.europa.eu/eurostat/data/database

UNFCC (2018) *European Union NIR 2018.* Available from: https://unfccc.int/documents/65886

European Climate Foundation (2010) *Roadmap 2050.* Available from: http://www.roadmap2050.eu/attachments/files/Volume1_fullreport_PressPack.pdf

2.2 Energy Efficiency

Context

Energy efficiency is recognised as a fundamental building block for a successful energy transition that delivers more sustainable, secure and cost-effective energy. The OECD expects EU GDP to double over the next 40 years. With a 40% reduction in GHG emission target to be achieved by 2030, energy efficiency will play a crucial role in delivering cost-effective decarbonisation.

Trends

Since 2005, EU energy consumption has fallen by 10% in primary energy and 7% in final energy terms. As illustrated in Figure 20, energy consumption decreased gradually between 2005 and 2014 to a level that was momentarily below the 2020 target.

However, recent annual increases in energy consumption mean that it is now uncertain whether the EU will meet its 2020 energy efficiency target. Figure 20 shows the provisional 2017 estimates sitting well above the 11-year trendline, and above the linear pathway from 2005 to the 2020 targets.

Whilst the reversal in the decadal trend in energy consumption reduction over the last 3-4 years has put hitting the 2020 target in jeopardy, figures show it remains within reach. In absolute terms, an 80 Mtoe reduction in primary energy consumption is needed by 2020, and a corresponding 22 Mtoe fall in final energy consumption. Given that previous annual reductions have exceeded both figures and with 2 years remaining, this target remains achievable but may require additional efforts.

Data and analysis from the ODYSSEE-MURE project suggest that changing weather has been an influential factor in the recent increases in energy consumption, with an unusually warm winter across Europe in 2014. Figure 21 provides a breakdown of the drivers and shows that since 2014, it is estimated that energy intensity savings were balanced out by the impact of changing weather conditions (+/- 13 Mtoe)[9].

40%

reduction in GHG emission target to be achieved by 2030

80

Mtoe

Mtoe reduction in primary energy consumption is needed by 2020

-26%

the European Commission estimates that total emissions are in line to fall by 26% below 1990 levels by 2030.

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[9] Activity: change in value added in industry, services and agriculture, in traffic in transport; Demography: effect due to the increasing number of dwellings; Lifestyles: more appliances and larger dwellings for households; Structural effects: industry (and services), modal shift in transport services; Other effects: behaviours for households, value of product in industry, labour productivity in services and "negative" savings due to inefficient operations in industry and transport.

Figure 20 - EU primary and final energy consumption compared to 2020 and 2030 targets (source: EEA)

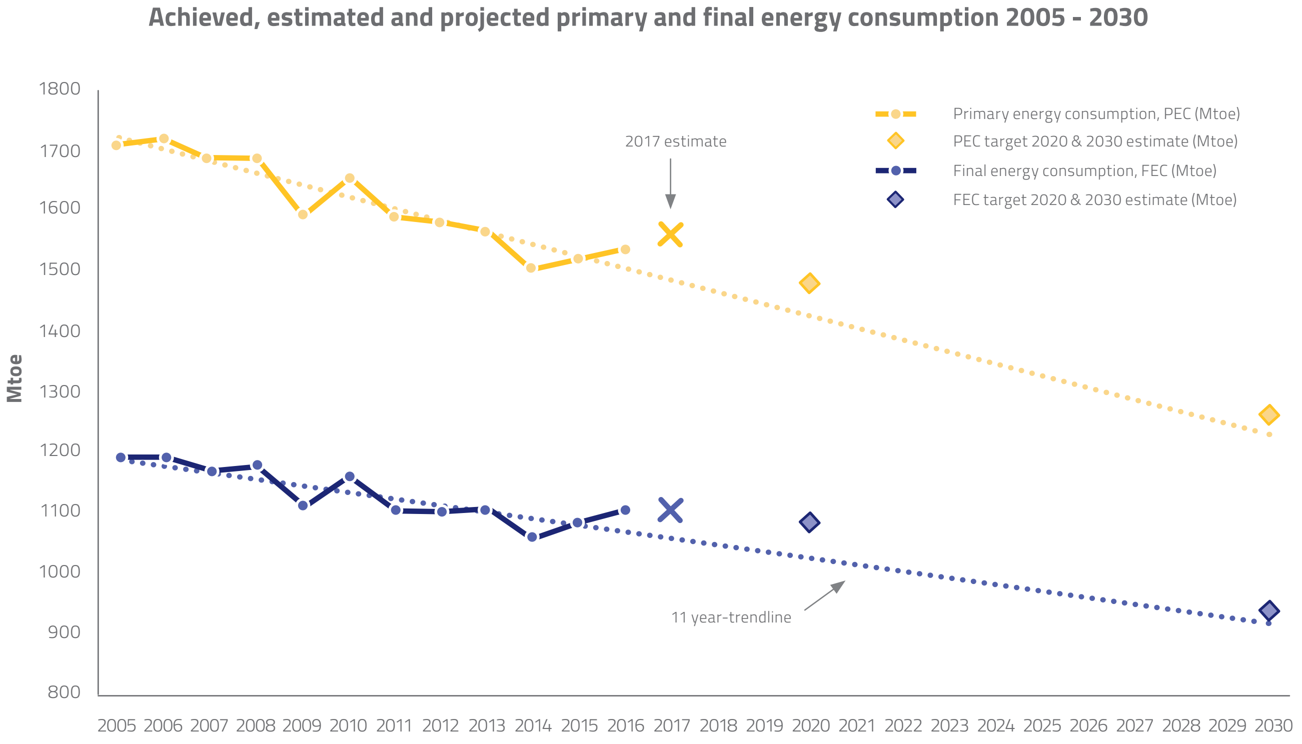


Figure 21 - Change in EU final energy consumption over time (source: ODYSSEE)

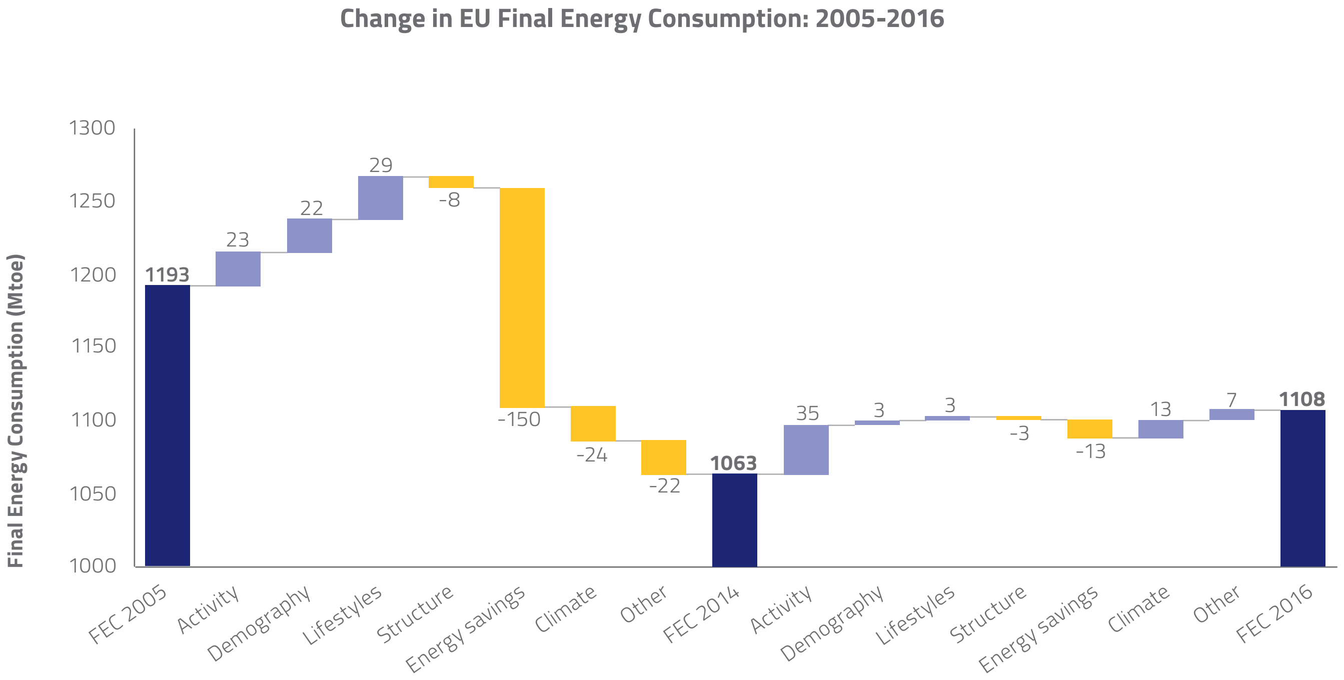


Figure 22 - EU GDP (€bn, 2013) compared to gross inland consumption of energy (Mtoe)

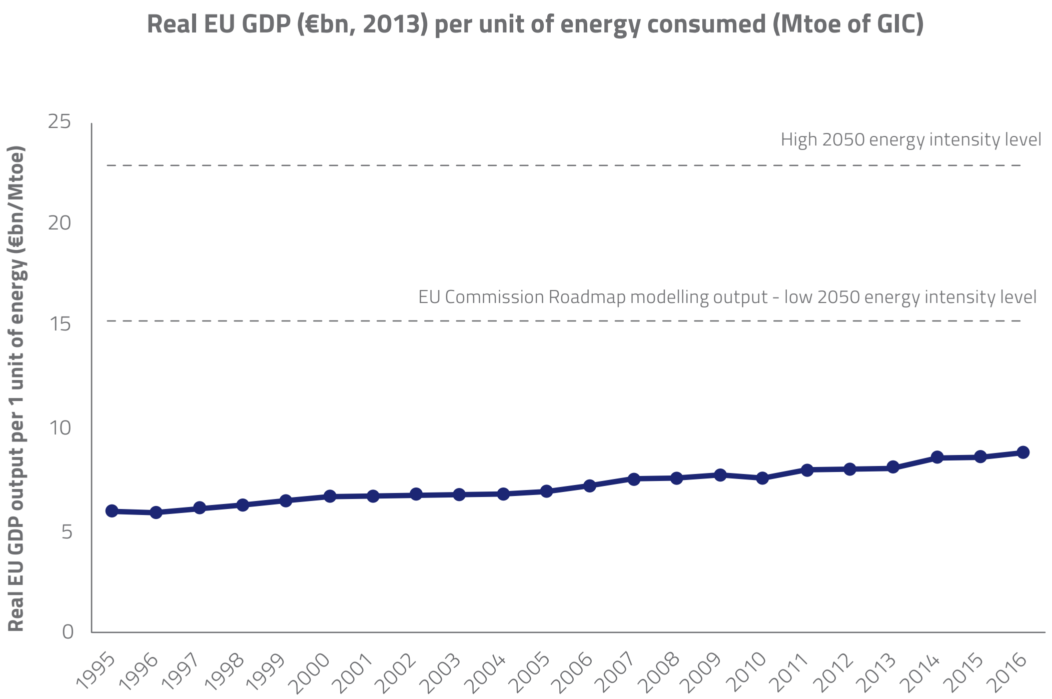


Figure 21 also shows the impact of increasing economic activity on energy consumption. Given that the European economy is expected to grow over the next three years, and as the impact of weather is clearly uncertain, further progress in reducing energy intensity – the consumption needed per unit of economic output (usually GDP) – is needed.

Figure 22 illustrates that ratio between EU GDP and units of energy needed to support economic output has been rising over time i.e. the EU generates more GDP per unit of energy in 2016 than in 1995. This is evidence that the EU-28 has been successful at "decoupling" energy consumption and economic growth. Indeed, this decoupling has led to a reduction of energy intensity of 35%, or a rate of just over 1.4% per year.

Figure 22 graphic includes the results of the European Commission's 2050 Roadmap modelling exercise for comparison. These dotted lines show that there are still improvements to be made in reducing energy intensity by 2050.

Sources:

OECD (2018) *GDP long-term forecast.* Available from: https://data.oecd.org/gdp/gdp-long-term-forecast.htm

EEA (2018) *Energy intensity.* Available from: https://www.eea.europa.eu/

Eurostat (2018) *Simplified energy balances – annual data.* Available from: http://appsso.eurostat.ec.europa.eu/

European Commission (2018) *Gross domestic product.* Available from: http://ec.europa.eu/economy_finance/ameco/

European Commission (2017) *Report form the Commission to the European Parliament and the Council.* Available from: https://ec.europa.eu/energy/sites/ener/files/documents/

European Commission (2018) *2050 Long-term strategy.* Available from: https://ec.europa.eu/clima/policies/strategies/2050_en

ODYSSEE-MURE (2018) *Decomposition Tool.* Available from: http://www.indicators.odyssee-mure.eu/decomposition.html

2.3 Renewable Deployment

Context

The share of total power generation delivered by renewable energy sources (RES) is a key sustainability data point. In Europe the picture is diverse, with some nations delivering RES generation volumes equivalent to 90% to 100% of total generation, and others less than 10% (as shown in Figure 23). With the diverse resources that are in different geographies, we see a patchworked energy system where demand is satisfied by diverse energy sources. Overall progress towards RES targets has been strong, although 2016-2017 saw stunted progress.

Trends

To drive decarbonisation, the European Union has committed to 20% of gross final energy demand being delivered by renewable sources by 2020. As noted, (see page 5 graphic), the Clean Energy Package sets a 32% target for 2030, with an upward revision clause that may be activated by 2023.

With independent national targets, different resource endowments, geographies and climatic conditions within Europe, the European energy mix remains diverse. Figure 24 uses ENTSO-E data to present the percentage of energy produced from RES sources in 2017. The median values show great diversity, with Denmark and Norway seeing 70% and 97% RES proportions, and Hungary seeing just over 10%.

We also see a significant variability in the share of RES throughout the year; with the share of RES in the generation mix in Denmark varying from 0% to 100% within 2017, illustrating the country's important wind generation, compared to Norway which was constantly supplied by at least 90% RES throughout the year, due to its hydro power. Figure 24 utilises 15-minute electricity production data from ENTSO-E's Transparency Platform to illustrate the share of RES in each country's generation mix throughout the year. The box and whisker plots detail the distribution between periods of high and low RES penetration, with the horizontal line in the middle of the box denoting the median and outer edges the first and third quartiles. The distance between these quartiles is particularly large in the case of Denmark and Latvia and suggests significant fluctuation in RES share from the median throughout the year.

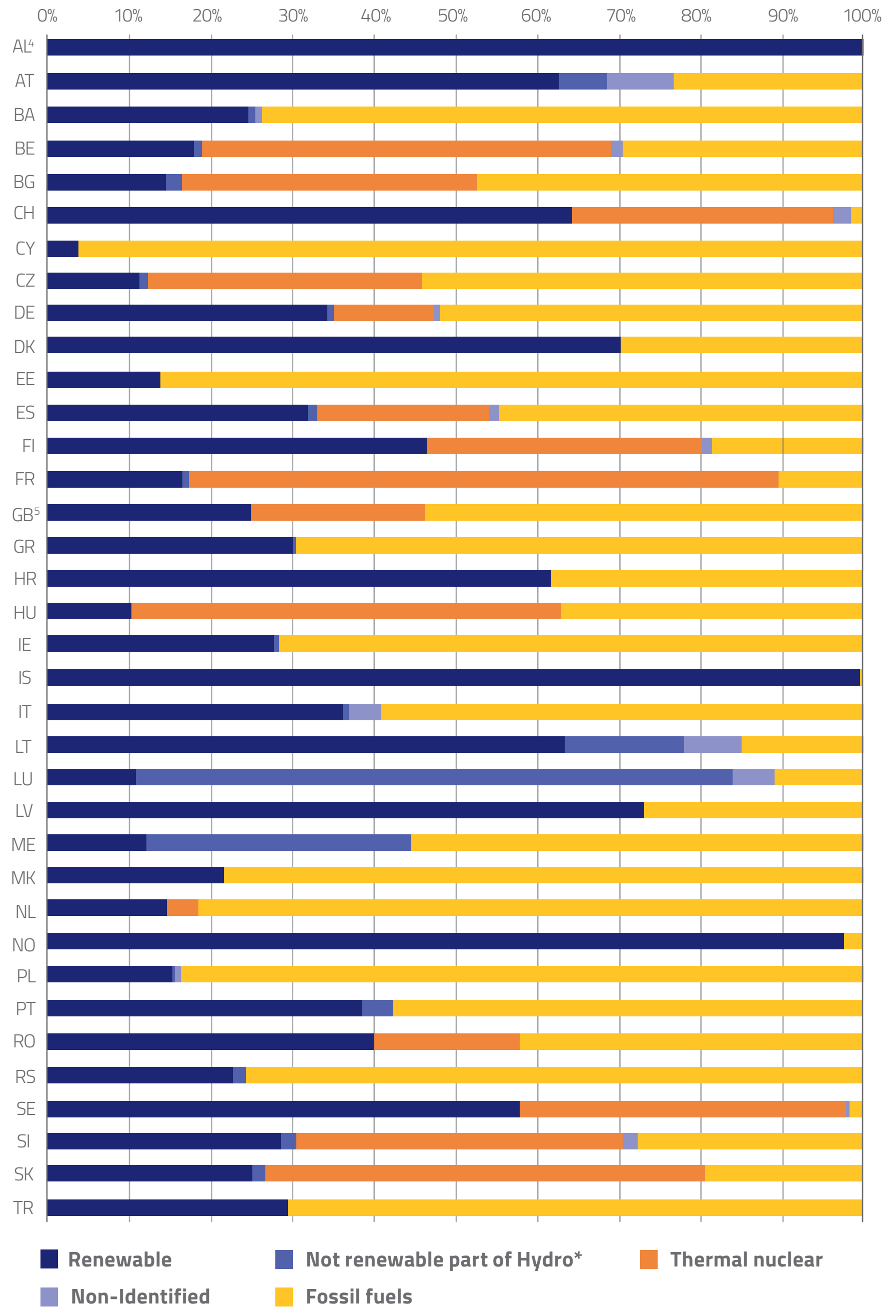
The distribution and range of the above data demonstrates the true diversity of the European electricity mix. The examples of Denmark, Latvia, and Portugal show nations that have enough installed capacity to produce two thirds of their energy demand from renewables, but with median generation values lower than this. This issue characterises one of the core challenges with integrating renewable energy generation; the concurrency of variable renewable energy supply (vRES) with demand. Adding storage to the system, improving interconnection, and harnessing demand-side response can support a greater penetration of vRES and complement the operation of these assets by helping to match supply and demand.

Overall, there has been an 11% increase in net RES generation between 2015 and 2017, predominantly driven by Germany, Poland and Austria. Latvia has seen the largest overall increase in the period but has considerably lower energy demand than the other countries considered. Fve countries have seen a reduction in relative RES generation over the period. Overall since 2015, TSOs have helped to integrate 54 GWs of additional variable RES (here defined as wind and solar).

The European electricity supply remains largely powered by non-renewable sources, with close to 70% of net generation in 2017, as opposed to 30% from renewable sources. This ratio has remained broadly constant over the last three years.

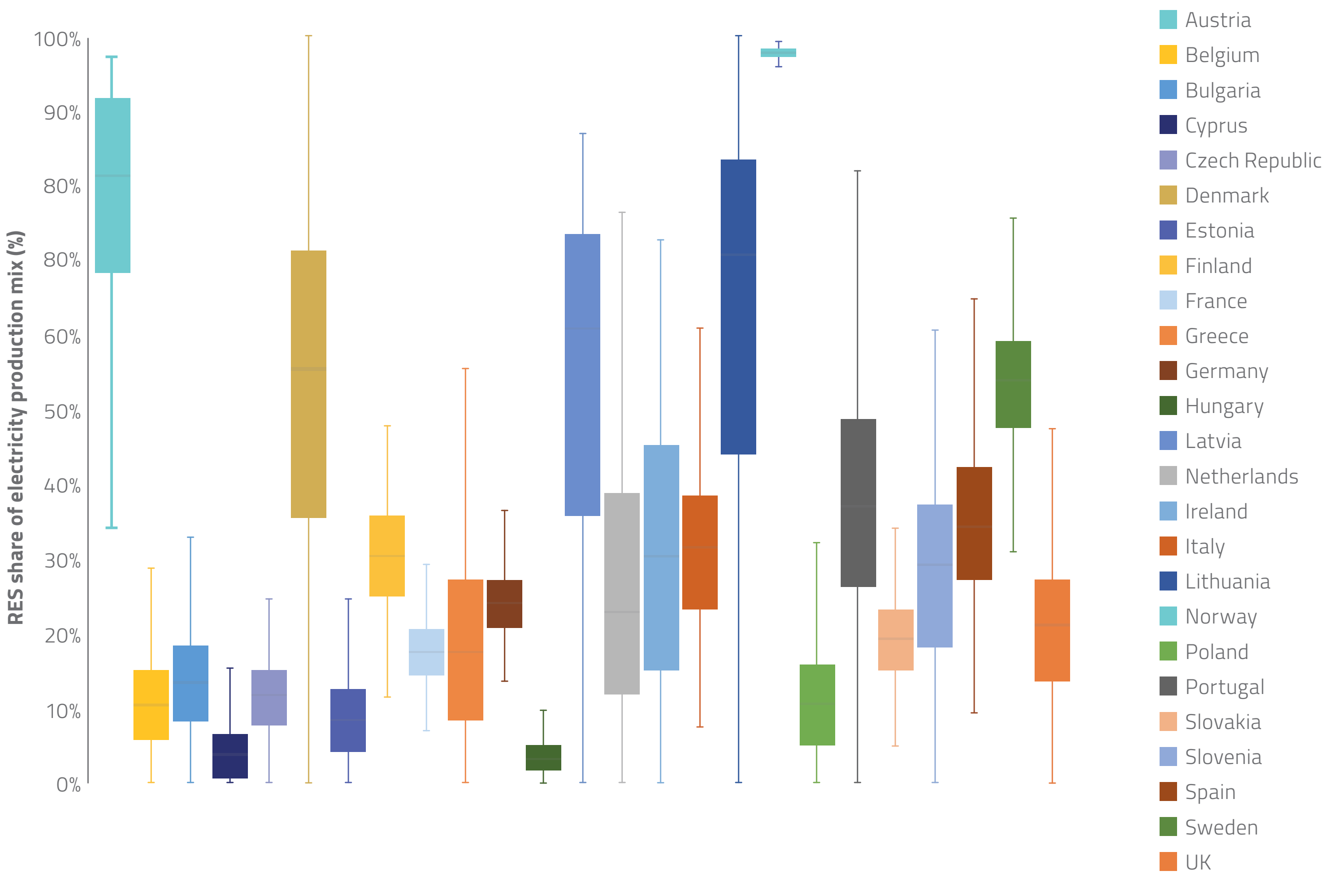
The European energy mix is characterised by the diversity of the nations; their individual renewable energy targets, their access to renewable sources, and their internal resources. This has created a patchworked energy system across Europe, which has seen good progress towards the near-term EU goals; however, in the longer-term greater ambition will be required to ensure that the 2050 Roadmap goals can be achieved.

Figure 23 - Share of energy produced by renewables in 2017 (source: ENTSO-E)



* Non renewable hydro covers the pumped storage hydroelectricity and the non renewable part of the mixed pumped storage hydroelectricity

Figure 24 - Distribution of RES-share throughout 2017 (source: ENTSO-E)



Sources:
ENTSO-E (2018) *Statistical Facsheet 2017.* Available from: https://docstore.entsoe.eu/Documents/Publications/Statistics/Factsheet/entsoe_sfs_2017.pdf
ENTSO-E (2018) *Transparency Platform.* Available from: https://transparency.entsoe.eu/

€2.5b-€4b per year

BENEFITS OF ELECTRICITY MARKET COUPLING/INTEGRATION

+7 TWh

OF CROSS BORDER EXCHANGES IN ENTSO-E BETWEEN 2016 AND 2017

26%

INCREASE IN EFFICIENT USE OF INTERCONNECTION BETWEEN 2010 AND 2017

Chapter 3 - Market Integration

The integration of European power markets allows electricity to flow freely across the continent, and in response to price signals. Market integration allows for the best use of existing assets across Europe, helping system operators balance supply and demand efficiently, and optimises the system. This keeps prices competitive for consumers, lowers supply risks and supports renewable integration.

