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Regional measures under risk preparedness in the electricity sector

Practical tools and information for the preparation of the risk preparedness plan

Spisto A., Poncela M., Flego G., Chondrogiannis S., Antonopoulos G, Fulli G., Masera, M.

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Contents

Foreword

This work is a review of the main elements of the regional measures as foreseen in the Risk Preparedness Regulation (RPR) EU 2019/941. According to the Regulation, to ensure a common approach to electricity crisis prevention and management, the competent authority of each Member State (MSs) should draw up a risk-preparedness plan on the basis of the regional and national electricity crisis scenarios ((artt.. 10-11-12-13 of Regulation 2019/941) and European Commission Recommendations (EU) 2020/775). This should describe effective, proportionate, and non-discriminatory measures addressing all identified electricity crisis scenarios. The objective of this study is to provide Member States that are in the process of implementing the provision of the regulation with practical tools that could prove helpful in the definition of the regional measures and arrangements. This analysis is based on a number of regulatory documents, like the network code on electricity transmission system operation and the network code on emergency and restoration. Further useful information for the preparation of the plan regards the most frequent causes of outages, the associated effective remedial actions, the best practices as in crisis management, and the economic impacts of electricity crises, may be obtained from the scientific literature and from direct experience of key grid and market operators.

A further aim of this study is to highlight what are the indirect effects of this regulation on current practices of MSs dealing with electricity emergencies and energy security. While it fosters regional cooperation for assistance in the case of electricity crisis in one Member State, in fact, it also signals the importance to improve other forms of cooperation between Member States that may contribute to reduce the costs of risks associated to electricity crises and blackouts. Examples of those type of cooperation can be more flexible international energy trade agreements, cooperation in financing investments that play a role in preventing or alleviating electricity crises and whose costs and benefits can be fairly shared by the cooperating parties.

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Authors

Spisto A., European Commission, Joint Research Centre (JRC), Petten, The Netherlands

Poncela M., European Commission, Joint Research Centre (JRC), Ispra, Italy

Flego G., European Commission, Joint Research Centre (JRC), Petten, The Netherlands

Chondrogiannis S., European Commission, Joint Research Centre (JRC), Ispra, Italy

Antonopolous G., European Commission, Joint Research Centre (JRC), Petten, The Netherlands

Fulli G., European Commission, Joint Research Centre (JRC), Ispra, Italy

Masera, M., European Commission, Joint Research Centre (JRC), Petten, The Netherlands

Abstract

Experiences of electricity outages pushed countries around the world to sign formal cooperation agreements and to establish supranational bodies to coordinate actions in the event of a crisis. In Europe, there are multiple examples of voluntary regional and bilateral cooperation between transmission system operators (TSOs). These voluntary agreements are often based on existing procedures implemented by the TSOs for emergency prevention and management. TSOs implement the operational measures applicable in case of emergency and often take initiatives to establish cross-border cooperation schemes. The risk preparedness regulation (RPR) puts together existing regulatory tools and the expertise and capabilities of EU Member States (MSs) in handling electricity crises at national, and across national borders level (regional dimension), while adding some important elements to strengthen the possibility of cooperation among MSs and between MSs and non-EU countries that are interconnected and part of the European synchronous: solidarity of a Member State with the technical ability to offer assistance to another Member State in crisis, with the final goal to protect public safety and personal security; a common EU-framework for the definition of national, regional, and bilateral measures to be included in the risk preparedness plans; cost-efficiency and effectiveness of the management of a crisis through cooperation, and efficient use of resources; legally binding rights and obligations of the parties of the assistance agreement; fairness of the remuneration of the assistance.

In order to ensure a common approach to electricity crisis prevention and management, the RPR states that the competent authority of each Member State shall draw up a risk-preparedness plan on the basis of the information collected from various sources – i.e. the regional (with more MSs involved) and national electricity crisis scenarios ((artt. 10-11-12-13 of Regulation 2019/941), the short term adequacy assessment. The plan shall describe effective, proportionate, and non-discriminatory measures addressing all identified risks and adequacy issues. Finally, the plan shall also include the post-crisis activities of reporting and monitoring of the occurrences, in order to gather the lessons learnt from the event, and to improve the risk preparedness plans and management of future electricity crises.