Analysis carried out for the European Commission in 2013 suggested that the benefits of electricity market coupling/integration were in the order of €2.5 - €4 billion a year[10].

This chapter considers the progress made against this objective. TSOs and NEMOs have made progress in coupling markets (3.1) and this has been reflected in an increased efficiency of interconnector use (3.3), and day-ahead price convergence in Baltic states in particular. However, cross-zonal capacity challenges remain an important area for further industry engagement and collaboration. Here market network codes (3.4) will continue to play a crucial role in harmonising regulations so that they deliver fair, efficient and safe trading outcomes across Europe.

3.1 Market Coupling

Context

Market coupling refers to the integration of two or more electricity markets through a coordinated and harmonised process of optimising inputs (demand and available generation), and communicating outputs (matched trades, prices and scheduled exchanges), given network constraints (available capacity on cross zonal lines).

This is where the network code for Capacity Allocation and Congestion Management (CACM) (see 3.4) plays a fundamental role in setting transparent conditions for fair and safe access to cross zonal capacity. The CACM is therefore at the cornerstone of Europe's market coupling efforts and the development of a single market for electricity. Increasing the coupling of markets – both at the day-ahead and intraday level - leads to lower prices for consumers and greater social welfare.

Trends

Initially starting with the coordination of TSOs and NEMOs in proximal countries to enable isolated coupling, there has been wider spread of market coupling over the past five years. In particular coupling of day-ahead markets (single day-ahead coupling – SDAC) has made good progress, with 27 countries involved with one of two parallel coupling projects (which could be merged in the future)[11]. Together these countries account for more than 90% of European electricity consumption.

Both projects make use of a common pricing algorithm (PCR EUPHEMIA) to calculate electricity prices across Europe, and implicitly allocate cross-border capacity. Ireland and Greece both joined the Multi-Regional Coupling (MRC) project in November 2018 demonstrating continued momentum and further progress. Additionally, all TSOs and NEMOs are finalising a governance agreement - the Day Ahead Operational Agreement (DAOA) – to formally set the terms for cooperation between involved parties moving forward.

Intraday coupling has been implemented more slowly than at the day-ahead level, as there are more operational complexities associated with continuous trading ranging from technical issues to market design and governance. However, as of summer 2018, the majority of Europe is now served by the Intraday Operational Agreement (IDOA) with 26 countries signed up to the agreement.

The XBID started as a joint initiative by NEMOs and TSOs from 11 countries, to create a coupled intraday cross-border market. It went live on 12 June 2018 and currently consists of 14 countries[12] (see Figure 26). A 'second wave' will go ahead in Summer 2019. The XBID Platform has been confirmed as the Single Intraday Coupling (SIDC) which shall enable continuous cross-border trading across Europe.

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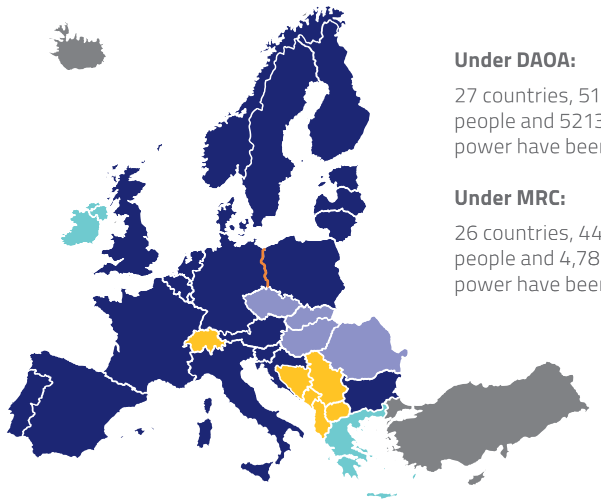
[10] https://ec.europa.eu/energy/sites/ener/files/documents/20130902_energy_integration_benefits.pdf

[11] 22 countries are connected via the MCR project as at December 2018, these are: Austria, Belgium, Croatia, Denmark, Estonia, Finland, France, Germany, Great Britain, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovenia, Spain and Sweden. A further 4 countries are involved with the 4M Market Coupling project, these are Czech Republic, Slovakia, Hungary and Romania.

[12] Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Latvia, Lithuania, Norway, the Netherlands, Portugal, Spain and Sweden

Figure 25 - State-of-play in day-ahead market coupling across Europe, as of December 2018 (source: ENTSO-E)



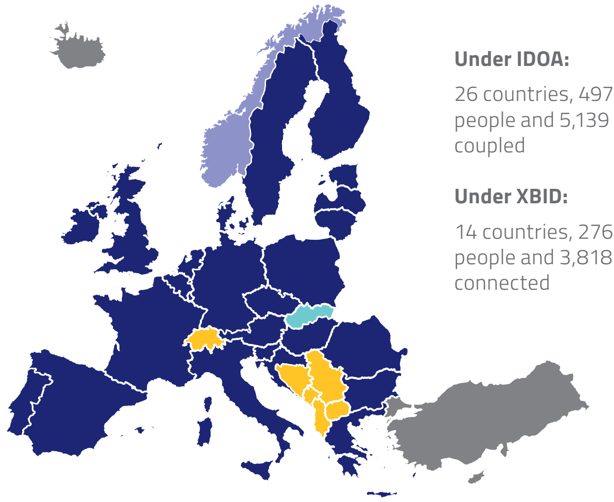
Under DAOA:

27 countries, 517 million people and 5213 TWh of power have been coupled

Under MRC:

26 countries, 443 million people and 4,788 TWh of power have been coupled

Figure 26 - State-of-play in intraday market coupling across Europe, as of December 2018 (source: ENTSO-E)



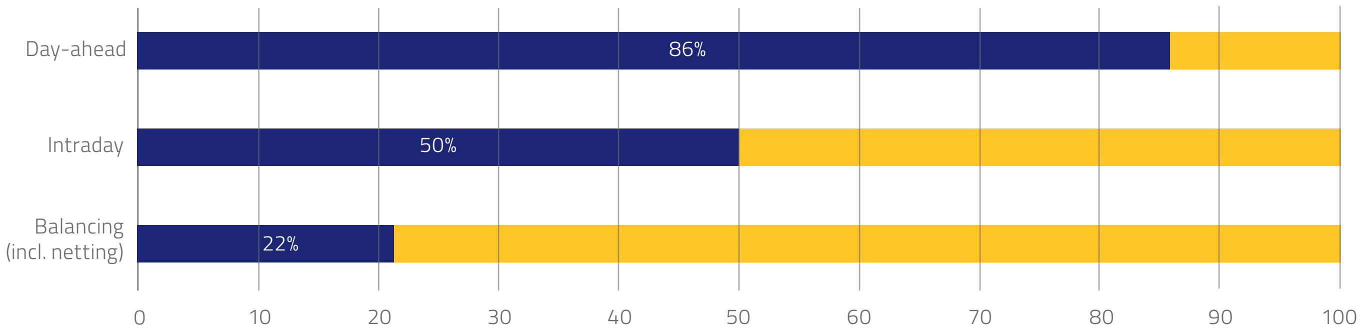
Under IDOA:

26 countries, 497 million people and 5,139 TWh are coupled

Under XBID:

14 countries, 276 million people and 3,818 TWh are connected

Figure 27 - Europe's interconnector efficiency for day-ahead, intraday and balancing trades (source: ACER)



The progress made in day-ahead market coupling is reflected in the uplift in the level of efficiency in interconnector use, i.e. the percentage use of available commercial capacity in the 'right economic direction', from around 60% in 2010 to 86% in 2017. Intraday efficiency has remained lower around 50%, although with increased participation in day-ahead coupling and the application of SIDC, this should increase in the future.

Use of interconnection has to be considered in light of levels of congestion of the European grid. ENTSO-E's Bidding Zone Technical Report includes detailed figures showing how congested the European grid is (see 1.4 Ancillary Services and Congestion Management for more information).

> "The progress made in day-ahead market coupling is reflected in the uplift in the level of efficiency in interconnector use from around 60% in 2010 to 86% in 2017."

Sources:

Irish Power Spot Market Launched, EPEX, 2018. <https://www.epexspot.com/document/39794/181002_EPEX_ECC_I-SEM.pdf>

First Joint Report on the Progress and Potential Problems with the Implementation of Intraday and Day-Ahead Coupling As Well As Forward Capacity Allocation, ENTSO-E, 2018. <https://docstore.entsoe.eu/Documents/Network%20codes%20documents/NC%20CACM/First_Joint_Report_FCA_and_CACM.PDF>

Annual Report on the Results of Monitoring the Internal Electricity and Natural Gas Markets in 2017, ACER, 2018. <https://acer.europa.eu/Official_documents/Acts_of_the_Agency/Publication/MMR%202017%20-%20SUMMARY.pdf>

3.2 Price Convergence

Context

Price convergence is a valuable indicator of the success of market integration achieved through market coupling and interconnection. Conversely, a lack of market integration is visible if two neighbouring countries have very divergent electricity prices. Of course, individual price differences at a point in time may just be a result of market conditions, while macro-trends over a period illustrate fundamental electricity market integration patterns.

In 2014, following a period of incremental pan-European coupling, the wider price coupling of day-ahead markets in North Western Europe took place, which was the first step towards the pan-European Price Coupling of Regions (PCR) project. It combined the Central Western European (CWE) area with Great Britain, the Nordics and the Baltics – since its inception Spain, Portugal and Italy have joined.

Trends

Figure 28 provides an overview of price convergence within European market coupling regions between 2008 and 2017. There is a clear increase in the price convergence in the Baltic, CWE and South-Western European (SWE) markets, as demonstrated by the increase in the number of hours in which full price convergence occurs across the years (proxied as 0-1 €/MWh difference – blue bars). The increase in interconnection capacity in the Baltic area has been noted as a key contributor to this trend. For the CWE region, the price convergence in the past few years can be partly attributed to the implementation of flow-based market coupling in 2015, whereas the recent price divergence in the SWE region is influenced by a changing electricity generation mix in Spain and Portugal causing large price swings.

The average day-ahead price of all European countries in 2017 was 42.38 €/MWh. The total price range of day-ahead prices is 24.60 €/MWh, which indicates that considerable variability across Europe remains[13].

Interconnection between these regions may increase price convergence. For example, after the completion of the NordBalt link between Lithuania and Sweden in December 2015, the price difference between the two countries fell from 8.2 €/MWh in 2015 to 7.3 €/MWh in 2016. Although prices are affected by factors outside of interconnection, especially in the short-term (yearly), at least part of this price convergence could be explained through the interconnection gain.

However, it should be noted that some price divergence is likely. Indeed, the interconnection levels required for full price convergence may be prohibitively high for the social welfare benefit delivered. Bespoke cost-benefit analysis using in-depth modelling is the optimum way to determine whether an interconnector is required, and is the approach taken by the ENTSO-E Ten-Year Network Development Plan (TYNDP).

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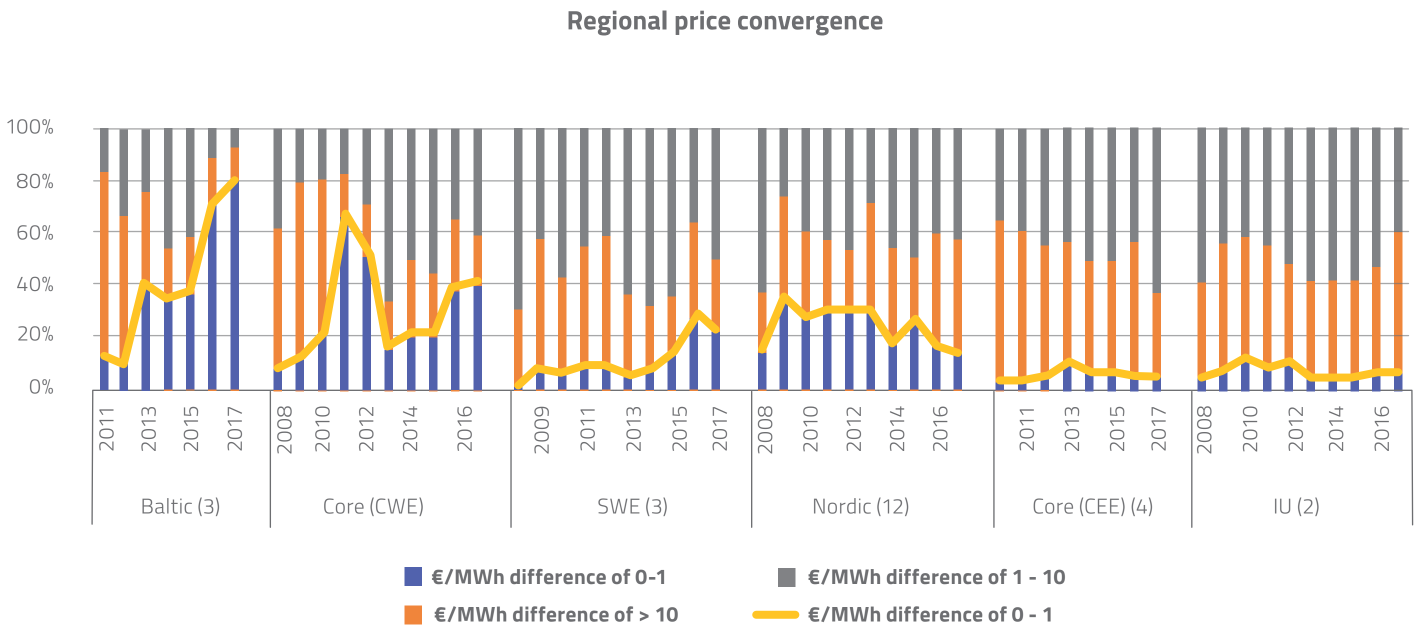
[13] More information and specific day-ahead prices can be found on the ENTSO-E Transparency Platform. NEMOs do not currently allow this data to be used in reports.

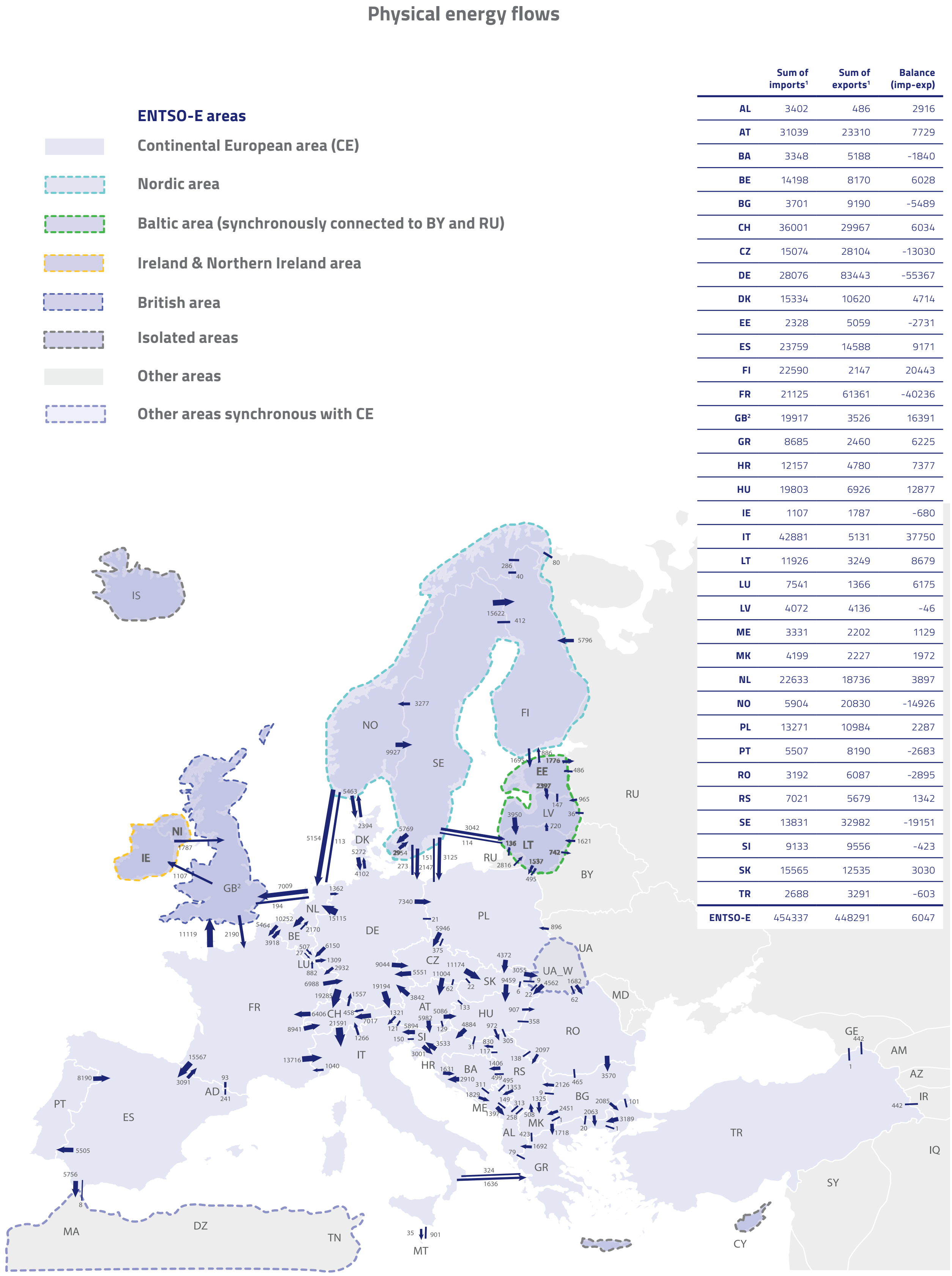
Figure 28 - Day-ahead price convergence in Europe by capacity calculation region (ranked) – 2008-2017
(sources: ENTSO-E and ACER calculations)



Sources:
ACER (2018) *Electricity Markets Volume.* Available from: https://acer.europa.eu/Official_documents/Acts_of_the_Agency/Publication/MMR%202017%20-%20 ELECTRICITY.pdf

ENTSO-E (2018) *Transparency Platform: Day-ahead prices.* Available from: https://transparency.entsoe.eu/transmission-domain/r2/dayAheadPrices/show

Figure 29 - Map of Europe showing physical energy flows in GWh, 2017 (source: ENTSO-E)



	Sum of imports¹	Sum of exports¹	Balance (imp-exp)
AL	3402	486	2916
AT	31039	23310	7729
BA	3348	5188	-1840
BE	14198	8170	6028
BG	3701	9190	-5489
CH	36001	29967	6034
CZ	15074	28104	-13030
DE	28076	83443	-55367
DK	15334	10620	4714
EE	2328	5059	-2731
ES	23759	14588	9171
FI	22590	2147	20443
FR	21125	61361	-40236
GB²	19917	3526	16391
GR	8685	2460	6225
HR	12157	4780	7377
HU	19803	6926	12877
IE	1107	1787	-680
IT	42881	5131	37750
LT	11926	3249	8679
LU	7541	1366	6175
LV	4072	4136	-46
ME	3331	2202	1129
MK	4199	2227	1972
NL	22633	18736	3897
NO	5904	20830	-14926
PL	13271	10984	2287
PT	5507	8190	-2683
RO	3192	6087	-2895
RS	7021	5679	1342
SE	13831	32982	-19151
SI	9133	9556	-423
SK	15565	12535	3030
TR	2688	3291	-603
ENTSO-E	454337	448291	6047

3.3 Physical Energy Flows

Context

One challenge of Europe's zonal electricity market design is that electricity does not always flow across borders in perfect response to price differentials – i.e. from low to high prices in response to system needs. Unscheduled flows can reduce cross-zonal capacity for other trades, hinder the short-run efficiency of the market and harm security of supply.

Whilst this topic is complex, this sub-chapter presents current physical energy flows across Europe, and a summary of the efficiency of cross-zonal capacities.

Trends

Between 2016 and 2017, total physical energy flows between European countries increased from 460 TWh to 467 TWh. This total still sits below the 2015 level of 484 TWh. Figure 29 illustrates the physical energy flows for 2017. France saw the largest change in physical energy flows, with an additional 11.7 TWh flowing into the country and an additional 11.2 TWh flowing out per year, over the period 2015 - 2017. France is however still a significant net exporter.

8.2 €/MWh
in 2015 to
7.3 €/MWh

Price difference between Lithuania and Sweden before and after the completion of the NordBalt link

42.38 €/MWh
average day-ahead price of all European countries in 2017

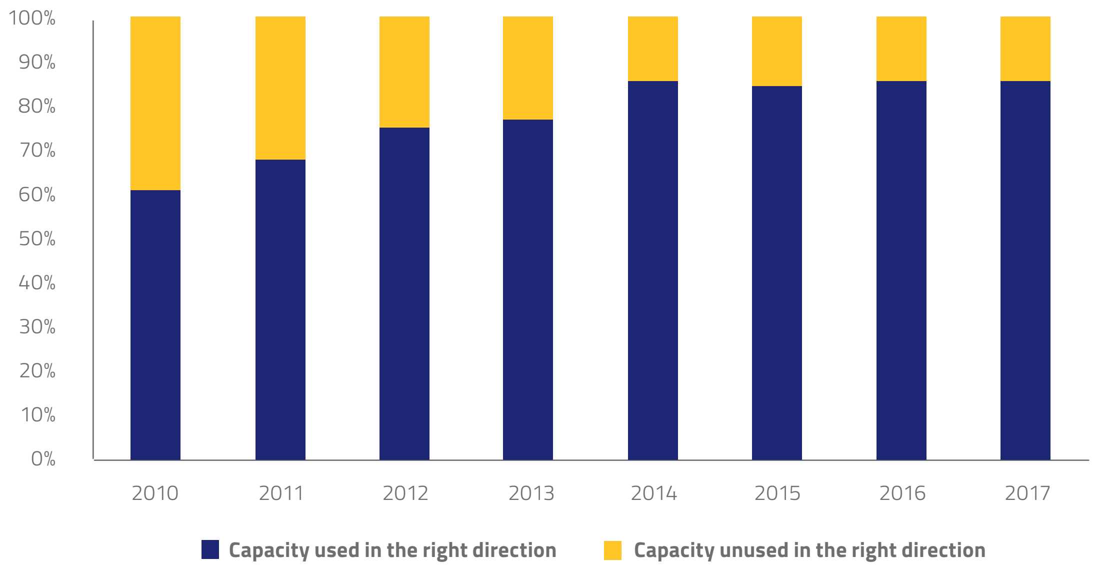
A challenge consistent amongst many countries is the limited capacity made available to cross-zonal exchanges, which support the efficient functioning of the internal electricity market, rather than unscheduled flows for instance.

Whilst increasing cross-zonal capacity remains a challenge, the interconnector capacity that is made available is being used more efficiently. This is particularly the case in the day-ahead market where market coupling (see 3.1) has supported an increase in capacity made available for exchanges in the right economic direction – i.e. from low to high prices. This can be seen to have increased from 60% in 2010 to 86% in 2017 in Figure 30.

When considering the intraday market, the efficient utilisation of cross-zonal capacity remains low, according to ACER. In 2017, on average 50% of the capacity was used efficiently. 2016-17 saw an increase in the aggregated cross-zonal volume on the intraday markets by 3%, which is a consistent trend since 2010. The ACER figures on interconnection use are contested. However, it is clear that limited capacity at borders can be tackled by further investment in the grid, full implementation of network codes, fit for purpose market design, digitisation etc.

Increased transparency on how the network is constrained and how capacity is calculated is equally important.

Figure 30 - Progress made in the efficient use of electricity interconnectors in the DA market timeframe over the last 8 years – percentage of available capacity (NTC) used in the 'right direction' in the presence of a significant price differential (>1 euro/MWh)



Sources:
ENTSO-E (2018) *Statistical Factsheet 2017.* Available from: https://docstore.entsoe.eu/Documents/Publications/Statistics/Factsheet/entsoe_sfs_2017.pdf
ENTSO-E (2016) *Statistical Factsheet 2015.* Available from: https://docstore.entsoe.eu/Documents/Publications/Statistics/Factsheet/entsoe_sfs2015_web.pdf
ACER (2018) *Annual Report on the Results of Monitoring the Internal Electricity and Natural Gas Markets in 2017.* Available from: https://acer.europa.eu/Official_documents/Acts_of_the_Agency/Publication/MMR%202017%20-%20ELECTRICITY.pdf

3.4 Market Network Codes

Context
The European market network codes harmonise the operational practices for cross-border trade in long- and short-term electricity products and reserves, as well as harmonising procedures related to imbalance settlements. There are three codes:

- **Forward Capacity Allocation (FCA):** sets out the terms for cross-zonal capacity calculation and allocation in forward markets. This allows market participants to secure cross-border capacity some time in advance.
- **Capacity Allocation and Congestion Management (CACM):** outlines binding guidelines for the operation of harmonised day-ahead and intra-day markets across Europe and defines methodologies for calculating how much capacity there is for safe use on cross border lines.
- **Electricity Balancing (EB):** aims to create a market where countries can at all times share the resources used by their TSOs to make generation equal demand. It is also about allowing new players such as demand response and renewables to play a role in the market.

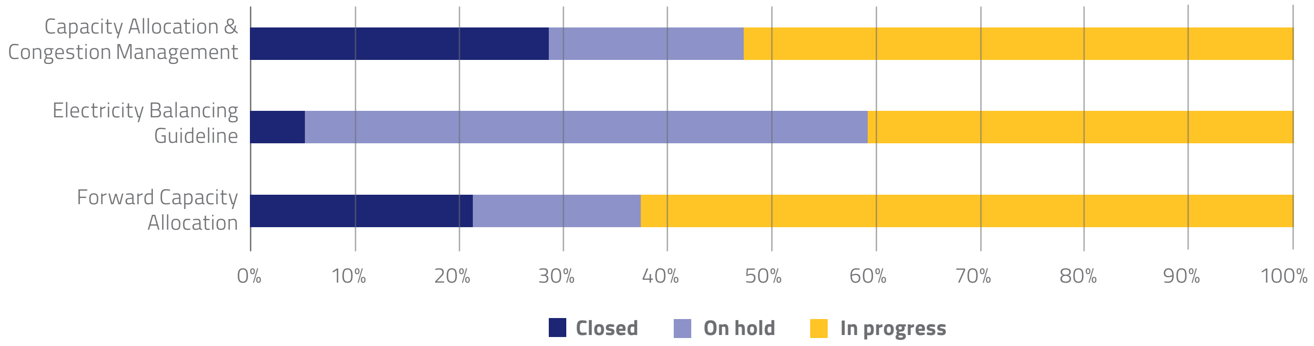
Status
All market network codes entered implementation phase by the beginning of 2017. The current state of implementation of all the market network codes is shown in Figure 31. The majority (72) of the deliverables for all the responsible bodies are 'in progress'.

CASE STUDY

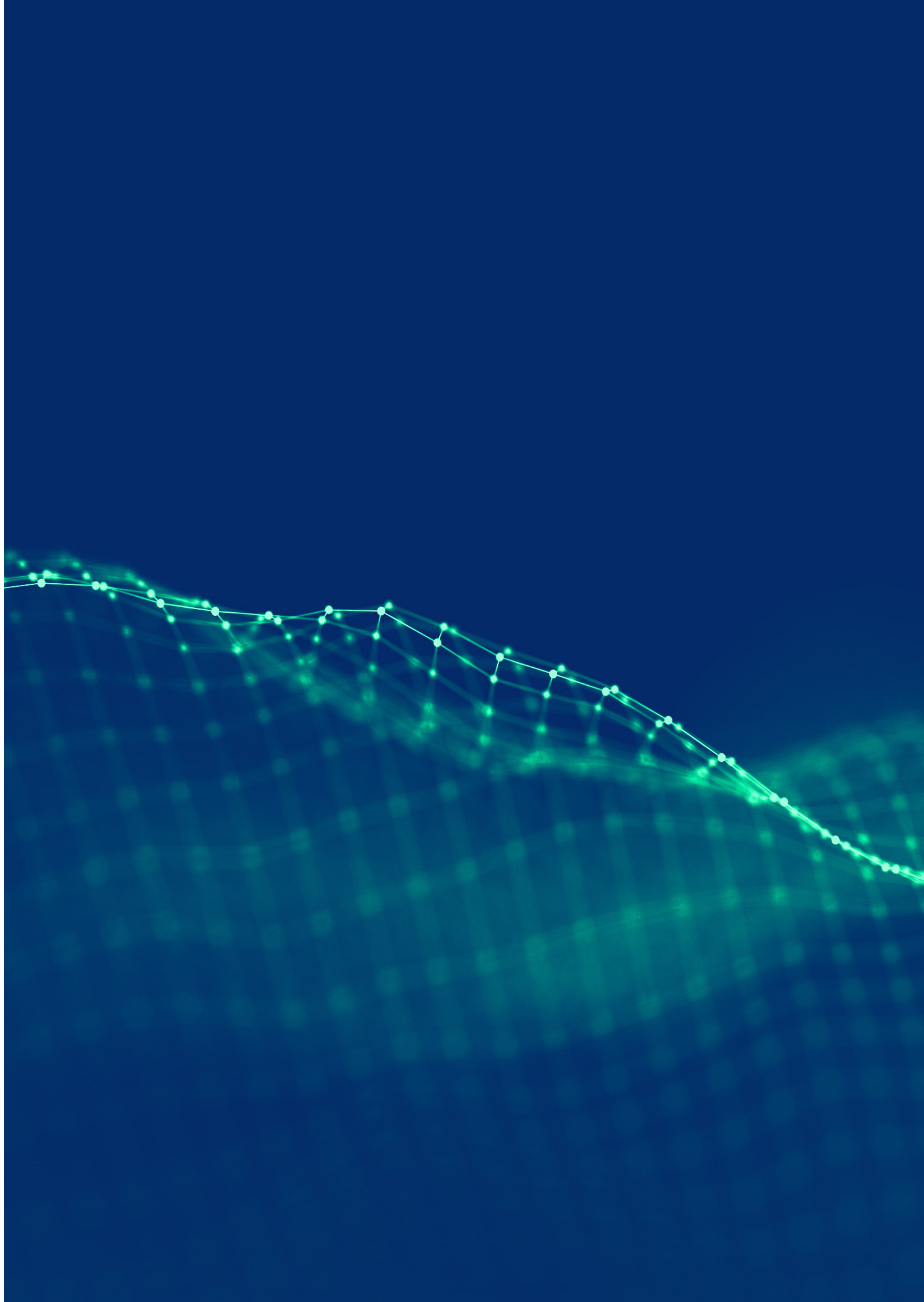
Value created by the network codes

The development of the market codes carries the promise of direct and noticeable welfare gains for the European consumer. Increasing the size and liquidity of energy markets across Europe in theory allows for more efficient dispatch and market outcomes, helping to keep prices competitive. FTI - ENTSO-E research suggests that €0.7 – 1 billion per year of social welfare gains are realisable from the implementation of the network codes. ACER analysis suggests that greater progress in the development of the energy markets could lead to even greater welfare gains estimated at around €5 billion per year.

Figure 31 - Status of deliverables under CACM, EB and FCA implementation programme (source: ENTSO-E)



> All market network codes entered implementation phase by the beginning of 2017



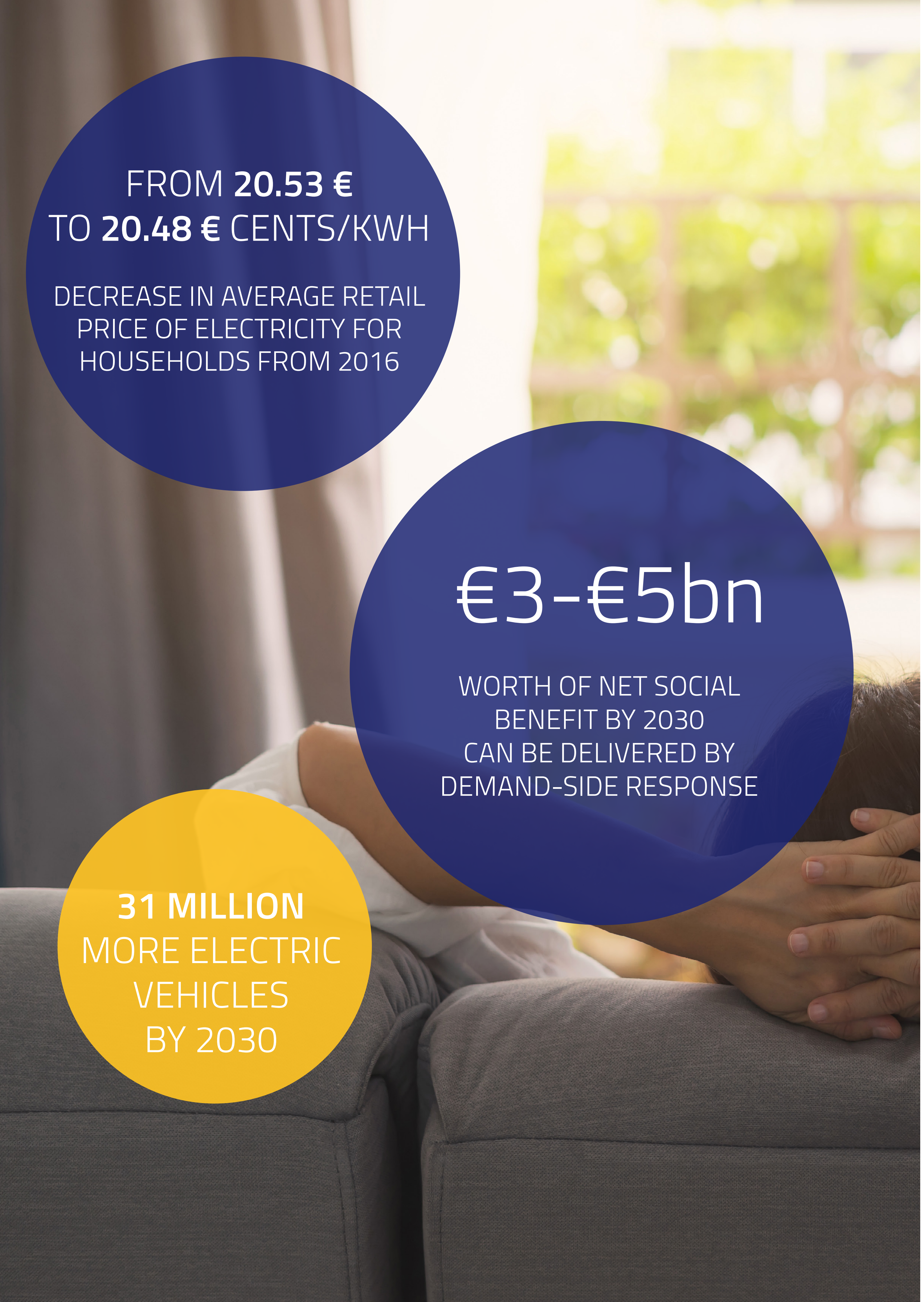
Sources:

ACER (2018) *Market Codes – Guidelines on the Integration and Functioning of EU's Internal Electricity Market.* Available from: https://acer.europa.eu/en/Electricity/MARKET-CODES/Pages/default.aspx

ENTSO-E (2018) *Network Codes.* Available from: https://electricity.network-codes.eu/network_codes/

ENTSO-E (2017) *Annual report – network codes, the value created by network codes.* Available from: https://annualreport2017.entsoe.eu/network-codes/

S&P Global Platts (2018) *EU could gas billions if power bidding zones are changed. ACER.* Available from: https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/102318-eu-could-gain-billions-if-power-bidding-zones-are-changed-acer



FROM **20.53 €**
TO **20.48 €** CENTS/KWH

DECREASE IN AVERAGE RETAIL PRICE OF ELECTRICITY FOR HOUSEHOLDS FROM 2016

€3-€5bn

WORTH OF NET SOCIAL BENEFIT BY 2030 CAN BE DELIVERED BY DEMAND-SIDE RESPONSE

31 MILLION
MORE ELECTRIC VEHICLES BY 2030

Chapter 4 - Customer

The Clean Energy Package rightly emphasises customers central place in the energy transition. Initial progress has been made in encouraging industrial and household customers to offer energy services, but more can be done to ensure that all customers can participate in a wider range of markets, with new technologies and greater access to information. This will provide greater choice, open new service opportunities and enable more direct participation in the energy transition.

This chapter considers the evolving energy services (4.1 - 4.2) and the new technologies (4.3 – 4.4) which are supporting customers taking a growing role at the heart of the transition.

Ultimately, the energy transition must deliver a secure, sustainable and affordable energy system for European households and business use. This chapter therefore also tracks the evolution of power prices and energy poverty (4.5 – 4.6), noting that with over 50 million Europeans thought to be in energy poverty, greater progress can be made in this area.

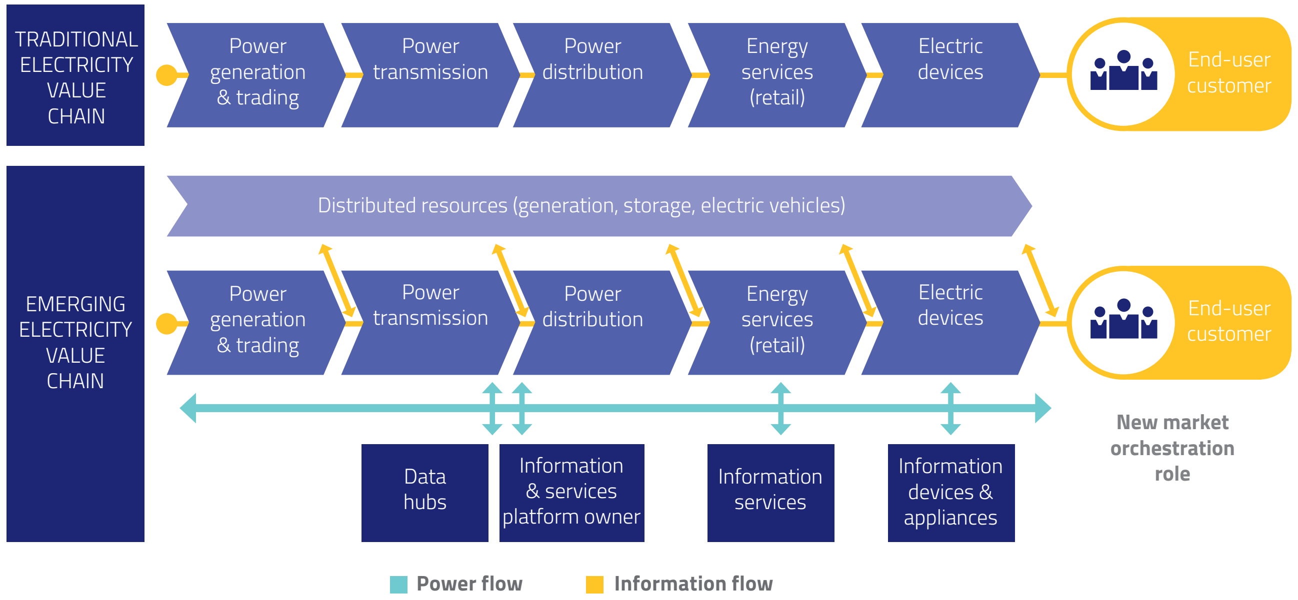
4.1 Demand Side Response (DSR)

Context

The electricity system is transitioning from a traditional model whereby power is sent from centralised plants to customers, to a new system characterised by multi-directional flows, dynamic demand, and smart appliances. This shift will require investments in infrastructure, changes to price signals, implementation of market codes and business models which deliver increasing flexibility to the grid. The rise of smart technologies looks set to change the role that consumers play in the energy market and paves the way for active market participation. Moving away from predictable energy usage to a more dynamic consumption pattern, the consumers' role is transitioning along with the wider energy system.

Smart technologies and dynamic, system-cost reflective pricing can unlock the potential for demand response flexibility. For instance, through shifting energy use from an expensive time-period to another, efficiency opportunities can be capitalised upon. Flexibility providers can therefore help network operators ensure that the balance between supply and demand of electricity is maintained, with potential for savings for customers as well.

Figure 32- New multi-sided orchestration platforms (source: ENTSO-E)



Analysis published by the European Commission (Newbury, D. et al) suggests that demand-side response can deliver between €3 - €5 billion worth of net social benefit by 2030.

Trends

There are two types of DSR: *implicit* response to price signals (e.g. changing demand based on time-of-use tariffs), and *explicit* responses which are influenced by incentives offered in the wholesale, balancing, ancillary-service and capacity markets. This subchapter considers the development of explicit demand response which is conventionally measured via direct market payments.

Additional to market-price driven ('implicit') DSR, regulators are formally opening participation in energy markets to responders, many of which aggregate together smaller loads to offer flexibility services to the system. This type of 'explicit' DSR, underwritten by wholesale, balancing, ancillary-service and capacity market contracts is playing an increasingly prevalent role. The emergence of aggregator business models has allowed industrial and commercial customers to actively engage in these energy markets and benefit commercially from the delivery of DSR and flexibility services to the grid.

Although an increasing number of markets are more favourable to demand response, the reporting of exact volumes is low. Figure 33 provides a summary of the DSR volumes (MW) reported across four countries - Great Britain, France, Finland and Belgium – which are at the forefront of encouraging and reporting DSR. Between these markets, the reported volume of DSR increased by 225%, from 25,842 MW to 84,028 MW between 2016 and 2017. The values reported give the maximum DSR capacity contracted in each service across a year, these capacities are not necessarily all available at the same time or completely fulfilled. The French NEBEF market is dominant in terms of the volumes permitted to participate on the market. There, consumers can participate in the energy market by shifting demand. A high proportion (87.6%) of the capacity contracted in 2017 was fulfilled.

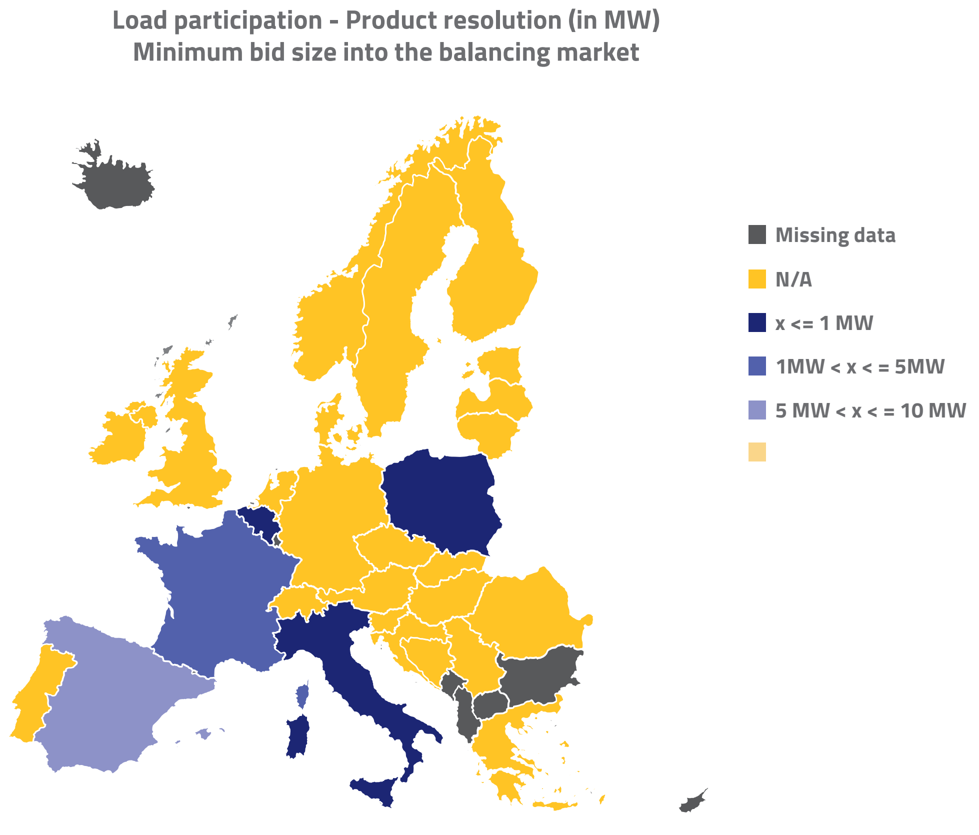
Even when markets are explicitly open to new energy services including demand-response and aggregator participation, market rules are naturally slower to adapt and reflective of traditional market structures, service requirements and generation sources. For example, scale is important, and load participation tends to be conditional on a minimum bid size (MW). Whilst this gives the incentive for increased aggregation, which has some benefits (e.g. security of a more diverse asset portfolio), it acts as a barrier to smaller market players and potentially reduces participation and competition. Member States can support increased levels of demand-response to participate in balancing markets by opening these products up to lower bid sizes.

Figure 33 - Volumes (MW) of demand side response reported in Great Britain (GB), France, Finland and Belgium from 2014-17[14]

DSR Volumes (MW)

Country	Type of DSR	ENTSO-E	2014	2015	2016	2017
GB	Frequency Response	FCR		374	707	617
	STOR	RR		1745	1821	1369
	DSBR	RR		515	0	0
	Fast Reserve	FRR			180	300
	Intraday				97	
France	NEBEF (wholesale)		900	3173.8	22169.16	78183.6
	FCR	FCR				60
	aFRR	aFRR			10	
	mFRR	mFRR				480
	RR	RR				1075
Finland	Day Ahead					400
	Intraday					100
	FCR	FCR			379	241
	mFRR	mFRR				200
	RR	RR				10
	aFRR	aFRR			70	
Belgium	R1	FCR		27		68
	R2	FRR				144
	R3	mFRR		321	210	780
	Strategic Reserve	RR		97		
	ICH				199	
	Total (MW)		900	6252.8	25842.16	84027.6
	Y-o-Y % Change			595%	313%	225%
	3-Year Average					378%

Figure 34 - Minimum size bid (MW) of load participating in balancing markets (source: ENTSO-E, 2017)



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[14] The online sources for these volumes are as follows, please note GB values are taken for the year in which the predominant share of the tax year sits. SEDC 2017, GB 2015 National Grid, GB 2016 National Grid, GB 2016 Ofgem, GB 2017 National Grid, France NEBEF RTE, France 2017 RTE, Finland 2016 Fingrid (potential demand), Belgium 2016 & 2017 Elia.

Sources:

SmartEn (2017) *Explicit Demand Response in Europe.* Available from: http://www.smarten.eu/wp-content/uploads/2017/04/SEDC-Explicit-Demand-Response-in-Europe-Mapping-the-Markets-2017.pdf

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4.2 Aggregators

Context

Aggregators can empower customers and assist system operators by bringing together multiple small loads and generating assets to provide flexibility services to the grid in return for compensation. They therefore can play an important role in delivering energy services from atypical sources such as industrial processes or household batteries, by altering the electricity consumption or production of consumers in response to market incentives and system needs.