This study addresses the regional dimension of electricity crises management in the European Union and elaborates on the national and regional rules and procedures that are relevant for the definition of target measures and regional cooperation agreements. In this context, we identify the essential elements for the prevention, preparation for and management of a crisis as a practical guide for the preparation of the risk preparedness plan, with the objective to extend and develop the European Commission's Recommendations (EU) 2020/1775 (European Commission, 2020b). This analysis is based on a number of regulatory documents - like the guideline on electricity transmission system operation and the network code on emergency and restoration - and other studies on the most frequent causes of outages, the associated effective remedial actions, the best practices in crisis management, and the economic impacts of electricity crises.

The RPR recalls other EU legal frameworks that establish tools for the preparation and management of crises or platforms for cooperation between MSs, some of them beyond the energy field. It is important that competent authorities consult the existing platforms of cooperation and risk assessments. In the same way, it is important that the first risk preparedness plans build on existing cooperation structures and provide clear and transparent mechanisms of cooperation to increase its efficiency in case of need.

In this study we also try to highlight the indirect effects of the RPR on the incentives towards cross-country cooperation, i.e. flexible international energy trade agreements, international joint investments that play a role in preventing or alleviating electricity crises, and costs and benefits sharing agreements between the cooperating parties.

1 Introduction

Experiences of electricity outages has led countries around the world to sign formal cooperation agreements and to establish supranational bodies to coordinate actions in the event of a crisis. Table 1 shows examples of voluntary regional and bilateral cooperation agreements existing in Europe. These voluntary agreements are often based on existing procedures implemented by TSOs for emergency prevention and management. TSOs implement the necessary operation measures applicable in case of emergency and often take initiatives to establish cross-border cooperation schemes, such as, for example, the Mutual Emergency Assistance Service (MEAS), an existing voluntary TSO-TSO contract agreement1 established in 2011, by France, Italy, Spain, Portugal, and Germany with their respective neighbours for reciprocal TSO support in emergencies.

Table 1. Examples of existing cooperation schemes and forums for discussion

Regional agreements	**Countries**
Mutual Emergency Assistance Service (MEAS) TSO-TSO contracts (European Commission, 2016)	FR, IT, ES, PT, DE
CORESO (Coordination of Electricity System Operators) (CORESO, 2021)	FR, UK, BE, PT, IT, DE
Transmission System Operator Security Cooperation (TSC) (TSCNET, 2021)	AT,CH, CZ, DE, DK, HR,HU, NL,PL, SI
Pentalateral Energy Forum (Beneux, 2021)	AT, BE, DE, FR, LU, NL
Baltic Energy Market Interconnection Plan “BEMIP” (Commission, 2021)	DE, DK, EE, FI, LT, LV, PL, SE
Electricity Coordination Group (Commission Eurorpean a., 2021)	Member States, national regulators, ACER, ENTSOE and the Commission
Mediterranean Transmission System Operators (Med-TSOs) [2] (Med-TSO, 2021)	ME, GR, PT, CY, JORD, FR, EG, MAR, AL, SL, DZ, TN, LBYA, PS, TK, CR, ES, IT, ISR
The North Seas Energy Cooperation (Commission European b., 2021)	BE, DK, FR, DE, IE, LU, NL, NO, SW
Bilateral agreements (European Commission, 2016)	
“Black start” agreement between the UK and IE	
Separate agreements between the Italian TSO and its counterparts in four countries (FR, CH, AT, SI)	
Agreements between IT and SI TSOs cover data log and the exchange of foreign grid status (TM/TS)	
IT and FR TSOs are also bound by “common reserves”	
In MT, the DSO is linked by an Operational Agreement with the Italian TSO	

Legend. AL: Albania; DZ: Algeria; JORD: Jordan; MAR: Morocco; EG: Egypt; TN: Tunisia; LBYA: Libya, PS: Palestine, State of; TK: Turkey; ISR: Israel, FR: France, IT: Italy, ES: Spain, PT: Portugal, DE: Germany, UK: United Kingdom, BE: Belgium, AT: Austria, CH: Switzerland, DK: Denmark, HR: Croatia, HU: Hungary, NL: The Netherlands, PL: Poland, SI: Slovenia, LU: Luxembourg, EE: Estonia, GR: Greece, FI: Finland, LV: Latvia, LT: Let, SE: Sweden, CY: Cyprus, CR: Costa Rica, TM: Turkmenistan, ME: Montenegro, TS: Tunisia:, MT: Malta. IE: Ireland, NO: Norway.