These business models are in their infancy, and this subchapter provides an initial view on the number of aggregators operating in Europe.

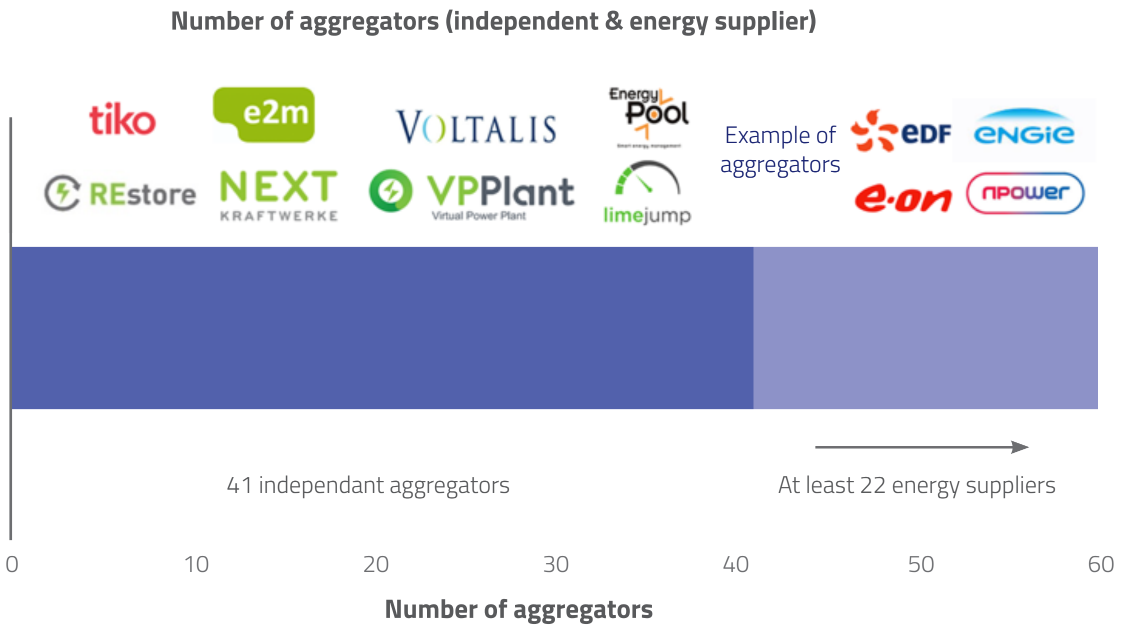
Trends

There are three categories of aggregators, classified by the type of services they offer: those that only aggregate power generation assets such as backup power generators, others that only aggregate electricity load (e.g. a business-site's demand for power), and the majority which does both. There is a strong link between the development of demand side response (DSR) as a flexible resource which can benefit the grid, and the development of aggregators. Indeed, the pooling of demand-resources from customers, such as industrial plant owners or nation wide supermarket chains, opens up the energy market to greater participation from a range of consumers. Aggregators play an important role as intermediaries, bringing together multiple sources of load/generation from customers who would otherwise find it too complex, too expensive or are too small to provide energy services to network operators.

Initially, aggregator service offerings have been focused on larger industrial and commercial customers, for which the volumes of energy supply and demand are relatively large, and administration costs are therefore relatively manageable. Future smart meter and smart consumer-goods rollouts create the opportunity for the expansion of these services to other customers, particularly prosumers and "prosumagers" – those consumers that generate electricity themselves (e.g. through solar PV) and those that additionally store the energy produced (e.g. using home-batteries). Here again it is likely that aggregators – possibly linked to energy suppliers – will continue to play a role in the future, bridging the gap between individuals and grid-level flexibility market players.

In 2019, the European aggregator market can be characterised as being split between independent aggregators which offer specific energy services and/or technologies, and larger energy retailers who have developed competencies to complement their existing supply businesses. The development of new energy companies and services is evidence of technology and policy evolving together to enhance competition in the energy market. Independent aggregators have forged specialised service niches and offered new flexibility services into the market (e.g. Limejump offering DSR into the balancing market for the first time in the UK). Existing energy retailers have reacted by developing their own expertise, through both internal competency development and external partnerships, mergers and acquisitions. Here Enel's acquisition of EnerNOC is a recent example of the consolidation taking place in the market, with mergers and acquisitions of smaller independent aggregators by the larger energy suppliers.

Figure 35 - Estimate of the number of aggregator companies active in Europe, 2018 (source: ENTSO-E)



Sources:
BestRES (2016) Existing business models for renewable energy aggregators. Available from: http://bestres.eu/wp-content/uploads/2016/08/BestRES_Existing-business-models-for-RE-aggregators.pdf

Figure 35 shows the results of a primary research exercise carried out for this publication, with 41 independent aggregators (without energy supply business) counted and at least 22 energy retailers engaging with these new services. This list has been compiled from an online literature review and is by its nature non-exhaustive given the rapid development of new businesses and new commercial models. For example, such aggregation services support a wider ecosystem of companies providing the technology and digital platforms which enable DSR and energy management. These companies have not been counted here as they do not directly engage with aggregation, but the development of such technologies will be crucial to the successful integration of these flexibility services into the future energy system.

4.3 Prosumers and Smart Consumer Technologies

Context

Prosumers are energy customers that, in addition to consuming, also generate electricity. They participate more actively in the energy system. The rise of prosumers can be considered as an enabler of the energy transition for two core reasons:

1. Proactive consumers can maximise the potential of emerging technologies that can be used at local level to deliver carbon reductions and reduce energy costs;
2. If they can be operated dynamically, the spread of energy assets at local level can help balance the overall energy system and thus support the penetration of more variable renewable energy sources.

As consumers engage more intimately with their energy use, the business case for investment in newer technology and energy efficiency may become more convincing. This in turn can drive faster decarbonisation and lower energy costs. However, to enable prosumers to come forward, the energy system will also have to evolve. Data will need to become available to energy users or their appointed representatives to allow them to access and respond to price signals in a straightforward manner either actively or with the support of third parties. Stronger cooperation between TSOs and Distribution System Operators (DSOs) will be key. The roll out of smart meters with granular reading intervals is also a key enabler which will allow organisations to compile, utilise and communicate data in a meaningful manner for prosumers.

Three consumer technologies are gaining commercial traction across Europe and are central to the decarbonisation of different sectors of the economy:

- Electric vehicles with "Vehicle to Grid" technology which can serve as power service providers;
- Electric heat pumps that respond to DSR signals, offering the potential to flatten demand peaks or respond to other system needs;
- Solar photovoltaics when coupled with storage systems.

Trends

Electric vehicles (EVs)

In 2018 a total of 364,000 EVs (BEV and PHEVs) are estimated to have been sold in Europe, 26% higher than for 2017. The share of EVs in Europe is currently 2% of new car sales. In December 2018, the Trilogue (representatives from the European Commission, European Parliament and the European Council) agreed that EV sales should account for 15% of new car sales by 2025 and 35% by 2030. The Trilogue will convene in 2019 to discuss, negotiate and finalise the post-2020 targets for EV adoption.

Beyond 2030, Bloomberg New Energy Finance (BNEF) has forecast the share of EV sales in Europe could rise to 67% by 2040. Countries that have made early progress in EV uptake are expected to be among the leaders in 2040, including Norway, France and the UK. The forecasts rely on likely future reductions in the price for lithium-ion batteries and prospects for other cost components in EVs and internal combustion engines. It also factors in the rising EV commitments from automakers and the number of new EV models in development.

Figure 36 shows actual sales of electric vehicles in Europe between 2013 and 2018. A trendline has been created based on the growth in historic EV sales. The yellow dots show the level of EV sales. The light blue dots show the level of EV uptake in 2020 and 2030 under the Distributed Generation (prosumers at the centre) scenario of ENTSO-E's Ten-Year Network Development Plan (TYNDP).

The dark blue dots show the level of uptake based on the current post-2020 regulation for EV adoption – 15% share by 2025 and 35% share by 2030. We assume new car sales in Europe continue to grow at the rate they have since 2013 (5% each year on average). By 2025, the level of new car sales in Europe reach 22 million. By 2030, this increases to 28 million. Applying the target shares yields over 3 million EV sales in 2025, rising to over 8 million by 2030.

Deployment of EVs under the TYNDP's Distributed Generation scenario is more aggressive relative to the EU's provisional targets. By 2030, the TYNDP estimates there will be around 31 million more EVs than under the EU's provisional target.

Heat pumps

In Europe 1.11 million heat pumps were sold in 2017, up from 11% in 2016. The total stock of heat pumps increased to 10.6 million. The European Heat Pump Association have forecasted that the stock of heat pumps will increase to 14.5 million by 2020. This is based on a constant annual growth of 11.5%. Between 2011 and 2016, average annual growth was 13% with a standard deviation of 2% - in line with the EHPA's 2020 target (11.5%). If we assume this 11.5% growth rate remains constant until 2040, the stock of heat pumps will increase to 129 million. Low and medium growth (derived from EHPA's assumptions) scenarios put the increase in heat pumps at 19 and 36 million units respectively.

Comparing this level of deployment with TYNDP scenarios shows some differences and similarities. Under the TYNDP Global Climate Action scenario, maximum heat pump deployment is 58 million by 2040. This compares with 129 million from the EHPA. Similarities in deployment exist in the other two scenarios. Under the TYNDP Sustainable Transition scenario heat pumps increase to 18 million and under the Distributed Generation scenario, deployment reaches 35 million. These deployment levels match the low and medium growth levels charted in Figure 37. It can be argued that a growth rate of 11.5% cannot be sustained indefinitely and therefore a deployment level of 129 million heat pump units in Europe is potentially challenging.

Solar PV

In 2017, newly installed solar PV capacity increased by 31% to 9.2 GW. Growth was driven largely by Turkey which added 2.6 GW of capacity while Germany, a distant second, added 1.8 GW of capacity. Of this newly installed capacity, 26% was attributed to residential rooftops. Across Europe, the share of residential solar varied across member states – Romania had a share of less than 1%, while Belgium and the Netherlands had shares around 60%.

Total solar PV capacity in Europe reached 114.0 GW in 2017 up 9% on the year before. Germany (38%) and Italy (17%) operate over half of this capacity and this is unchanged from the year before.

SolarPower Europe's medium scenario estimates total capacity to reach 208 GW by the end of 2022, an 82% increase on the level in 2017 (114 GW). A low scenario would see total capacity of 164.9 GW and a high scenario seeing total capacity of 269.4 GW, over twice the total capacity in 2017. By 2025, the TYNDP expects solar PV installed capacity to increase to 189 GW.

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Figure 36 - Electric vehicle sales (BEV & PHEV) in respect to EU targets and TYNDP 2018 (EUCO) projection (source: ENTSO-E)

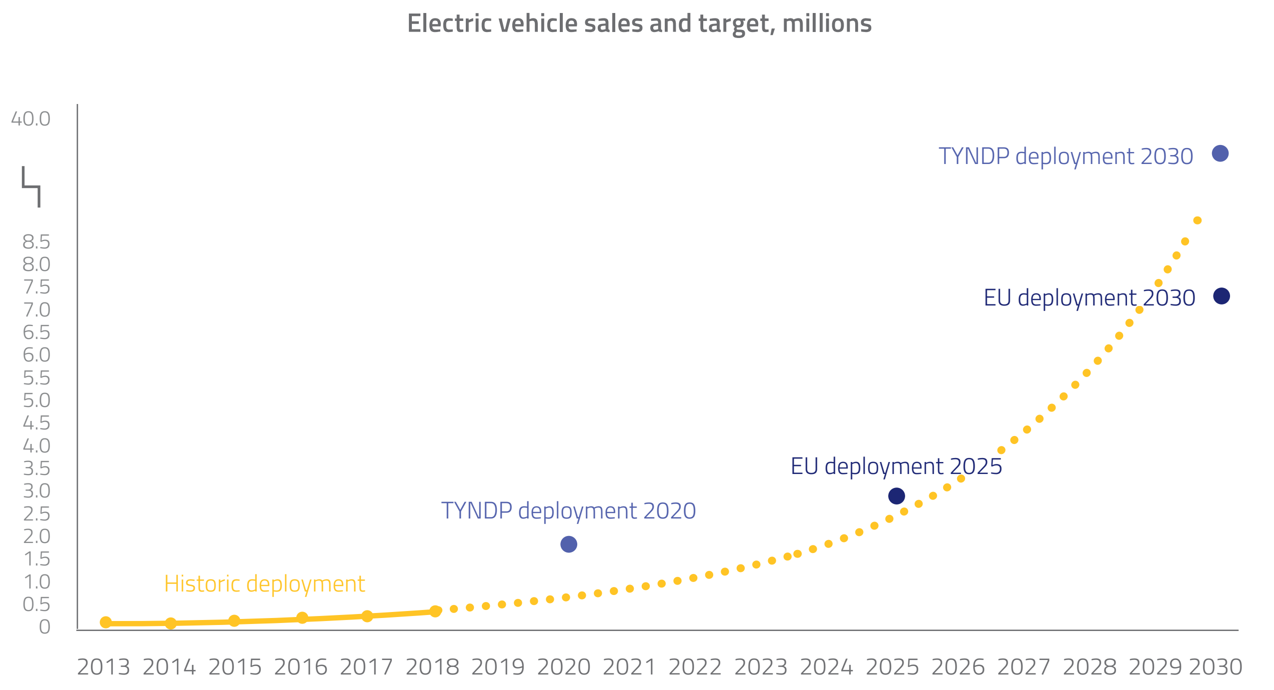
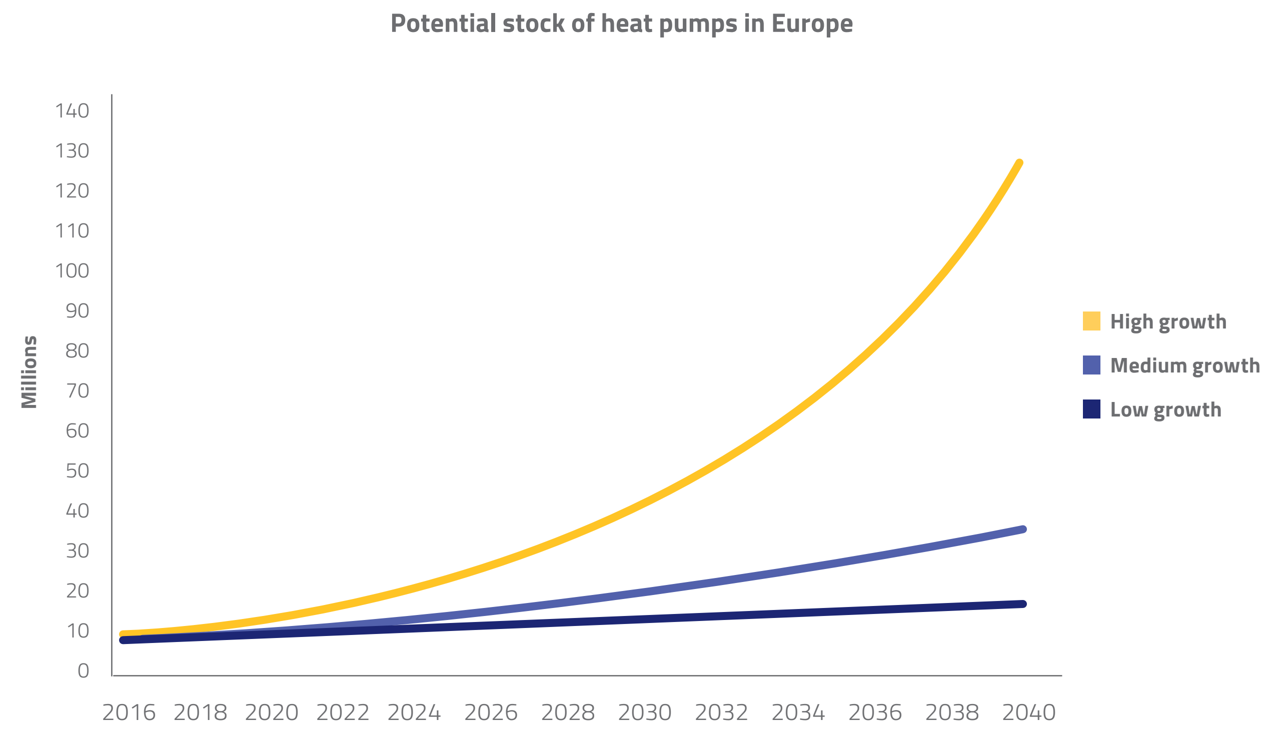


Figure 37 - European heat pump projections (based on EHPA assumptions)



4.4 Microgrids

Context
Micrograms are mainly used in rural or remote areas and in some industrial networks to link decentralised generation to localised demand. Indeed, in a densely populated Europe with meshed grids, there is no real incentive to go off-grid. Microgrids can be stand-alone or can be tied to the central grid. The opportunities of integrating microgrids together and with the central power system will be facilitated in the future as digitalisation progresses.

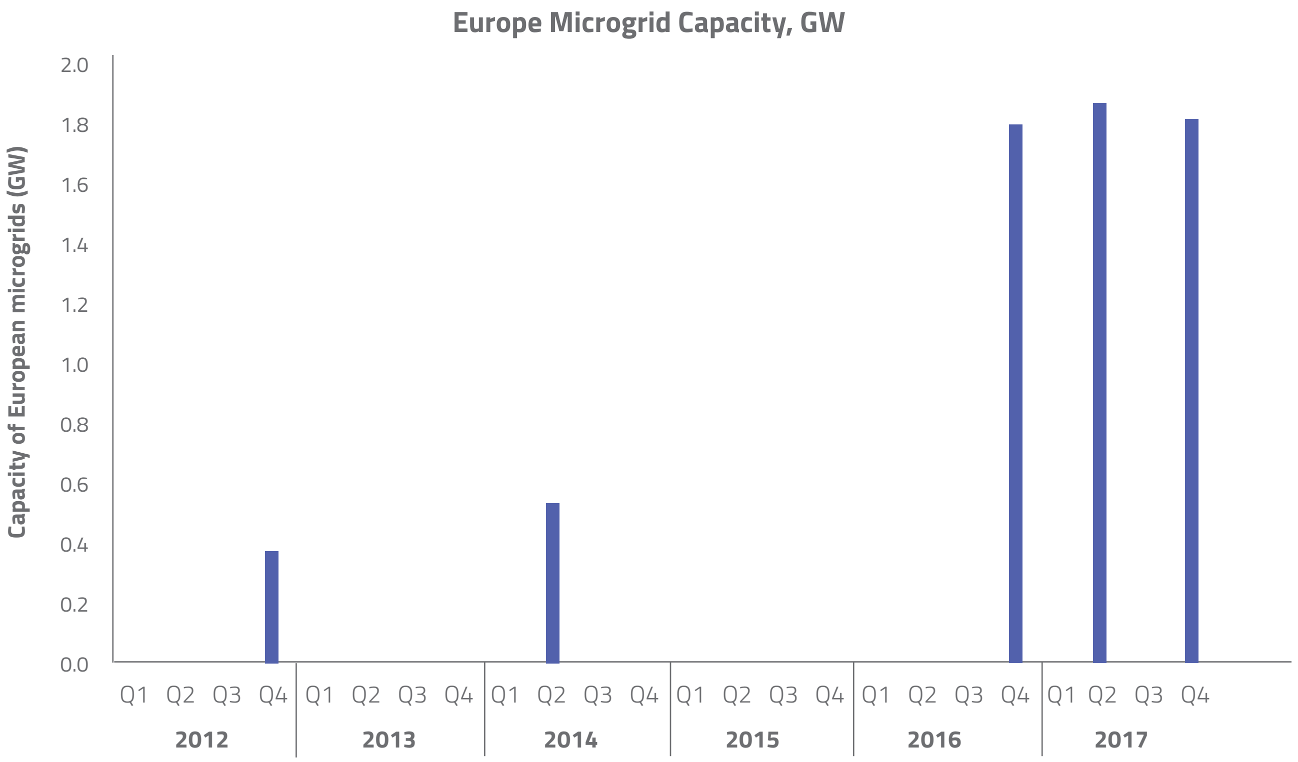
These localised systems will co-exist with the more centralised systems. Building these bridges across systems will allow for better security of supply (microgrids being able to support the central system and vice-versa) and more opportunities to value decentralised generation. This will be contingent on the development of novel business models, smart technology applications, increased energy storage and bespoke regulatory support.

Trends
Research conducted by Navigant has tracked the development of active grid-tied and remote microgrid projects. Worldwide, by the end of 2017, an installed capacity of 20GW had been realised. Of this, Europe accounted for roughly 9% - 1.8GW (Figure 38). European projects are predominantly located in remote, sparsely populated areas such as the Mediterranean, the Canary Islands and the Faroe Islands where macrogrid connections may be less reliable. This locational feature is indicative of the highly integrated European energy system in which TSOs and DSOs are highly effective at integrating consumer energy demand into the system. That said, there has been an increase in microgrid development in Europe; between late 2012 and late 2017, microgrid capacity in Europe increased almost 6-fold. However, this is a slower rate than elsewhere in the world where the Middle East and Asia have seen the greatest increase in capacity over the same period, whilst North America and the Asian Pacific maintain around ¾ of total installed capacity.

The combination of microgrid installations with smart technologies may be particularly influential in their ongoing development in local energy communities. Data collected by the European Commission Directorate-General Joint Research Centre (JRC) for the Smart Grid Project Outlook Report demonstrates that there has been an increased number of research and innovation projects that involve smart microgrids. The most recent report (2017) shows that there are 28 ongoing projects (with fully completed entries in the JRC database).

Collecting information on microgrids can be challenging as they are not always affiliated with organisations which report publicly. As the energy transition continues, and our understanding of their application and roll-out rate increases, a more holistic understanding of their integration into the European energy system will be developed.

Figure 38 - Microgrid capacity in Europe in GW (source: Navigant)



Sources:
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4.5 Retail Electricity Prices

Context
The price of electricity is often fundamental to the affordability of living in a home or running a business. The essential nature of electricity can expose consumers to fluctuations in price, for good or bad as a result of inelastic demand.

The shift to an energy system dominated by variable renewable energy sources looks set to alter the traditional composition of market prices. The final retail price offered is a culmination of several components, which can be split into 'energy and supply', 'network costs', and 'taxes, fees, levies and charges.' Unlike traditional fossil fuel generation, renewables have very high upfront but near-zero marginal costs, creating potential downward pressure on wholesale prices (a component of 'energy and supply'). However, the inherent variability of some forms of RES such as solar or wind places an increasing role on the balancing system to ensure that the equilibrium between demand and supply is maintained - potentially creating upward pressure on 'network costs.'

TSOs will play an important role in integrating new sources of generation and facilitating the energy transition. They play a crucial role in supporting the efficient and affordable integration of renewables into the system. Ultimately, this has an important influence on network costs and end prices for customers.

Trends
2017 saw the average retail price of electricity decrease to 20.48 €cents/kWh for households from 20.53 €cents/kWh in 2016[15]. Non-household consumers also saw a price decrease from 11.33 €cents/kWh in 2016 to 11.21 €cents/kWh in 2017 (for 'medium' consumption: 500MWh to 1999MWh). Figure 39 shows the retail price for the 'medium' households since 2012, as well as the proportional contributions of the different components to the price each year. The 'network cost' is the ratio between the revenue related to transmission and distribution tariffs and the corresponding volume of kWh for the consumption band for each year. 'Energy and supply' is the total price minus the 'network cost' and all taxes and levies.