The establishment of the CORESO (COoRdination of Electricity System Operators) followed a serious electrical power disruption in Europe in 2006 when 15 million people were left without power due to a lack of coordination between Transmission System Operators (TSOs) in the Central Western Europe (CWE) area. This event pushed the European Commission, together with TSOs, to start looking into ways to improve coordination between TSOs to guarantee the safe operation of the interconnected system with a view to maintaining security of supply.

[1] Other voluntary initiatives are briefly presented in section The regulatory background of the Risk preparedness regulation and the links with other EU legal frameworks.

[2] See “Mediterranean Project” Task 1 “Common Set of Rules for a Mediterranean Power System and Transmission Grid Code”

In the national energy and climate plan (NECP) MSs are also called to describe the efforts in place to establish effective regional agreements with other MSs. In the NECP of Belgium dedicates a section to the activities undertaken under the voluntary cooperation with some European countries. In 2015 Belgium, the Netherlands, Luxemburg, France, and Germany set up the Pentalateral energy forum (PLEF), a regional voluntary initiative aimed at fostering actions towards security of supply in the region (Table 2). Switzerland takes part to the PLEF as an observer. It needs to be acknowledge that the PEF sets out already some of the elements of the RPR in terms of regional agreements, like for example, the willingness to cooperate to foster safety and security of supply, cross-border cooperation, a better assessment of the costs of the electricity as signals to new investments.

Table 2. Pentalateral Energy Forum – main objectives and actions

Main objectives of the agreement	Main current and future actions
Cooperation on security of supply SupportGroup2 (SG2) of PLEF	-Memorandum of agreement on security of supply cooperation; -PENTEX 2018: exercise for mutual understanding of national concerns, identify the main potential regional crisis (cross-border) situations and to assess mitigation measures (PLEF, 2019) and (PLEF, 2017). -regional Generation Adequacy Assessment (GAA) (last assessment 4/2020 for the 2021 and 2025 horizons (PLEF, 2020)
Shared visions towards decarbonisation and common approach to ensure SoS	Common understanding of the expectations and challenges in creating a future decarbonised electricity system.
cross-border cooperation on renewable electricity	Possibilities of opening up national/cross-border calls for tender and organising joint calls for tender for interested Penta countries
Integration of electromobility options and services without any regional restrictions	Removal of obstacles to the cross-border roll-out of electromobility and charging services and interoperability within the Penta region.
Common approach to carbon pricing	Investigating political approaches to introducing carbon pricing in the energy system; Impact assessment on CO2 emissions reduction, security of supply, price trends and ensuring a fair situation for their industries
Market integration	Increase cross-border trade and social well-being and optimise the advantages for consumers.

Source: NECP Belgium 2020

The North Sea cooperation framework translates into concrete actions for the common interest of some central and north European Member States to jointly develop wind energy projects. The objectives of this agreement combine a sustainable, secure and affordable offshore renewable energy supply in the North Sea with a cost-effective use of cross-border connection of offshore wind farms to the grid, and on corresponding market arrangements" (Belgium NECP (CONCERE and CNC Belgium)) (Table 3). Part of this initiative are Belgium, the Netherlands, Luxemburg, France, Germany, The United Kingdom, Ireland Denmark, Norway and Sweden with participation from the European Commission.

The Nordic countries has a long tradition in a cooperative approach to electricity crises. There are two main fora where Nordic cooperation takes place: the Nordic Energy Authorities' Group for Emergency Matters in the Power Sector (NMK), and the Nordic Forum for Emergency Matters regarding the Power sector (NEF) composed by the NMK, the TSOs, and organisations of the power industry in the region ((The Nordic Forum for Emergency Matters regarding the Power Sector, Edition no.1 2005 12 15).