[15] The values are for average, 'medium' consumption households, those that consume between 2500kWh-4999kWh, and are aggregate to an EU-28 level

Figure 39 - Retail price for medium consumption (2500kWh to 4999kWh) household consumers and the proportional contribution of the different components towards the price, from 2012-2017 (source: Eurostat)

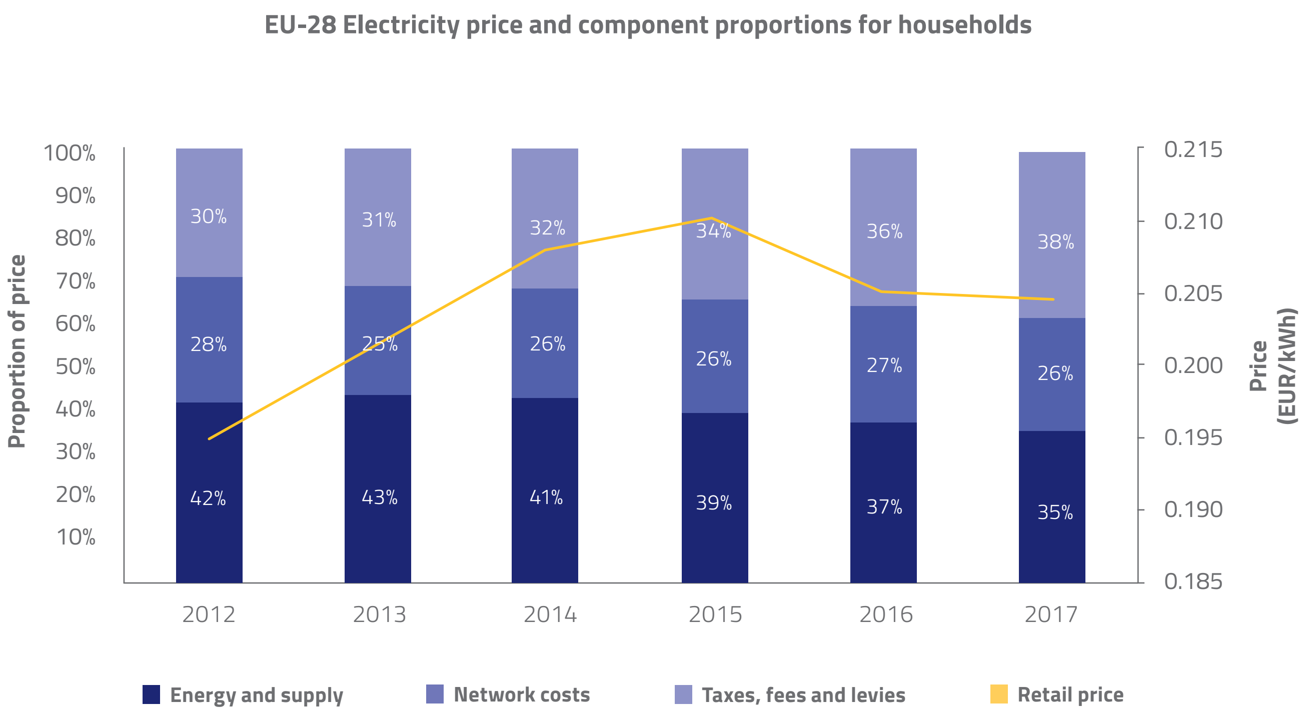
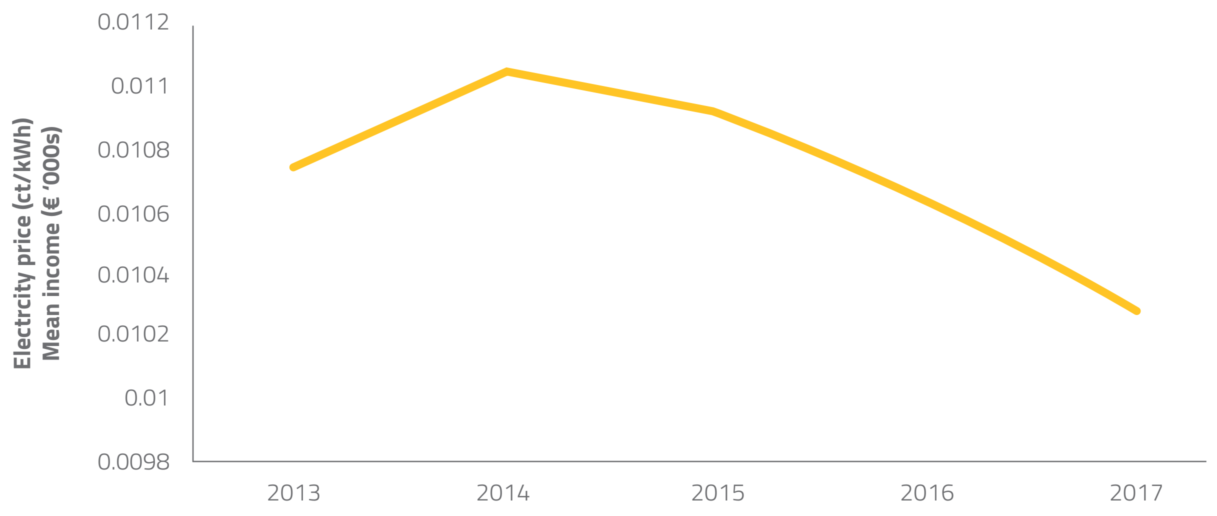


Figure 40 - EA-19 household electricity prices relative to income, 2012-2017 (source: Eurostat)



Between 2012 and 2017 'energy and supply' made up a decreasing proportion of the final price, whilst 'network costs' have stayed relatively stable over the years. It suggests that efforts made by network operators and regulators have mitigated against any upward price pressure from the variability of RES generation. This outturn is consistent when looking at non-household prices.

These changes in the retail price are, however, relatively arbitrary, unless they are made relative to any shifts in income levels. For household consumers, what matters most is the proportion of their incomes spent on electricity and resultant impact on disposable income. Figure 40 illustrates this relative change for households. It shows that the affordability of electricity has improved each year since 2014. In 2017 incomes rose and prices fell, continuing this trend. Again, this is consistent with the trend observed with non-household consumer prices relative to GDP.

4.6 Energy Poverty

Context

Energy is an indispensable good. Evidence shows that living under uncomfortable temperatures and the stress of high energy bills is associated with respiratory and cardiac illness. Energy poverty occurs when the energy services (providing warmth, cooling, lighting, cooking and power) that can be afforded in the home fall below an adequate standard to provide a fulfilling quality of life.

Although there is no fixed definition agreed across Europe, between 50 and 125 million people are estimated to be in energy poverty. Eradicating it is a priority of the European Commission and Member States. The European Commission launched the Energy Poverty Observatory (EPOV) in early 2018 to improve the availability of information on this topic.

Trends

There is no single measure for energy poverty across Europe. The following 'Energy Poverty Index' (EPI) (see Figure 41) blends various measures into one[16], with data from EPOV and Eurostat on energy prices, self-reported energy poverty levels and the income of the lowest quartile being combined. The higher the EPI value, the higher energy poverty is across Europe. The EPI has been developed to give an overarching figure, which can be used as a reference for the energy poverty situation in Europe over time.

The EPI has trended downwards over recent years with the value falling to 74.2, from 82.6, between 2015 and 2016, indicating a decreasing level of energy poverty across Europe. It is however still above the 2009 level of 65.1. The year-on-year improvement since 2013 can largely be explained by the rising incomes of the bottom quartile across the EU and relatively stable gas and electricity prices. Although these incomes have risen steadily since 2009, the electricity and gas prices for households were far cheaper than in 2017, which is why the EPI still sits above the 2009 level.

[16] The EPI calculations took EU-level averages each year for each variable. The calculation uses a weighted average of household electricity and gas prices to reflect the proportion of each in space heating. This is then multiplied by the self-reported percentage of those unable to keep their home adequately warm as one of EPOV's primary energy poverty indicators. The value is then divided by the average income of the first quartile of earners, arguably those most vulnerable to energy poverty. Finally, the value is multiplied by a scale factor to make the numbers more palatable.

Sources:

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> “Between 50 and 125 million people are estimated to be in energy poverty. Eradicating it is a priority of the European Commission and Member States.”

The EPI also shows a strong variation in energy poverty between European countries. Traditionally, there has been an uneven concentration of energy poverty across Europe, with Eastern Europe the worst affected. This is reiterated from the EPI with Bulgaria (835.6), Lithuania (414.8) and Romania (384.7) all having values well above the 2017 European average (74.2).

The lack of a common definition for energy poverty means that EPOV tracks a variety of indicators, which together build a picture of the current position of energy poverty in Europe. These are split into primary and secondary measures. One of these primary measures, ‘Inability to Keep Home Adequately Warm,’ provides a trend on the self-reported level of energy poverty across Europe. This measure reiterates the vast differences in energy poverty between countries within the EU (see Figure 42).

Photo by Jacek Dylag on Unsplash

Sources:
EPOV (2018) *What is energy poverty?* Available from: https://www.energypoverty.eu/about/what-energy-poverty

EPOV b (2018) *Inability to Keep Home Adequately Warm.* Available from: https://www.energypoverty.eu/indicator?primaryId=1461&type=bar&from=2016&to=2016&countries=AT,BE,BG,CH,CY,CZ,DE,DK,EE,EL,ES,EU,FI,FR,HU,HR,IE,IS,IT,LT,LU,LV,MT,NL,NO,PL,PT,RO,RS,SE,SI,SK,UK&disaggregation=none

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Figure 41- Energy Poverty Index (sources: calculations based on EPOV, 2018 and Eurostat, 2018)

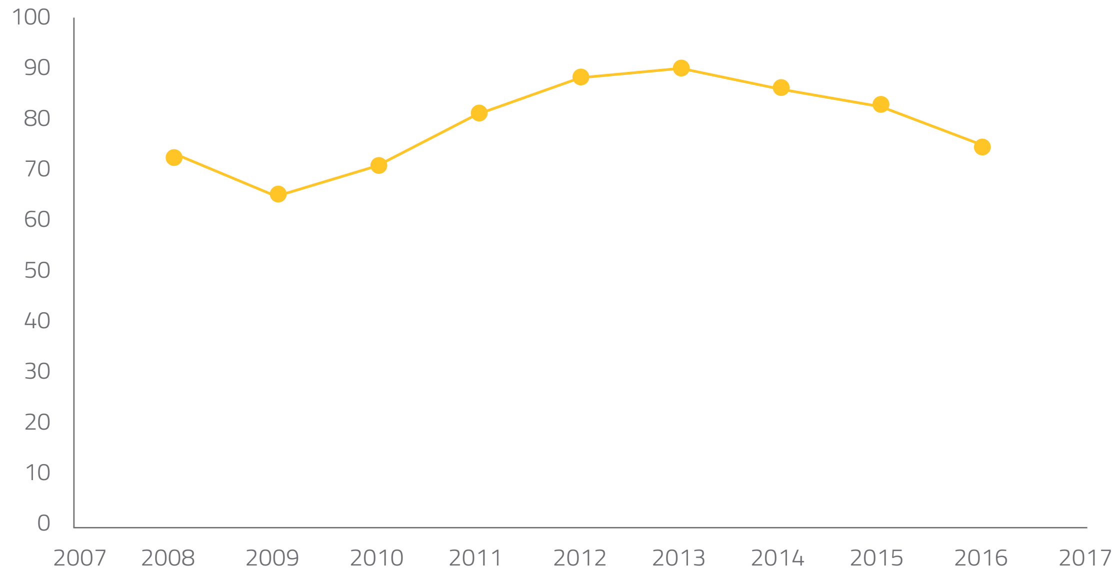
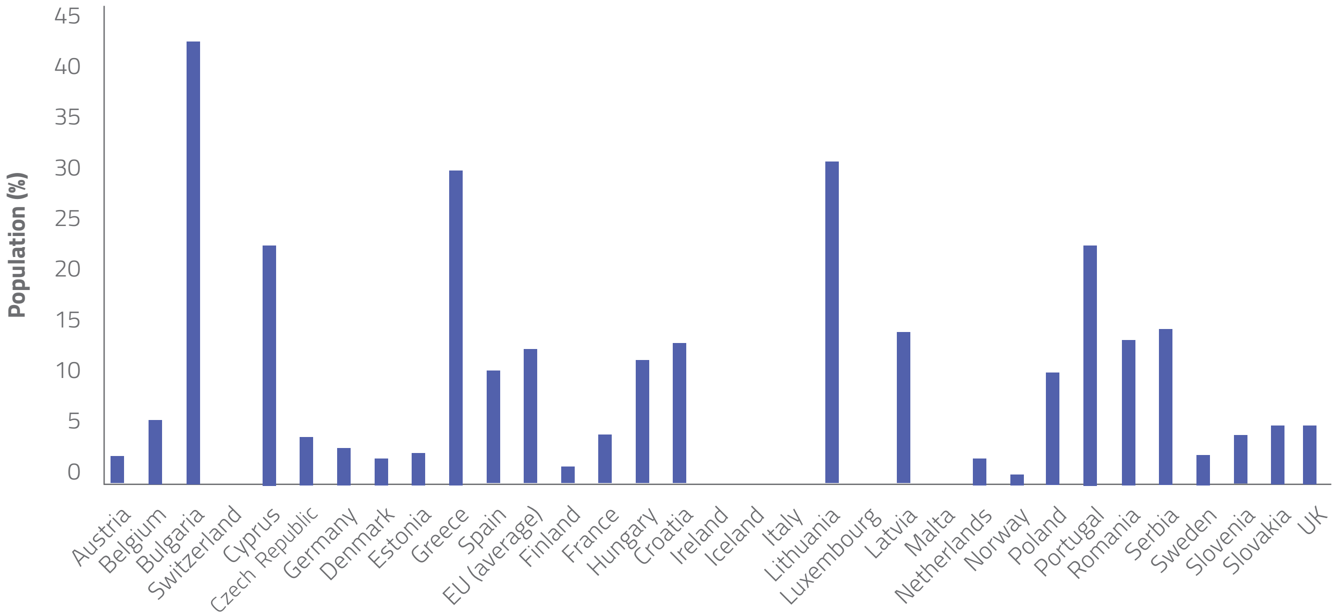


Figure 42 - Inability to keep home adequately warm, country level, 2016 (source: EPOV, 2018)



€114 bn

INVESTMENTS IN GRID INFRASTRUCTURE FOR TRANSMISSION AND STORAGE PROJECTS BY 2030

€43 bn per year

EXTRA COST OF 'NO GRID' SCENARIO BY 2040

15 EUROPEAN COUNTRIES

INCREASED THEIR INTERCONNECTION LEVELS BETWEEN 2016 AND 2017

Chapter 5 - Infrastructure Development

In its modelling of a "no grid" scenario for 2040, ENTSO-E demonstrates that a lack of investment in the transmission system would increase marginal costs (3%-29%), double clean energy curtailment, and harm security of supply.

Reaching Europe's climate and energy targets and engagements under the Paris Climate Agreement will require a mix of solutions (energy efficiency, optimisation of the use of the existing grid, more responsive demand, geographical optimisation of renewables generation - to name a few). However, meeting these climate and energy targets will not be possible without extending the physical grid. This is not only essential for lowering emissions, such action will also reduce customer bills in the long term and avoid clean energy spillage.

Expanding (as well as adapting) the power transmission network is therefore required. TSOs are engaged with spending on research and innovation (5.1), interconnector targets (5.2) and European Projects of Common Interest (PCIs) (5.3). Increasing interconnection across Europe is one of several technical developments which will support the integration of variable renewables into the power system.

Coupling the power system with alternative sources of energy supply and demand from other sectors of the economy (e.g. transportation or heating) is well-understood to offer value to the whole energy system and support decarbonisation. Here again, infrastructure investments will be key to promote power-to-gas and other P2X technologies.

One illustration of moving sector coupling forward are the joint TYNDP scenarios co-created by ENTSO-E and ENTSOG.

5.1 Investments into Grid Development

Context

The grid is a prerequisite for the cost-effective integration of variable renewables and therefore needed for GHG emission reduction. Suitable investment in the grid enables better market integration, competitive power prices and continuous access to electricity for all Europeans.

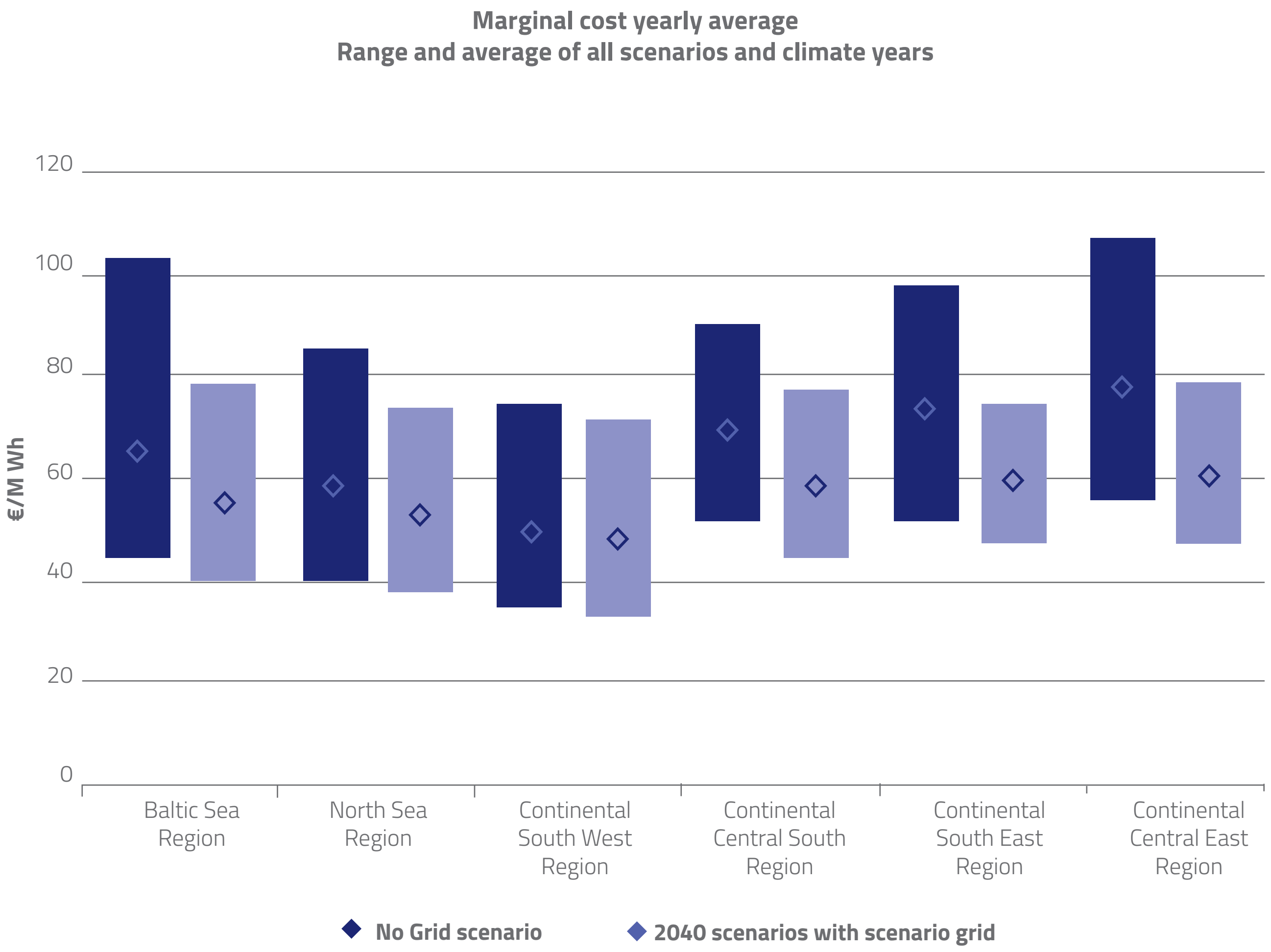
TSOs are responsible for designing national, regional and pan-European grid development plans. Modelling exercises provide information on cost-benefit trade-offs of investment options and are an essential tool for regulators and policy-makers. Likewise, these plans are used by investors to better understand where the extension of infrastructure will likely need to take place. ENTSO-E is responsible for producing the Ten-Year Network Development Plan (TYNDP) which analyses not only pan-European transmission but also storage projects. In its modelling exercise, ENTSO-E gathers a wealth of information and analysis of socio-economic, technological, environmental and market trends. This can be used by other risk-averse sectors (banking, insurance, etc.) policy-makers, investors, researchers and start-ups.

Trends

As part of the 2018 TYNDP, ENTSO-E carried out an in-depth modelling exercise to consider the costs of failing to invest in developing the physical power grid in Europe through a 'No Grid' scenario. Using the organisation's expertise in power system analysis, credible assumptions and relevant data, the analysis details the likely costs of inaction by 2040.

Figure 43 is a comparison of the marginal cost in each region under No Grid and the 'scenario grid', in which there is enough investment in grid infrastructure to facilitate all the projected TYNDP scenarios in the report. Under No Grid, the average marginal price rises for all regions. The increases range from +3% to +29% depending on the region. By 2040 the cost of this ('No Grid' scenario) would be an extra bill of €43 billion per year in the average case. Over several years, this would be above the total expected cost of €150 billion for the new grid in the TYNDP 2016, plus internal reinforcements and a discount rate of 25%.

Figure 43 - Range and average annual marginal cost per regional group in No Grid scenario and Scenario Grid (source: ENTSO-E)



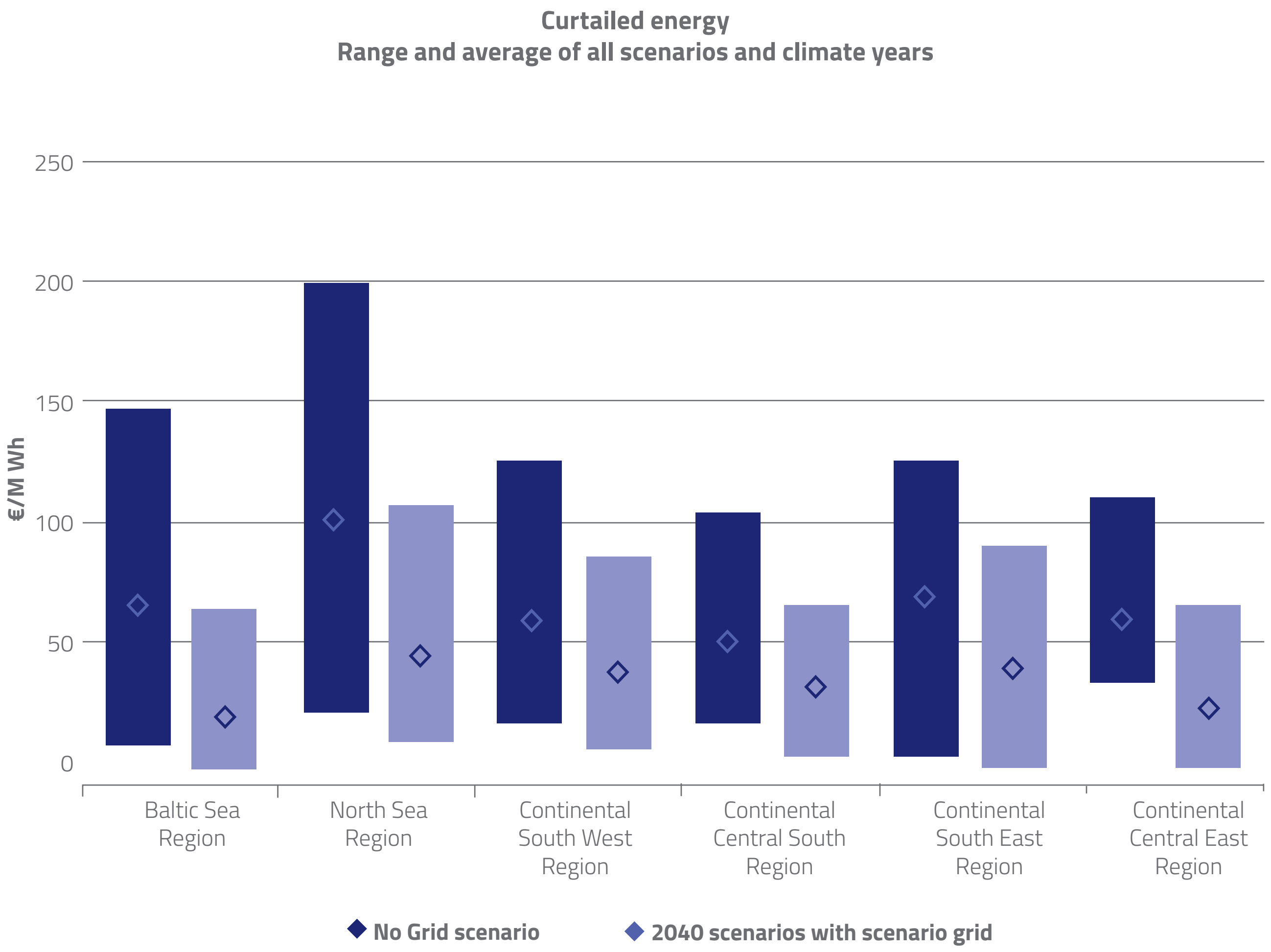
Additionally, under the No Grid scenario each region would see a higher level of curtailed energy as illustrated in Figure 44. Modelling suggests at least 156 TWh of renewable energy will be wasted (curtailed) per year on average. This is resultant from a lack of cross-border capacity to export renewable energy, creating wastage.

Even under the scenario grid, there is still a large amount of curtailed energy. This signals that further reducing the future levels of curtailed energy would require greater network development, storage deployment and a complementary geographical spread of RES. The No Grid scenario creates cross-border limitations that would mean local production peaking units would have to compensate for these constraints. Given that such peaking plants run on fossil fuels, this could create challenges for GHG emission reduction efforts.

The ENTSO-E Ten-Year Network Development Plan (TYNDP) 2018 foresees up to €114 billion (~€10.4 billion annually) of investments in grid infrastructure for transmission and storage projects by 2030. This is corroborated by a similar figure in the annual investment level envisaged by the OECD, IEA and EC of around €9.9 billion.

The 'Technologies for Transmission System' report from ENTSO-E provides a high-level assessment on the availability of transmission technologies, today and up to 2030, and highlights the opportunities for project promoters to implement new solutions to cope with future network development. These new and innovative technologies, combined with current technologies, have their own learning curves and innovation cycles. This ongoing technological progress means that investment in R&I plays a part in the development of a European grid that is future-proofed, and compatible with emerging technologies.

Figure 44 - Curtailment of energy (TWh) in 2040 under No Grid scenario and Scenario Grid (source: ENTSO-E)



TSOs are currently spending on average less than 0.5% of their annual turnover on R&I. Further details of spending are shown in Figure 46 which indicates R&I spending as a percentage of TSO revenue between 2010-2015. As an illustrative target, the Europe 2020 strategy sets an objective for R&D expenditure as a proportion of GDP (3%). Since 2015 there has been ongoing interaction between industry and policymakers, via ACER, aimed at improving the regulatory framework on R&I and advocating for innovation incentive mechanisms.

Figure 45 - Projected investment breakdown per ENTSO-E member country (2014-2030), € billion (source: ENTSO-E)

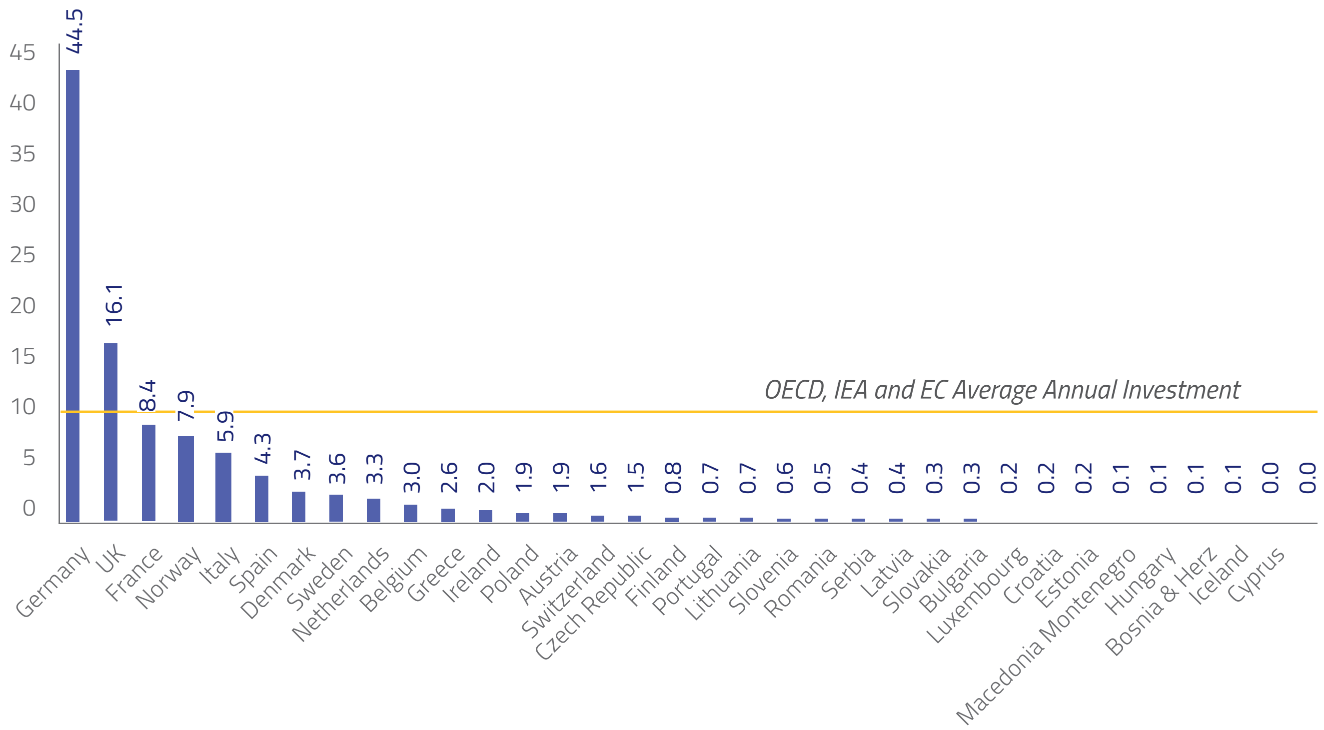
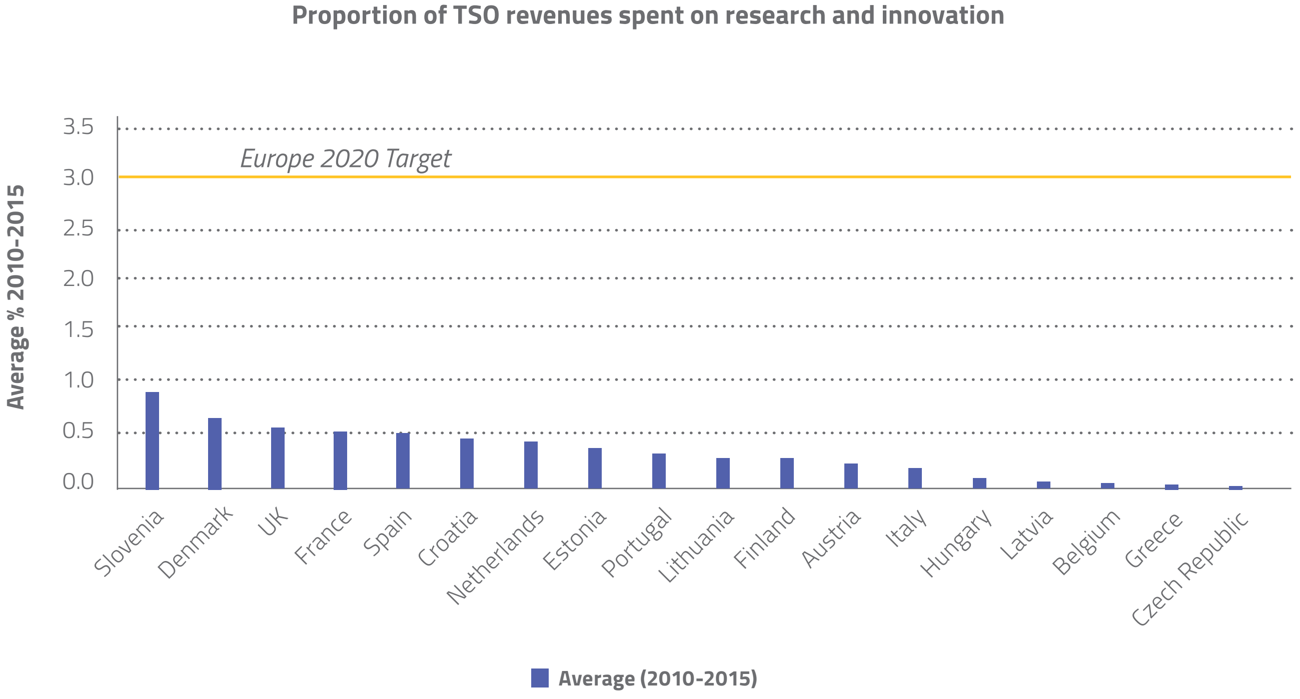


Figure 46- R&I spending in percentage of TSO revenues (2010-2015) (source: ENTSO-E)



5.2 Interconnection Target

Context

In October 2014, the European Council set a target for Member States to achieve an interconnection level of 10% of their installed electricity production by 2020. This has been extended to 15% by 2030 under the Clean Energy Package and reflects the importance of interconnection. In order to make the 2030 target operational, the European Commission set up an expert group (ITEG) consisting of 15 key European Stakeholders, including ENTSO-E and ACER. The recommendations from this group were proposed in September 2017. Following these recommendations, the Commission will operationalise the 15% target through more specific thresholds to indicate the urgency of action needed. Additional interconnection actions should be prioritised by Member States, TSOs, regulators or European institutions if any of the following three thresholds are met:

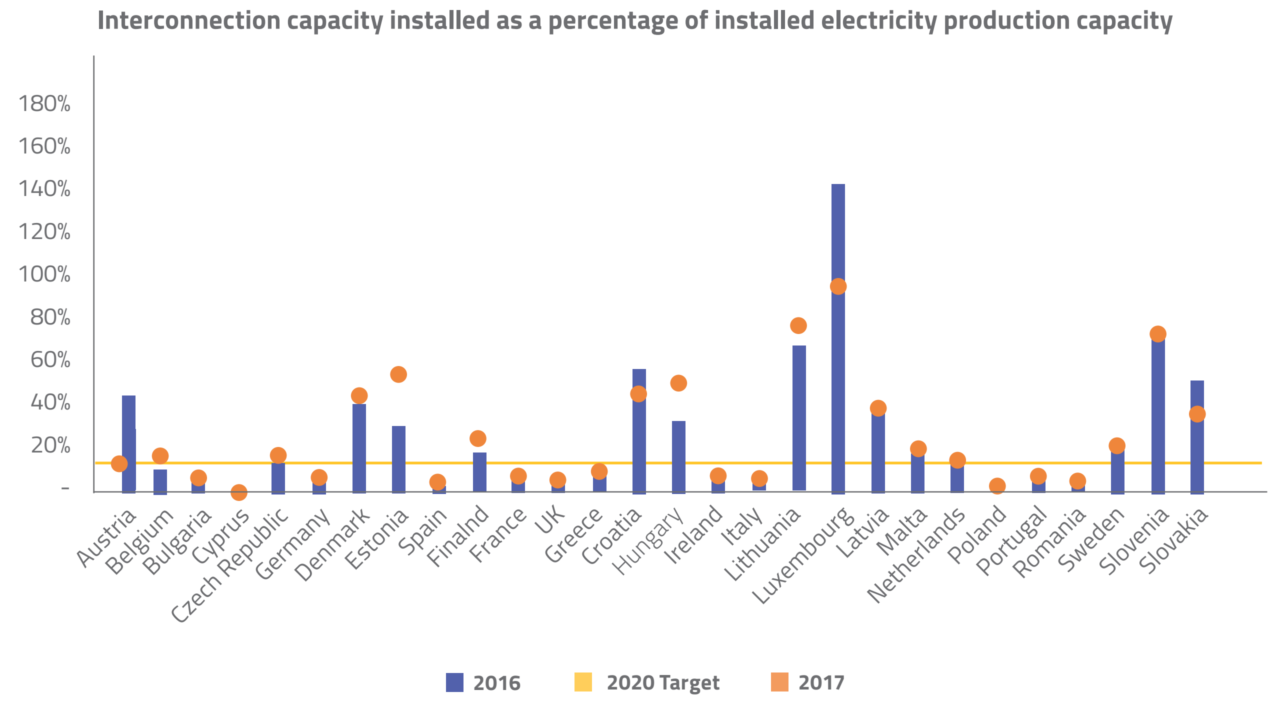
1. The price differential exceeds an indicative threshold of €2/MWh between countries, regions or bidding zones
2. Nominal transmission capacity of interconnectors is < 30% of peak load
3. Nominal transmission capacity of interconnectors is < 30% of installed renewable generation capacity

Trends

Figure 47 illustrates the interconnection level for each country as a percentage of their installed electrical production. Between 2016 and 2017, 15 European countries increased their interconnection levels relative to their installed electricity production capacity, however for five countries this ratio dropped. Therefore, in 2017, 17 countries exceeded the 10% target. By 2020 four countries are expected to miss this target: Cyprus, Spain, the UK and Poland.

Figure 48 shows the extent to which countries are meeting the three thresholds. The map indicates that increasing the interconnection of peninsulas to the main European grid is a priority. The boundary between the Iberian Peninsula and the rest of Europe, for example, is one of the most congested in Europe. Policy-makers show support for increased capacity there, with the

Figure 47- Interconnection levels in 2016 and 2017 (sources: European Commission and ENTSO-E)



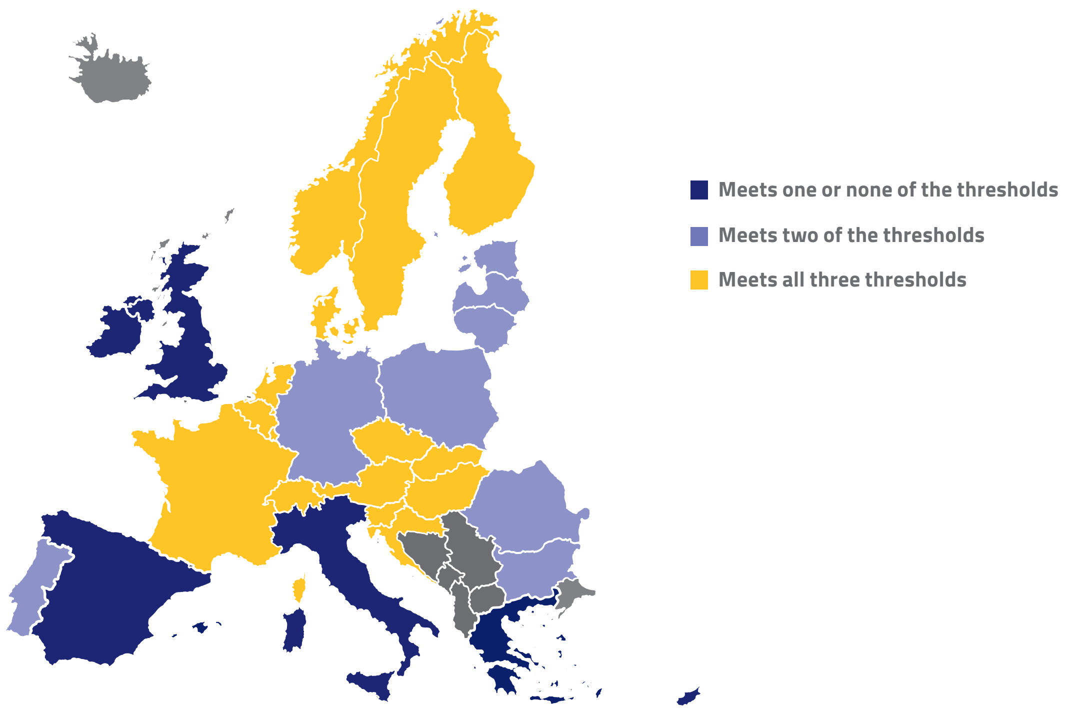
Sources:

ENTSO-E (2018) *R&I Roadmap 2017-2026.* Available from: http://riroadmap.entsoe.eu/wp-content/uploads/2016/06/entsoe_ri_roadmap_2017-2026.pdf

ENTSO-E (2016) *TYNDP 2016.* Available from: https://www.entsoe.eu/publications/tyndp/tyndp-2016/

ENTSO-E (2018) *European Power System 2040.* Available from: https://docstore.entsoe.eu/Documents/TYNDP%20documents/TYNDP2018/european_power_system_2040.pdf

Figure 48 - Colour-coded map of Europe showing countries currently meeting 2030 target thresholds (source: European Commission)



Madrid Declaration (March 2015) signed by the European Council, France, Spain and Portugal.
The EU promotes interconnection development and investment through a series of Projects of Common Interest (PCIs – see 5.3). PCIs are key infrastructure projects and the latest round of PCIs in 2017 underlined the importance of electricity interconnection, with 61% of the 173 projects selected for electricity transmission and storage needs. The selected electricity PCIs should allow for Member States to meet or progress towards their targets in 2020 and 2030, specifically the latest round of PCIs aim to facilitate regional integration of the Iberian Peninsula with France, Ireland with Continental Europe and across the Central South-Eastern region.

5.3 Projects of Common Interest

Context

Projects of Common Interest (PCIs) are key infrastructure projects that connect energy networks across Europe with the objective of delivering affordable, secure and sustainable energy for all citizens. These projects have been granted special regulatory conditions and/or funding to aid their completion. Typically, PCIs should help at least two EU countries, improve the functioning of energy markets and enable market integration, to boost competition, diversify energy sources and integrate renewables. These strategically important projects can benefit from improved regulatory conditions, lower administration costs and opportunities to obtain funding from a pot of €35.35 billion.

Regulation (EU) No 347/2013 states that PCIs are selected from the TYNDP. It means that a promoter wanting to have a project labelled as a PCI first needs to apply for the project to be included in ENTSO-E's TYNDP. Figure 49 illustrates where PCIs sit in accordance with the TYNDP, regional and national development plans.

Trends

The PCIs of 24 November 2017 include 106 projects related to electricity and storage. These were selected from projects included in the 2016 TYNDP. Many electricity PCIs are in an advanced phase - 63% are at permitting stage or beyond. In 2017-2018 the progress made in electricity PCIs showed that 1 was commissioned, 68 stayed the same status, 14 indicated progress and 1 project regressed. This means that 53% of electricity PCIs are "on time" with a further 4% "ahead of schedule" (see Figure 50).

According to ACER, the average expected duration of implementation of electricity PCIs is around 10.5 years, with the shortest duration less than three years and the longest over 19 years. For 105 of the electricity PCIs, the total cost of investment is €49.3 billion (in 2018 values) of which 82% is attributed to transmission projects, 17% on storage and 1% on smart grids. This is a similar level to a total of €51.8 billion from the 2015 list, based on TYNDP 2016 CAPEX values. For transmission PCIs, total considered benefits amount to €70 billion, which is €29.5 billion above the estimated costs, illustrating the value that PCIs can add.

Figure 49 - PCI process (source: ENTSO-E)

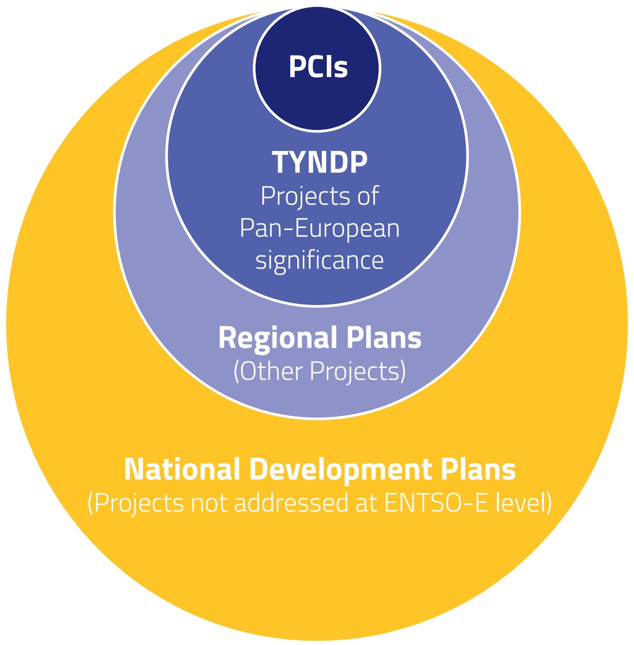
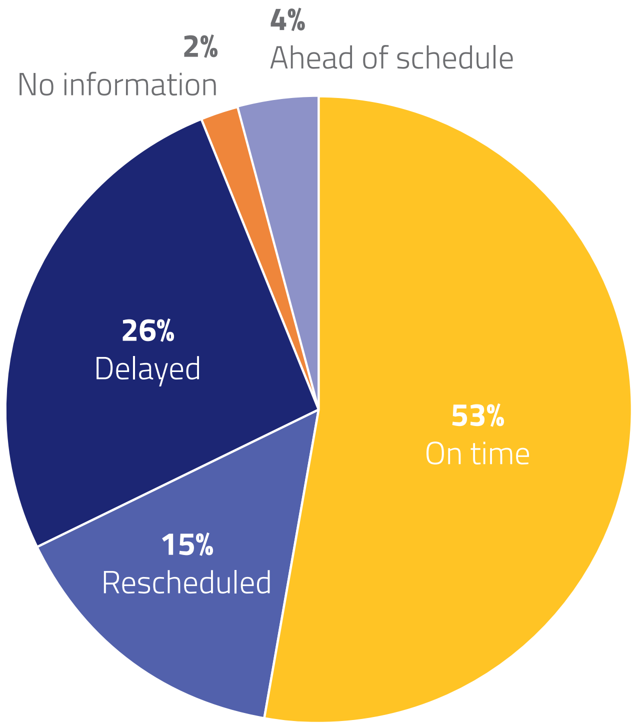


Figure 50 - Progress of electricity PCIs, 2017-18 (source: ACER)



Sources:

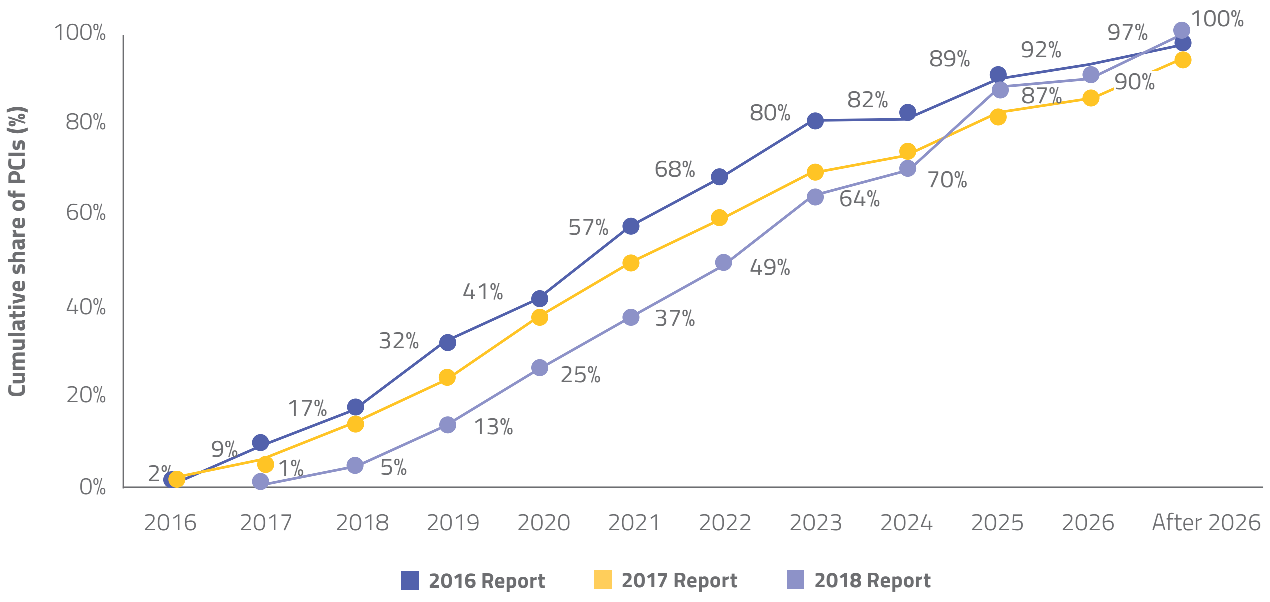
ENTSO-E (2018*) TYNDP 2018 Executive Report.* Available from: https://tyndp.entsoe.eu/Documents/TYNDP%20documents/TYNDP2018/consultation/Main%20Report/TYNDP2018_Executive%20Report.pdf

ACER (2018) *Annual Report on the Results of Monitoring the Internal Electricity and Natural Gas Markets in 2017.* Available from: https://acer.europa.eu/Official_documents/Acts_of_the_Agency/Publication/MMR%202017%20-%20SUMMARY.pdf

European Commission (2018) *Projects of Common Interest.* Available from: https://ec.europa.eu/energy/en/topics/infrastructure/projects-common-interest

European Commission (2017) *Communication on strengthening Europe's energy networks.* Available from: https://ec.europa.eu/energy/sites/ener/files/documents/communication_on_infrastructure_17.pdf

Figure 51 - Cumulative share of PCIs reaching commissioned phase (%) (source: ACER)



Promoters of PCIs reported to have spent €5.8 billion on the current PCIs by the end of 2017. This spending to date may influence the number of PCIs reaching commissioned phase over the next few years. Indeed, compared to previous reports, ACER estimate that a lower cumulative share of PCIs will reach commissioned phase by 2024 (see Figure 51) and, to get back on track, around 50% of the overall budget should be spent in the next four years.