Other initiatives extend beyond the European Union, as the Continental Europe Synchronous Area is made of 25 countries and covers most of Europe's continent and some countries are connected to other neighbouring regions (e.g. Spain is connected with Morocco). This cooperation beyond the EU borders is recognised in Article 20 of the RPR with regard to the Energy Community Contracting Parties. An interesting example of cooperation between EU MSs and Southern and Eastern Mediterranean countries is Med_TSO (Med-TSO, s.d.), an association of TSOs of the Mediterranean Sea operating the High Voltage Transmission Networks of 19 Mediterranean Countries. They cooperate on the integration of the regional power systems. The activity of Med-TSO is supported by the European Union. The clean energy for all Europeans (CEP) offers various opportunities for EU MSs to cooperate with South Eastern Mediterranean countries. The centre for Mediterranean integration (CMIMARSEILLE, 2015) was established to improve cooperation opportunities for renewable energy deployment, to contribute to market integration and ultimately to define the conditions for a more secure and reliable energy system (Fraunhofer ISI, 2019). The Central and South Eastern Europe energy connectivity (CESEC) project is an initiative aimed at accelerate to integration of gas and electricity markets in the South Eastern European Region. It was set up initially by Austria, Bulgaria, Croatia, Greece, Hungary, Italy, Romania, Slovakia, and Slovenia and joined later on by eight Energy Community Contracting Parties: Ukraine, the Republic of Moldova, Serbia, the Republic of North Macedonia, Albania, Bosnia and Herzegovina, Kosovo (in line with UNSCR 1244 and the ICJ Opinion on the Kosovo declaration of independence), and Montenegro ((European Commission, 2020a).

Table 3. The North Sea cooperation framework

Main objectives of the agreement	Main current and future actions
Supporting activity to offshore renewable energy development	Maritime Spatial Planning Development and regulation of offshore grids and other offshore infrastructure Support framework and finance for offshore wind projects Standards and technical rules in the offshore wind sector
Environmental protection	Common environmental impact assessment methodology to understand the possible ecological limits of large-scale wind development in the North Seas and to utilise the potential of the maritime area
Additional objective of the cooperation	Harmonisation of standards and technical rules to contribute to further reducing costs of offshore wind deployment
Financing of projects	Setting up of a dedicated platform on best practice and design of support schemes; agreement on common principles for the financial support; share information on respective national tender schedules enabling the most continuous and timely tender pipeline across the North Seas region

Source: NECP Belgium 2020

Parties to those voluntary agreements acknowledged the importance of coordination with other TSOs, the tight cooperation with national DSOs, the establishment of central source of information for all the countries that are affected by the critical event, and the importance of a harmonised methodology for the monitoring of the crisis and the management of its evolution. In case of common weather events, shared weather monitoring and forecasts would also prove useful.