Looking ahead, the TYNDP 2018 has around 39 additional projects that have been assessed on a cost-benefit analysis basis; these could be added to the 4th PCI list, which is due from the European Commission in Q4 2019.

Sources:

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ACER (2017) *Consolidated Report on the progress of electricity and gas Projects of Common Interest for the year 2016.* Available from: http://www.acer.europa.eu/official_documents/acts_of_the_agency/publication/consolidated%20report%20on%20the%20progress%20of%20electricity%20and%20gas%20projects%20of%20common%20interest%20for%20the%20year%202016.pdf

ACER (2016) *Consolidated Report on the progress of electricity and gas Projects of Common Interest for the year 2015.* Available from: https://www.acer.europa.eu/Official_documents/Acts_of_the_Agency/Publication/CONSOLIDATED%20REPORT%20ON%20THE%20PROGRESS%20OF%20ELECTRICITY%20AND%20GAS%20PROJECTS%20OF%20COMMON%20INTEREST%20for%20the%20year%202015.pdf

5.4 Storage

Context

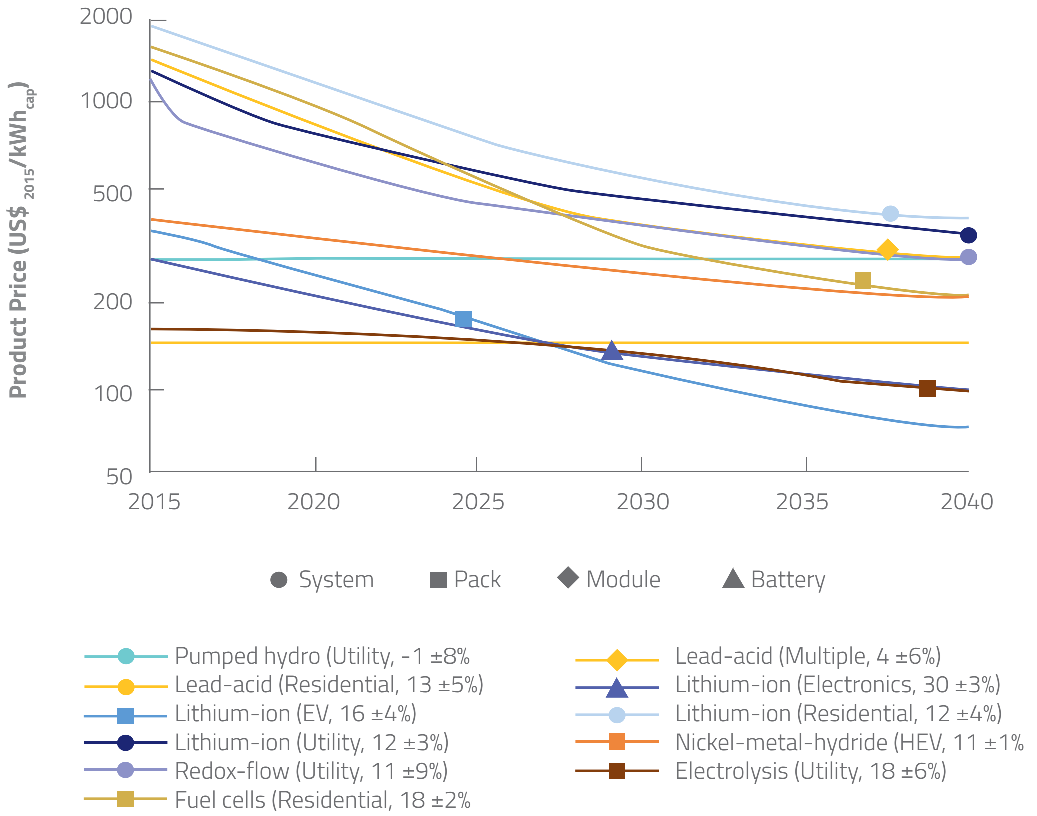
The TYNDP recognises that storage and other flexibility resources will have an important role to play for the system. Indeed, storage assets can improve the utilisation of RES generators, storing excess energy when the wind blows or sun shines rather than curtailing generation, and using the energy later when needed. All else equal, this reduces the investment needed in variable RES capacity and can defer the need for costly infrastructure upgrades. Thus, the take-up of storage assets becomes a potentially important enabler of the energy transition to smooth generation and offer system services in the future.

Transmission grid-connected storage encompasses devices or technologies which store electrical energy in-front of consumers' meters - i.e. they are connected directly to the grid. Traditionally, deployment has taken place exclusively at this level, but recent cost reductions in behind-the-meter consumer storage devices create the conditions for growth in distributed storage systems (see Figure 52).

Together, these different levels of storage represent a key suite of technologies, which help to solve some of the balancing challenges faced today and those that will increasingly be faced tomorrow, and offers more avenues for consumers to participate in the market. Storage technologies can offer a wide range of services, from regulating system frequency on a second-by-second basis, to dealing with inter-seasonal balancing challenges across different times of year.

Storage technologies support the flexible operation of the power system, helping to balance out the peaks and troughs in supply and demand across different timescales. As Figure 53 suggests, different technologies have different characteristics which align with particular service and value-added propositions. The flexible power system of the future will need to develop ancillary services and other market mechanisms which value each of these. The 2019 PowerFacts Europe report focuses on technologies which have deployed in larger volumes today, namely pumped hydro and battery storage.

Figure 52- Future cost of electrical energy storage relative to time (source: Imperial College London)



Trends

Since the 19th century, pumped hydro-power storage (PHS) has been present in the European energy system and is the most widely deployed storage technology in Europe in terms of capacity. PHS is a relatively dependable storage and generation technology, which has been integrated into the energy system of numerous European countries.

An assessment of energy system studies suggests researchers consider that, for an advanced-RES system, storage power may need to cover up to 4% of annual electricity demand. For context, under the 2018 TYNDP Global Climate Action scenario modelling, by 2040 storage would need to equate to around 167 TWh a year to cover this share of annual electricity demand. This exceeds the upper-end of the Joint Research Centre's estimate for PHS potential in European countries (between 54-123 TWh) and, as a result, other forms of storage such as batteries are likely to be needed.

In recent years the cost of electro-chemical battery storage has fallen significantly as interest amongst consumers, network operators and policy-makers has risen. The disruptive potential of battery storage is increasingly evident. As shown in Figure 54, the cost of lithium-ion battery packs in particular has become more cost-effective. This type of electro-chemical storage has seen a fall in costs by over 70% between 2010 and 2016. With costs also projected to fall to below $200/kWh by 2020, it seems likely that this will help to drive greater deployment of electro-chemical storage moving forwards.

Whilst current cumulative deployment of electro-chemical storage is modest by comparison with PHS, Figure 55 demonstrates the current dominance of lithium-ion batteries (240 MW installed) in this sector. New consumer offerings, such as electric vehicles and integrated solar and storage packages, will likely continue to support further cost reductions in this technology and provide further opportunities for an accelerated take-up of storage – both at a distributed and grid-level scale.

At the same time as this fall in battery storage costs, there has been a growth in the uptake of behind-the-meter battery storage in Europe over the past few years. This distributed storage growth looks to be driven by the UK, Nordic and German markets. The installed base has seen a sharp rise in recent years, with just over a five-fold increase between 2015 and 2018, from ~250 MWh to a predicted 1450 MWh in 2018, as shown in Figure 56.

Figure 53 - Storage technology characteristics (source: European Commission)

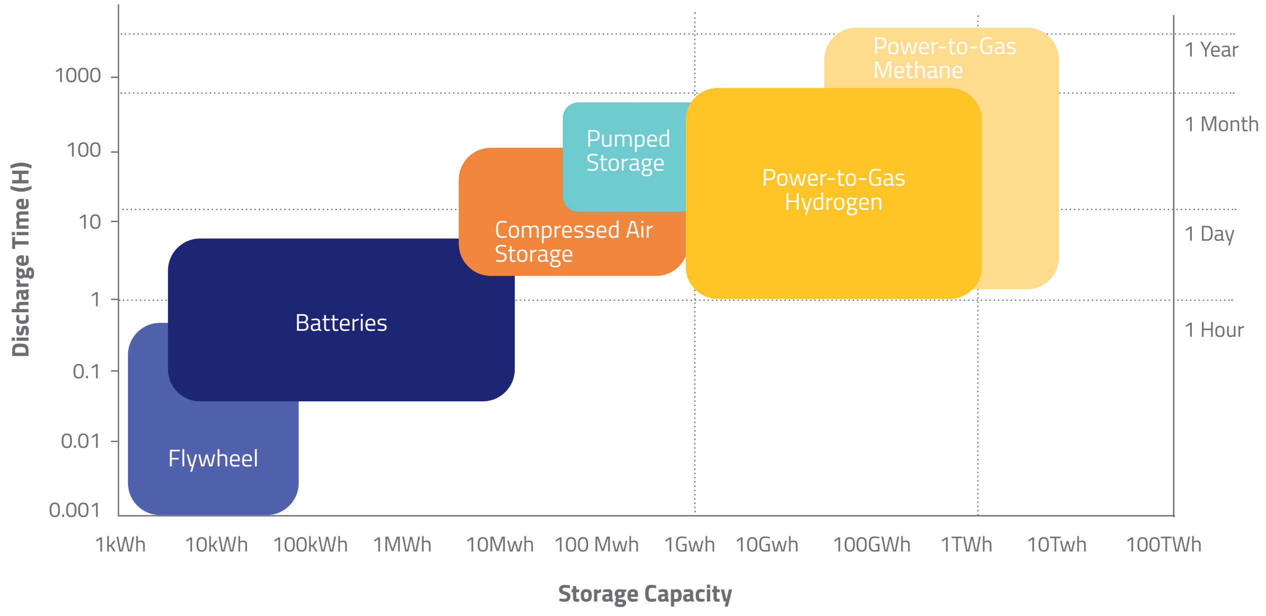


Figure 54 - Lithium-ion battery pack cost (source: Bloomberg New Energy Finance)

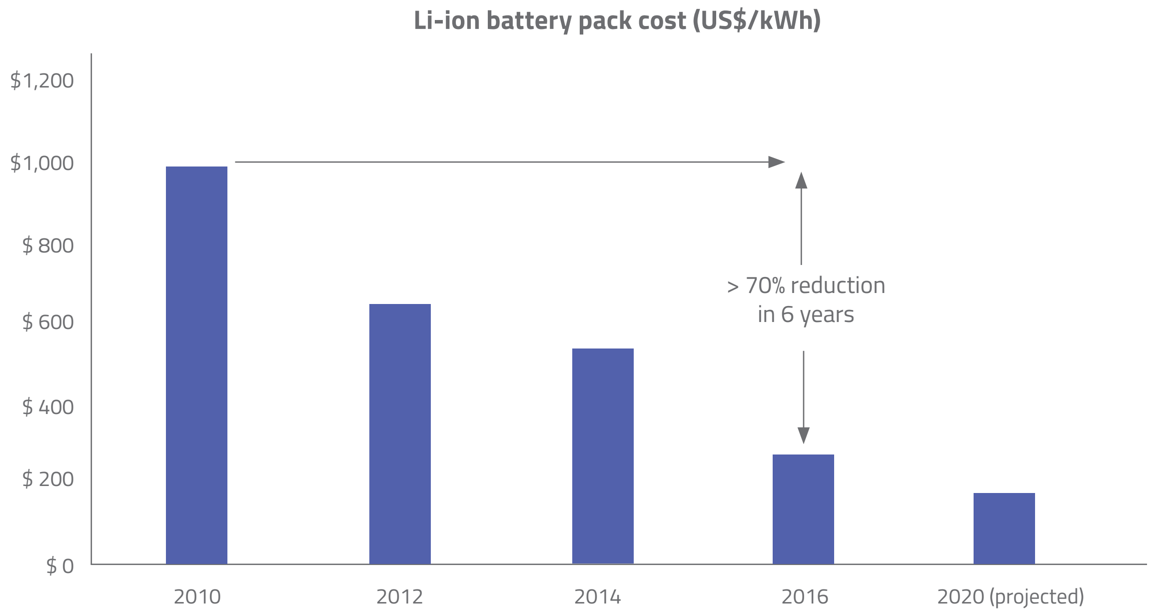
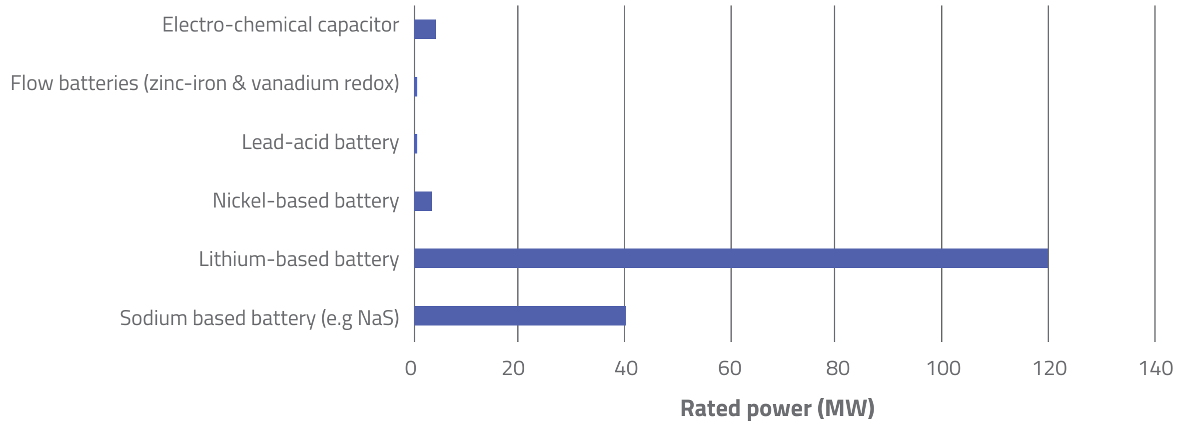


Figure 55 - Electro-chemical storage deployment in Europe (MW), 2018 (source: US Department of Energy)



In addition to the growth in household battery deployment illustrated above, increasing demand for electric vehicles (EVs) (see section 4.3) creates opportunities for customers and system operators to derive value from an increasing number of behind-the-meter batteries – both second-life batteries from old vehicles and idle EVs. Here, vehicle to grid (V2G) technology can allow for control of a bi-directional flow of electricity between the vehicle battery and the grid. V2G allows for the smart charging and discharging of the vehicle's battery. Future market structures and pricing regimes could therefore align consumers charging behaviour with network requirements.

For system operators, this smart charging capability creates the opportunity for idle EVs to provide valuable grid services. Additionally, it can mitigate against the network challenges caused by the increasing EV-charging requirements which may otherwise require investment in infrastructure. This allows for "smart" sector-coupling between transport and power.

Figure 56 - Distributed storage installed base (MW) (sources: EASE and Delta EE)

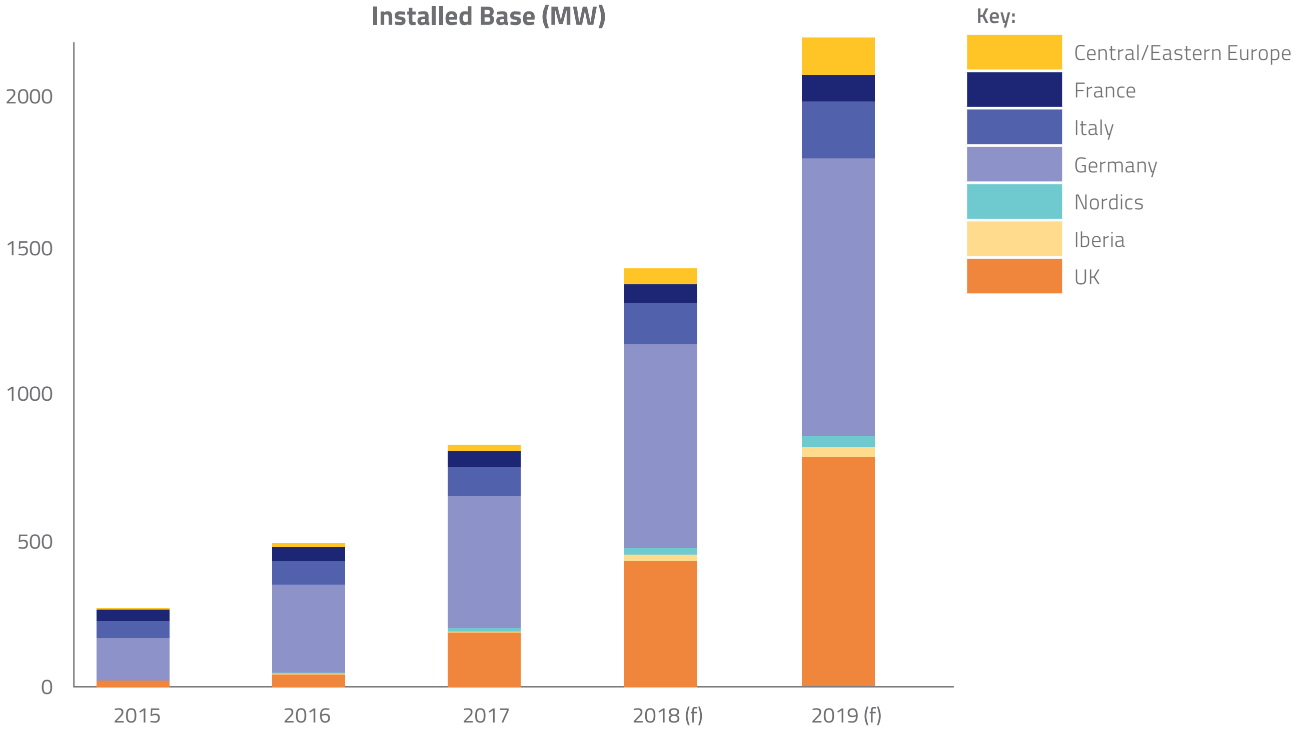
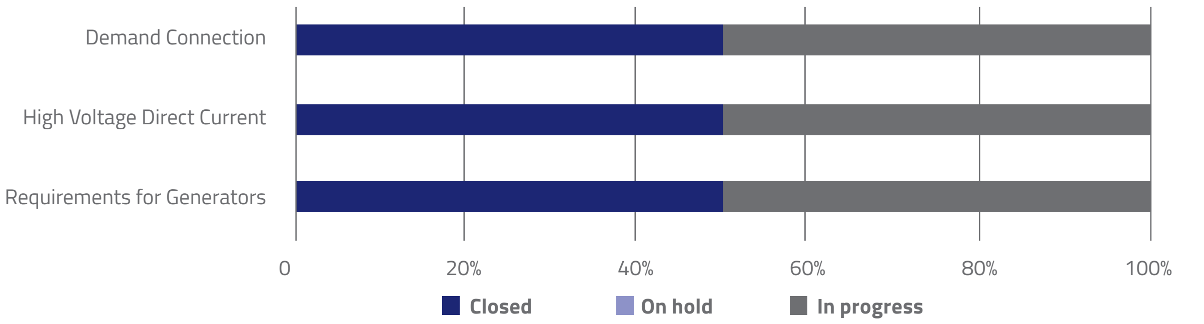


Figure 57 - Status of deliverables under RfG, DCC and HVDC implementation programme (source: ENTSO-E)



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5.5 Connection Network Codes

The Connection Network Codes are designed to create harmonised and fair rules to enable generation plants, demand response facilities and HVDC to connect to the transmission and distribution networks. The codes use a flexible framework that recognises the different rate of development and individual constraints in different European countries, including physical geography, scale and economic factors that impact transmission infrastructure.

- Requirements for Generators (RfG): sets the standards for all synchronous and converter-powered generators connecting to the grid. Existing generators are only subject to the code if significant changes are carried out. Reserve generators that are not synchronised to the system are not obligated.
- Demand Connection (DCC): sets the requirements for connecting large renewable energy production plants and demand response facilities. Existing connections are subject to the requirements if significant changes take place in them. If an installation does not meet the requirements, the network operator may withhold a permit to the connection.
- High Voltage Direct Current (HVDC): specifies the long-distance direct current connection requirements which are used to connect offshore wind generation with mainland energy systems, or to connect cross-country generation with loads over long distances.

Status
Of the six deliverables for the connection network codes, 50% are closed and 50% are in progress. Each of the DC, HVDC and RfG codes have two deliverables, they are "Monitoring" and developing "Non-binding guidance on implementation".

Sources:
ENTSO-E (2018) *Demand Connection Codes*. Available from: https://electricity.network-codes.eu/network_codes/dcc/

ENTSO-E (2018) *Network Codes*. Available from: https://electricity.network-codes.eu/network_codes/

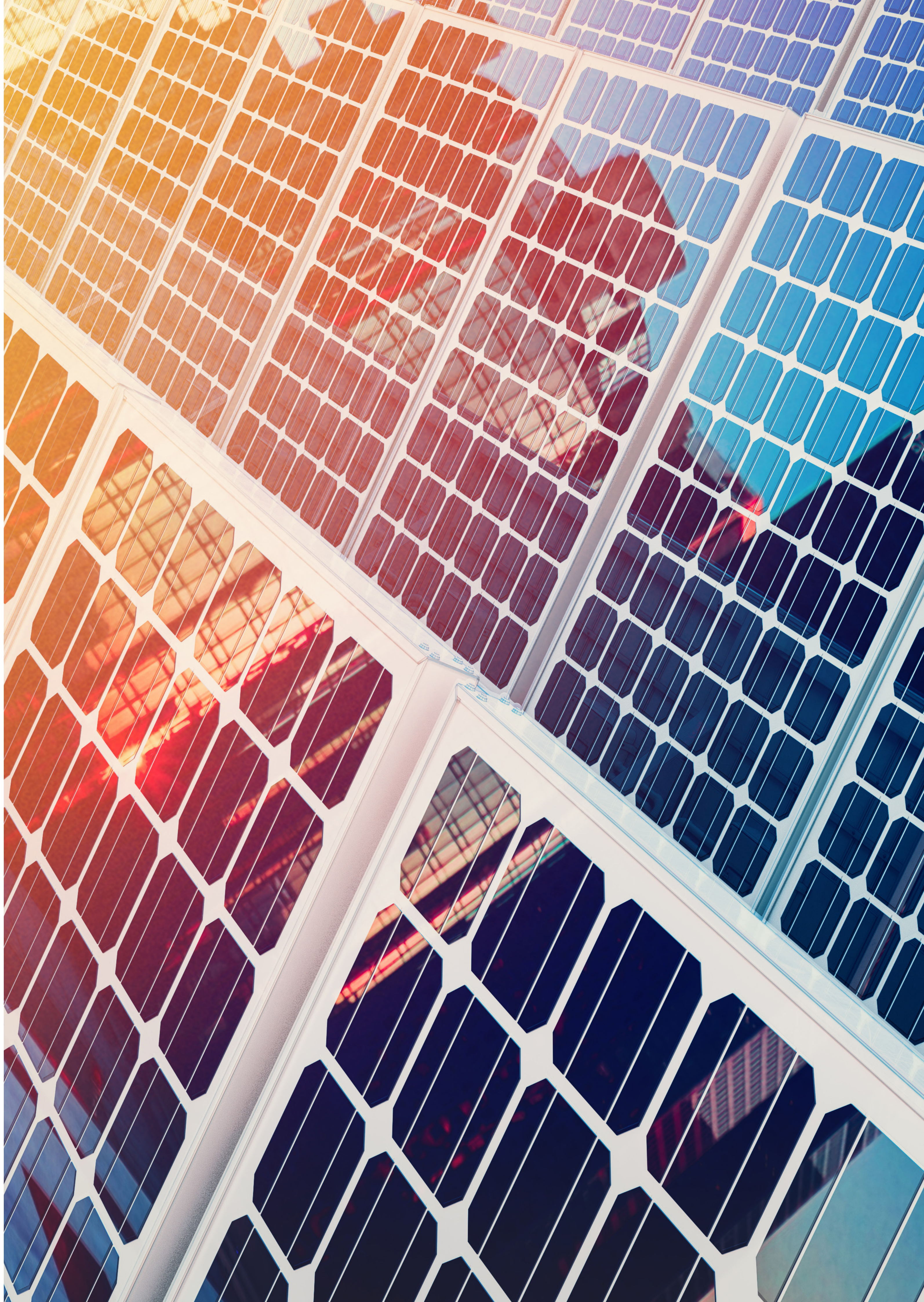
UTCE (2007) *System Disturbance on 4 November 2006*. Available from: https://www.entsoe.eu/fileadmin/user_upload/_library/publications/ce/otherreports/Final-Report-20070130.pdf

CASE STUDY

It is necessary to ensure that robust and appropriately designed codes are in place to support the integration of new generation assets into the grid; 260 GW of PV and wind are scheduled to be incorporated into the system. Furthermore, 11 GW of demand response are expected to come online.

The 2006 'system split' was a major event which had widespread social and economic implications. Had some key network codes already been implemented, such as RfG, SOGL and E&R, the repercussions of the system split may have been minimised:

- 17GW of load being shed
- 15 million households being cut off from their energy supply
- €300-500 million of losses from load shedding
- 20GW of generation tripped or disconnected.



200 MILLION

SMART METERS FOR ELECTRICITY WILL BE INSTALLED BY 2020

10 MILLION

FILES EACH YEAR ARE RECEIVED BY ENTSOE'S TRANSPARENCY PLATFORM

117 BILLION DATA POINTS
A YEAR FROM ELECTRICITY SMART METERS BY 2020

Chapter 6 - Cyber Physical Grid

For the power system, the rise of the "cyber physical grid" corresponds to the integration of an emerging ICT layer 'on top of' the physical grid: this digital layer thus complements and enhances the existing infrastructure, but it is not meant or able to replace it. This delivers value to customers and market-actors, maintains and enhances security of supply, helps utilise the grid cost-effectively and facilitates the energy transition.

Ultimately, digitalisation and the development of the cyber physical grid will enable the timely and transparent transfer of large amounts of data with extremely low transaction costs to facilitate some core development areas:

- Optimisation of existing power assets and integration of new ones;
- Optimisation of energy system management and interactions between DSOs;
- Support of coupling with heat, gas and transport sectors;
- Automation and overall optimisation of the power system and the introduction of new energy services;
- Support transparency and wide dissemination of data to enable market functioning.

Whilst the digital revolution is now underway, tracking its progress isn't straightforward. This chapter takes two parameters which are indicative of the progress being made towards a cyber physical grid. The first considers ENTSO-E's position as a planner and director of research and innovation for TSO investment in big data projects. The second subchapter analyses the increased use of energy system data, as proxied by the number of users registered on ENTSO-E's Transparency Platform.

6.1 Big data use

Context
Digitalisation will create numerous opportunities to deliver value to customers and stakeholders, through the provision of new services, the establishment of securer networks and facilitation of more efficient markets. However, the exponential increase in data generated by the energy system presents certain challenges for network operators.

Take smart meters as an example. Smart meters in Europe commonly support a level of data granularity whereby a reading can be taken every 15 minutes. Given that the European Commission has estimated that 200 million smart meters for electricity will be installed by 2020 based on an assessment of national commitments, not to mention the millions of additional sensors built into the transmission and distribution grids across Europe.

The challenges of mining and managing very large and complex datasets, and the opportunities born from using the data intelligently, are at the core of the "big data" concept, and an important opportunity for network operators moving forward. Data mining algorithms and artificial intelligence-driven analytics can help TSOs manage assets, predict and respond to potential problems in the network, and integrate distributed resources in an effective and efficient manner.

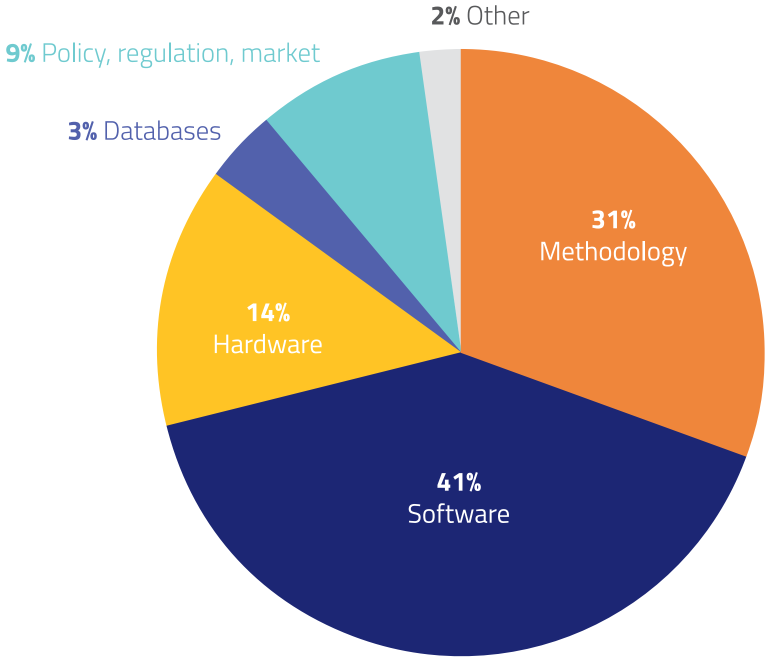
Trends
Utilities are increasingly investing in digital platforms to take advantage of big data, improve asset management, grid design and network operation. The acquisition of smart technology-led aggregator EnerNOC (now branded as Enel X) by Enel and Eneco Group's investment in Next Kraftwerke are both cases in point from 2017.

Alongside this, TSOs are developing their own digital capabilities by supporting R&I projects. Here collaboration is key. With the development of an integrated European power system, the best approach is to cooperate and share the fruits of innovation. Such cooperation is necessary if Europe's power system is to transition forward to meet society's ambition for clean, secure, abundant and cost-effective energy.

ENTSO-E continues to play a role in the coordination of these pan-European R&I activities. ENTSO-E publishes periodic R&I *roadmaps, implementation plans* and *monitoring* reports – highlighting key topics for further work and setting a framework for joint-action.

Figure 58 illustrates that the balance of R&I project accomplishments as analysed by the monitoring report. Software (41%) and database (3%) projects together account for a significant proportion of the activity accomplished under the 2013-2022 roadmap. This supports the position that huge amounts of the value creation from R&I in the coming decades will be made

Figure 58 - Areas of R&I achievement 2013-2016 (source: ENTSO-E R&I Roadmap 2017-2026)



from integrating digital systems into the power network.

To fully achieve the vision of the cyber physical grid, continued investments in R&D are needed to increase the data-processing capabilities across the entire energy value chain, borders and sectors. TSOs are cooperating with market players and stakeholders to develop market and system operation platforms and solutions according to the different layers of the cyber physical grid:

- Physical Grid Layer
- Data Layer
- System Operation Layer
- Market Layer
- Sector Coupling

Looking forward, in its 2017-2026 R&I Roadmap ENTSO-E provided a medium to long-term vision for research and innovation activities performed by TSOs. The publication released in June 2017 identified five challenge-orientated clusters, which group together 23 R&I topics:

1. Power system modernisation
2. Security and system stability
3. Power system flexibility
4. Power system economics and efficiency
5. **ICT and digitalisation of the power system**

ENTSO-E has made a preliminary estimate of the funding available for each R&I topic, based on the sum of EU programme support (e.g. Horizon 2020), funding from Member States, as well as finance from TSOs themselves and private investors. For topic 13, which trials the use of big data to support smart asset management technologies, the estimated budget is €8 million.

Future editions of this report will track the progress made in the cyber physical grid layers in Cluster 5 of the Roadmap - ICT and digitalisation of the power system - as well as in other specific relevant topics, for example "tools for smart asset management" - (included in Cluster 1) which intends to develop new smart asset management technologies, using big data processing and predictions to take advantage of network monitoring equipment.

Sources:
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ENTSO-E (2017) *R&I Implementation Plan.* Available from: https://docstore.entsoe.eu/Documents/Publications/

6.2 Data accessibility: ENTSO-E Transparency Platform

Context
It is important that energy market information is openly shared to enable the benefits of digitalisation to be enjoyed by customers and industry-stakeholders. To facilitate this, TSOs are developing data hubs and data exchange platforms, which makes relevant information available to different agents and users. There are numerous examples of national data-exchanges which support coordination between TSOs and DSOs and other actors (see THEMA report for ENTSO-E for more information).

Such open data provision is key to the efficient operation of an integrated European energy market and to maintaining Europe's security of supply. Accurate data bolsters market participants with the information needed to make efficient production, consumption and trading decision, and crucially is extended to all stakeholders regardless of size. The open provision of data is central to supporting new market entrants, the establishment of novel services, and more efficient outcomes, as well as ensuring that incumbents can trade and operate efficiently with one another.

This subchapter evaluates the use of ENTSO-E's Transparency Platform, a pioneering endeavour which provides accurate, and timely information on the state of the electricity system across Europe - to all participants openly and for free. The platform provides data on demand (forecasts and outturns), generation by type and plant, capacity available, prices, cross-border flows, reserves available, outages and more. The platform has a part to play in delivering a secure, integrated, and dynamic European power system of the future.

In practice, the Transparency Platform is supported by a group of more than 50 data providers – TSOs, power

Sources:
ENTSO-E (2016) *Annual report 2016.* Available from: http://annualreport2016.entsoe.eu/
ENTSO-E (2017) *Annual report 2017.* Available from: https://annualreport2017.entsoe.eu/
THEMA (2017) *Data Exchange in Electric Power Systems – Commissioned by ENTSO-E.*
Available from: https://docstore.entsoe.eu/Documents/News/THEMA_Report_2017-03_web.pdf

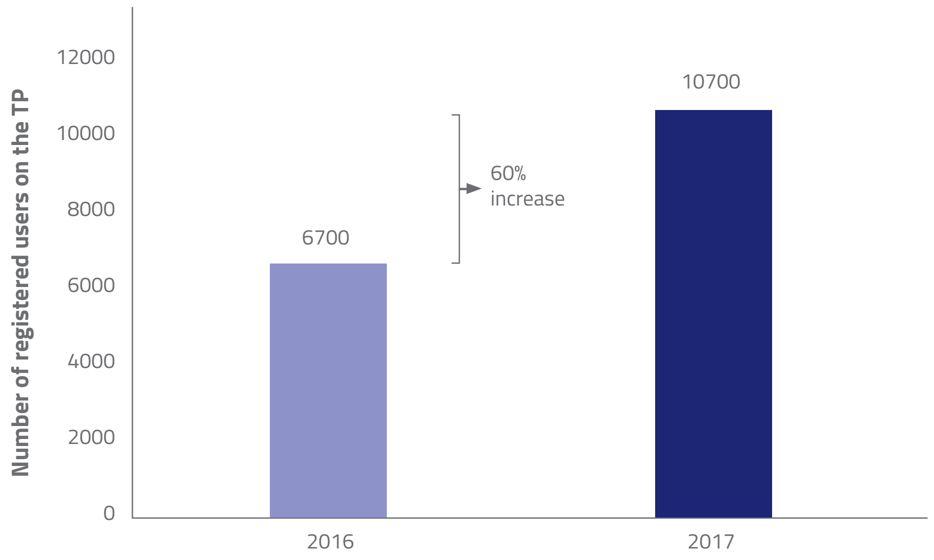
exchanges and other third parties. This group as well as members of the ENTSO-E-ran Transparency User Group have improved the completeness and quality of data uploaded over time. This is a process that will continue over the coming years. The platform will also see improvements to its usability.

Trends

Since its establishment in 2015, the Transparency Platform has grown in scope and influence. Providing a centralised database for European level electricity generation, transportation and consumption, the number of stakeholders using the platform has increased over time. Indeed during 2017, the number of registered users increased by 60%, from 6,700 to 10,700. Planned improvements to the platform's graphical user interface and manual of procedures are envisaged to support further increases in the number of users, for which the platform is used to inform business decisions and research amongst other functions.

The platform receives over 10 million files each year, and between 2,000 - 2,500 of users are active daily. Such open data provision is key to the efficient operation of an integrated European energy market and to maintaining Europe's security of supply.

Figure 59 - Number of registered users of ENTSO-E Transparency Platform

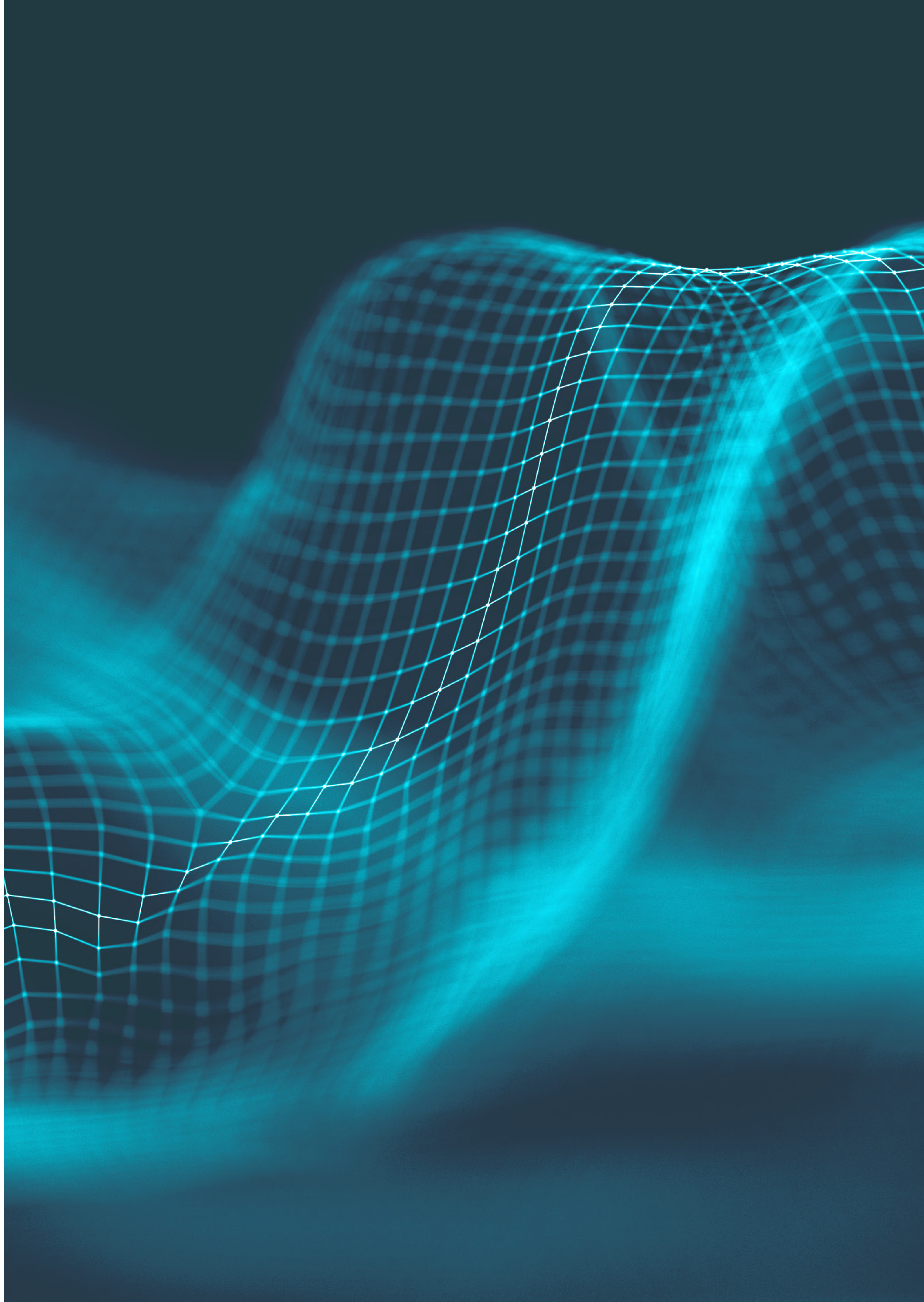


Sources:

ENTSO-E (2016) *Annual report 2016*. Available from: http://annualreport2016.entsoe.eu/

ENTSO-E (2017) *Annual report 2017*. Available from: https://annualreport2017.entsoe.eu/

THEMA (2017) *Data Exchange in Electric Power Systems – Commissioned by ENTSO-E*. Available from: https://docstore.entsoe.eu/Documents/News/THEMA_Report_2017-03_web.pdf



Glossary

ACER	Agency for the Cooperation of Energy Regulators
aFRR	Automatic Frequency Restoration Reserve
AL	Albania
AT	Austria
BA	Bosnia and Herzegovina
BE	Belgium
BEV	Battery Electric Vehicle
BG	Bulgaria
BNEF	Bloomberg New Energy Finance
CACM	Capacity Allocation and Congestion Management
CAPEX	Capital Expenditure
CEE	Central and Eastern Europe
CH	Switzerland
CGM	Common Grid Model
COP	Conference of the Parties to the UNFCCC
CWE	Central West Europe
CY	Cyprus
CZ	Czech Republic
DA	Day-Ahead
DAOA	Day-Ahead Operational Agreement
DE	Germany
DC	Demand Connection
DK	Denmark
DSO	Distribution System Operator
DSR	Demand-Side-Response
EB	Electricity Balancing
EBGL	Electricity Balancing Guideline
EC	European Commission
EE	Estonia
EECSP	Energy Expert Cyber Security Platform
EHPA	European Heat Pump Association
ENCS	European Network for Cyber Security
ENTSO-E	European Network of Transmission System Operators for Electricity
ENTSOG	European Network of Transmission System Operators for Gas
EPI	Energy Poverty Index
EPOV	European Union Energy Poverty Observatory
ER	Emergency and Restoration
ES	Spain
ETS	Emissions Trading Scheme
EU	European Union
EV	Electric Vehicles
FCA	Forward Capacity Allocation
FCR	Frequency Containment Reserve
FEC	Final Energy Consumption
FI	Finland
FR	France
GB	Great Britain
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GR	Greece
GW	Gigawatt
HR	Croatia
HU	Hungary
HVDC	High Voltage Direct Current
ICT	Information and Communication Technology
IDOA	Intraday Operational Agreement
IE	Ireland
IEA	International Energy Agency
IGCC	International Grid Control Cooperation
IS	Iceland
IT	Italy
JRC	Joint Research Centre
kWh	Kilowatt Hour
LOLE	Loss of Load Expectation
LT	Lithuania
LU	Luxembourg
LV	Latvia
MAF	Mid-Term Adequacy Forecast
MARI	Manually Activated Reserves Initiative
mFRR	Manual Frequency Restoration Reserve
ME	Montenegro
MK	Macedonia
MMR	Market Monitoring Report
MRC	Multi-Regional Coupling
MW	Megawatt
MWh	Megawatt Hour
Mtoe	Mega Tonnes of Oil Equivalent
NEMO	Nominated Electricity Market Operator
NGO	Non-Government Organisation
NL	The Netherlands
NO	Norway
OECD	Organisation for Economic Cooperation and Development
OPDE	Operational Planning Data Environment
P2X	Power-to-X
PCI	Projects of Common Interest
PCR	Price Coupling of Regions
PHEV	Plug-In Hybrid Electric Vehicle
PHP	Pumped Hydro-Power
PHS	Pumped Hydro Storage
PICASSO	Platform for International Coordination of Automated Frequency Restoration and Stable System Operation
PL	Poland
PT	Portugal
PV	Photovoltaic
R&D	Research and Development
R&I	Research and Innovation
RCC	Regional Coordination Centre
RES	Renewable Energy Source
RES-e	Electricity from Renewable Energy Source
RO	Romania
RfG	Requirements for Generators
RR	Replacement Reserve
RS	Russia
RSC	Regional Security Coordinator
SDAC	Single Day-Ahead Coupling
SE	Sweden
SGTF	Smart Grids Task Force
SI	Slovenia
SIDC	Single Intraday Coupling
SK	Slovakia
SO GL	System Operations Guideline
SWE	South West Europe
TERRE	Trans-European Restoration Reserves Exchange
TP	Transparency Platform
TR	Turkey
TSO	Transmission System Operators
TW	Terawatt
TWh	Terawatt Hours
TYNDP	Ten Year Network Development Plan
UK	United Kingdom
US	United States
V2G	Vehicle to Grid
vRES	Variable Renewable Energy Source
XBID	Cross-Border Intraday Initiative
Y-o-Y	Year-on-Year

Notes

Notes

ABOUT ENTSO-E

ENTSO-E, the European Network of Transmission System Operators for Electricity, represents 43 electricity transmission system operators (TSOs) from 36 countries across Europe. ENTSO-E was established and given legal mandates by the EU's Third Legislative Package for the Internal Energy Market in 2009, which aims at further liberalising the gas and electricity markets in the EU.

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