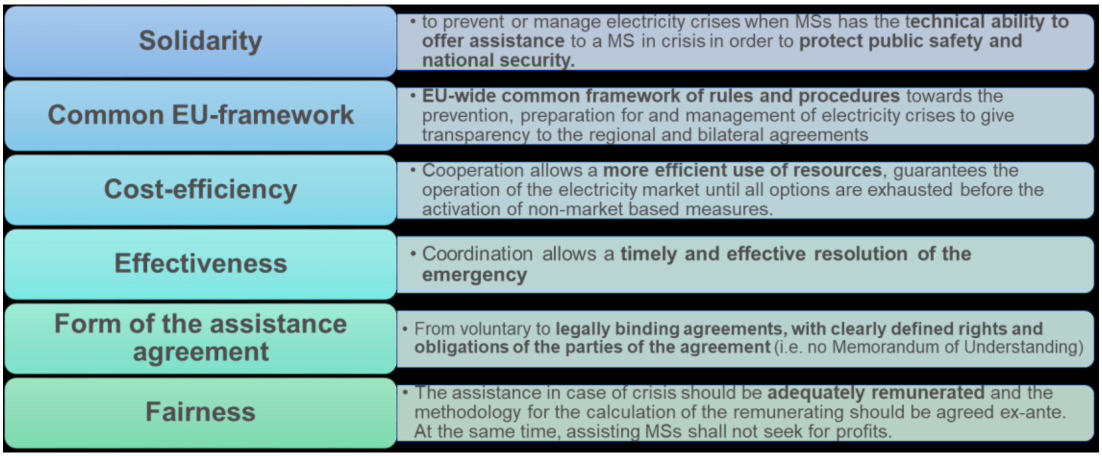
To ease the cooperation and the timely exchange of information, European TSOs - except for Cyprus which is not interconnected to the rest of EU MSs - can access and use the information platform created by ENTSO-E, composed of four different tools: the ENTSO-E Awareness System (EAS), the Real-time Awareness, the Alarm System (RAAS), and the Crisis Communication Tool (CCT) (ENTSO-E, 2021b),. The European Awareness System (EAS) is a technology platform developed by ENTSO-E in cooperation with the TSOs, after the 2003 blackout in Italy showed the importance of timely and reliable information exchange between TSOs in critical situations. The EAS allows transmission system operators to exchange information in real-time. All operators input a number of measurements including frequency and cross-border exchange. These measurements are then merged to provide an overall European view of each TSO on the platform. These platforms allow TSOs to get a real-time global view of the European grid, while the CCT enables TSOs to rapidly communicate an incident or potential incident to other TSOs. In addition, the ENTSO-E network code for emergency and restoration (for a more detailed discussion see section Non-market technical solutions) and the European critical infrastructure protection contact point are two more references for TSOs coordination and information exchange.

Box 1. Starting point of risk preparedness plans

All these existing cooperation structures, agreements, and exchange platforms should serve as a basis for the preparation of the regional measures of the risk preparedness plan and the assistance agreements in case of electricity crises.

The RPR puts together existing regulatory tools and the expertise and capability of European Members States in handling electricity crises, at national, and across national borders level, while adding some important elements to strengthen the possibility of cooperation among MSs and with non-MSs that are interconnected and part of the European synchronous. The RPR grounds the cooperation between MSs on some pillars (Figure 1).

Figure 1. Basic principles for cooperation and assistance under the Risk Preparedness Regulation



Source: authors' elaboration

The solidarity among MSs to prevent, prepare for and manage electricity crises when a MS has the technical ability to offer assistance to another MS in crisis, to protect public safety and national security. The RPR promotes a common EU-framework for the definition of national, regional, and bilateral measures to be included in the risk preparedness plans. The regulation fosters cost-efficiency and effectiveness of the management of a crisis through cooperation, allowing a more efficient use of resources; it promotes the operation of the electricity market until all options are exhausted before the activation of non-market based measures and allows a timely and effective resolution of the emergency. The form of the regional agreements for assistance shall be legally binding, with clearly defined rights and obligations of the parties of the agreement (see also section 3.4.1 on legal arrangements). Finally, the assistance in case of a crisis should be adequately remunerated and the methodology for the calculation of the remuneration should be agreed ex-ante. At the same time, assisting MSs shall not seek a profit when offering assistance.

The Regulation on risk-preparedness in the electricity sector (EU, 2019c) (the Regulation) sets the rules that provide electricity users entitled to receive special protection against disconnection with the highest possible level of uninterrupted electricity supply in critical situations. For all matters concerning a cross-border electricity crisis, Member States are called to agree on bilateral and regional measures to prevent, prepare for, and manage an electricity crisis.

The Regulation introduces an assistance mechanism between MSs as an instrument to prevent or manage electricity crises within the Union. When adopting the measures needed to implement the assistance mechanism, Member States have to agree on a number of technical, legal and financial issues in the regional or bilateral arrangements and describe them in their risk-preparedness plans.

This study addresses the regional dimension of electricity crisis management in the European Union. As it will be shown in the report, the management of national crises (crises that do not have effects on other MSs) is relevant also for the definition and agreement of regional measures. In the current interconnected system and single electricity market, it is rare that an electricity crisis would not have a cross-border impact. The national risk-preparedness analyses are aimed at: i) identifying the tools and procedures in place at MS level that could prevent the spread of the crisis to other countries, ii) identifying strengths (which type of support can be offered to neighbouring countries) iii) identifying gaps (the support that could be needed from neighbouring countries in case of a crisis). Moreover, the RPR invites MSs to adapt existing national rules and procedures to allow for the establishment of regional agreements.

The aim of the present study is to identify the essential elements concerning the regional measures for the prevention, preparation for, and the management of a crisis, as a practical guide for the preparation of the risk preparedness plan. The objective is also to extend and develop the guidelines described in Commission Recommendation (EU) 2020/1775 of 5th June 2020 (European Commission, 2020b).

2 The background of regional electricity crisis management in Europe

This section gives a short overview of the European regulations addressing risks in the electricity sectors and other national procedures on the prevention, preparation for, and management of outages.

2.1 The regulatory background of the Risk preparedness regulation and the links with other EU legal frameworks

Historically, the preparedness to electricity crises was mainly centred on the national perimeter and focused mostly on the adequacy of the available generation and infrastructure. While the responsibility of coping with the crisis was assigned to the national authorities and supported by cooperation among European Transmission System Operators (TSOs) according to the network code on electricity emergency and restoration (European Commission, 2017c), the RPR introduces the requirement of additional measures when the functioning of the market and the network codes are not enough to cope with the crisis. Moreover, the Regulation promotes coordinated preventive, preparatory, and mitigating measures in response to a crisis as a way to optimise the use of resources and reduce the risk of negative spillovers that the adoption of purely national measures could have on neighbouring Member States.

The RPR recalls other EU legal frameworks that establish tools for the preparation and management of crises or platforms for cooperation between MSs. The main ones are summarised in (Table 4).

The RPR establishes the basic links in its recitals:

- Most electricity incidents are effectively dealt with at the operational level. This Regulation focuses on electricity crises that have a larger scale and impact. It sets out what Member States should do to prevent such crises and what measures they can take should operational rules alone (system operation guideline, (European Commission, 2017b) and network code of emergency and restoration, (European Commission, 2017c)) no longer suffice.
- Security of supply is a shared responsibility among different national and Union actors as it is established in different articles of the common rules for the internal market for electricity Directive (the Electricity Directive from now on, see (EU, 2019b)). Additionally, the Regulation on the internal market for electricity (the electricity Regulation, from now on, see (EU, 2019d)) establishes the Regional coordination centres, the need to perform medium- to long-run resource adequacy assessments and this long-term adequacy assessments with the medium- and short-run adequacy assessments performed under the RPR.
- The electricity and natural gas systems are more and more interdependent. To ensure consistency, the risk of disruption of the gas supply should be consistent with the scenarios developed by the European Network of Transmission System Operators for Gas (ENTSOG) pursuant Regulation (EU) 2017/1938 concerning measures to safeguard the security of gas supply (EU, 2017).
- The RPR complements the Directive on security of network and information systems (EU, 2016) by ensuring that cyber-incidents are properly identified as a risk, and that the measures taken to address them are properly reflected in the risk-preparedness plans.
- The risk prevention, preparedness and planning actions set out in the RPR should be consistent with the wider, multi-hazard national risk assessments required under decision on a Union Civil Protection Mechanism (EU, 2019a) and with the national disaster risk management planning actions developed under such framework.
- The RPR together with the Council Directive on the identification and designation of European Critical infrastructures (EU, 2008) aims at creating a comprehensive approach on the energy security of the Union.

Table 4. EU legal frameworks of the Risk Preparedness Regulation

<table>
<tr><td colspan="3">Energy</td><td>Civil protection</td></tr>
<tr><td rowspan="4">(a) Electricity</td><td rowspan="2">Market design</td><td>Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity (EU, 2019d)</td><td>Decision No 1313/2013/EU of the European Parliament and of the Council of 17 December 2013 on a Union Civil Protection Mechanism (OJ L 347, 20.12.2013, p 924-947).</td></tr>
<tr><td>Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (EU, 2019b)</td><td>Commission staff working document: overview of natural and man-made disaster risks the European Union may face. SWD(2017) 176 final (European Commission, 2017d)</td></tr>
<tr><td rowspan="2">Network codes and guidelines</td><td>Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation (European Commission, 2017b);</td><td>Commission staff working document. Risk Assessment and Mapping Guidelines for Disaster Management. Brussels, 21.12.2010. SEC(2010) 1626 final (European Commission, 2010)</td></tr>
<tr><td>Commission Regulation (EU) 2017/2196 of 24 November 2017 establishing a network code on electricity emergency and restoration (European Commission, 2017c),</td><td>Cybersecurity</td></tr>
<tr><td colspan="2" rowspan="2">(b) Natural Gas</td><td>Regulation (EU) 2017/1938 on measures to safeguard security of gas supply to ensure consistency with the gas disruption scenarios (EU, 2017)</td><td rowspan="2">Directive (EU) 2016/1148 of the European Parliament and of the Council of 6 July 2016 concerning measures for a high common level of security of network and information systems across the Union (EU, 2016); Recently, the European Commission has adopted a proposal for a revised Directive on Security of Network and Information Systems (NIS 2 Directive, see (European Commission, 2020d)).</td></tr>
<tr><td>Commission recommendation (EU) 2018/177 of 2 February 2018 on the elements to be included in the technical, legal and financial arrangements between Member States for the application of the solidarity mechanism under Article 13 of Regulation (EU) 2017/1938 of the European Parliament and of the Council concerning measures to safeguard the security of gas supply (European Commission, 2018).</td></tr>
<tr><td colspan="2">(c)</td><td>Communication COM(212) from the Commission to the Council and the European Parliament on the comprehensive risk and safety assessments («stress tests») of nuclear power plants in the European Union and related activities (European Commission, 2012)</td><td>Commission Recommendation (EU) 2017/1584 of 13 September 2017 on coordinated response to largescale cybersecurity incidents and crises (European Commission, 2017a);</td></tr>
<tr><td colspan="2" rowspan="2">Critical Infrastructure</td><td rowspan="2">Council Directive 2008/114/EC of 8 December 2008 on the identification and designation of European critical infrastructures and the assessment of the need to improve their protection (EU, 2008); recently, the European Commission has adopted a proposal for a Directive of the European Parliament and of the Council on the resilience of critical entities (European Commission, 2020c).</td><td>Commission Recommendation (EU) 2019/553 of 3 April 2019 on cybersecurity in the energy sector (European Commission, 2019)</td></tr>
<tr><td>Commission Recommendation (EU) 2019/554 of 26 March 2019 Cybersecurity of 5G networks.</td></tr>
</table>

2.2 Existing national rules and procedures recalled by the Risk Preparedness Regulation

The RPR establishes a minimum set of essential principles to be adopted at the national level to avoid negative impacts of national measures on neighbouring countries in case of national electricity crises. When an electricity crisis originating in one country crosses the border and affects a neighbouring MS, it turns from being a national issue to a regional issue that requires coordinated, ex-ante agreed measures between Member States. In this case the Regulation defines also the rules for European MSs to provide and receive assistance in case of cross-border electricity crisis.

Many articles of the RPR and in many sections of the EC's Recommendations reference to existing national legal frameworks, procedures[3], and rules for the implementation of the provisions of the regulation wherever possible. This is justified by the fact that, while the ultimate goal of the regulation is "the political desire for assistance between Member States [...] to provide electricity users (with) special protection against disconnection with the certainty and security of an uninterrupted electricity supply", the regulation leaves Member States a wide range of freedom to choose the assistance mechanisms that best suit them.

The coordinated measures for assistance should possibly build on existing national frameworks and procedures wherever possible, adapted as necessary for assistance purposes. This may include the use of existing platforms or mechanisms for demand-side measures or existing customer compensation mechanisms. The adoption of existing and adapted national rules, procedures and national legal frameworks in the assistance measures should be agreed ex-ante between the parties of the regional/bilateral agreement and described in the risk preparedness plan.

2.3 Coordination and cooperation between national and regional authorities

The RPR establishes that regional cooperation should build on the existing regional cooperation structures used at the technical level. That is, groups of Member States sharing the same Regional Coordination Centre (RCC), so-called System Operation Regions (SORs). RCCs are proposed by the TSOs of each system operation region and approved by ACER. RCCs will have to be set up by 1st July 2022, although most of them are already in place (see for example Table 5).

Table 5. Example of a Regional Coordination Centre for the South-East Europe SOR TSOs

<table>
<tr><td>Seat of the RCC</td><td colspan="2">Thessaloniki (GR)</td></tr>
<tr><td rowspan="4">Participating TSOs</td><td>ESO EAD (BG)</td><td rowspan="2">TSOs belonging to SEE SOR</td></tr>
<tr><td>IPTO (GR)</td></tr>
<tr><td>Terna (IT)</td><td rowspan="2">TSOs operating in bidding zones and bidding zone borders adjacent to the SEE SOR</td></tr>
<tr><td>Transelectrica (RO)</td></tr>
<tr><td rowspan="2">Coordination tasks of the SEE RCC</td><td colspan="2">BG-RO border, in cooperation with Transelectrica</td></tr>
<tr><td colspan="2">GRIT CCR and for the IT CNOR, IT CSUD, IT SUD, IT SICI, IT SARD, and IT ROSN bidding zones in cooperation with Terna</td></tr>
<tr><td>Other information</td><td colspan="2">the participation in the RCC may include both TSOs from EU Member States and TSOs from non-EU Member States</td></tr>
</table>

Source: SEE SOR TSOs' proposal for the establishment of RCC[4]

[3] The latest updates on the national implementation of the network code on emergency and restoration (European Commission, 2017c) is monitored by ENTSO-E, and the documents for each country are available to the public https://www.entsoe.eu/active-library/codes/er/ .

[4] Full text available at https://www.tscnet.eu/tsos-of-the-central-sor-submit-rcc-proposal/

SORs, i.e. the geographical scope of each Regional Coordination Centre, (Table 6) are defined for each transmission system operators, bidding zones, bidding zone borders, capacity calculation regions (CCR) and outage coordination regions based on grid topology, including the degree of interconnection and of interdependency of the electricity system in terms of flows and the size of the region.

Table 6. System Operation Regions (SORs) as approved by ACER.

RCC	System Operation Region	CCR	TSOs	BZ	BZ borders
Baltic RSC	Baltic SOR	Baltic CCR	Litgrid AST Elering	LT LV EE	Baltic CCR borders
Nordic RSC	Nordic SOR	Nordic	Energinet Fingrid Svenska Kraftnat	DK1, DK2 FI SE1, SE2, SE3 SE4	Nordic CCR borders
CORESO	IU SOR	IU Channel	SONI EirGrid NGESO	SEM GB	GB-SEM channel CCR borders
(TSCNET)	Central Europe SOR	CORE Italy NORTH	RTE ELIA TenneT NL Amprion TransnetBW TenneT DE 50Herts Creos PSE CEPS APG VUEN MAVIR ELES SEPS HPS Transelectrica TERNA REE REN	FR BE NL DE/LU PL CZ AT HU SI SK HR / RO IT NORD ES PT	Core CCR borders Italy North CCR borders SWE CCR borders
	SEE SOR	SEE	ESO IPTO	BG GR	SEE CCR borders
(CORESO)	GRIT SOR	GRIT	Terna	IT NORD IT CNORD IT CSUD IT SUD IT SICI IT SARD IT ROSN	GRIT CCR Borders
CORESO	SWE SOR	SWE	RTE REE REN	FR ES PT	SWE CCR borders

Source: ACER's official website (ACER, 2020c)

If a SOR covers more than one CCR, the methodologies of each CCR shall apply and there is no obligation for harmonisation. The geographical scope of the Regional coordination centres (RCCs) is made of MSs belonging to regional cooperation structures defined at the technical level according to "[...] the grid topology, including the degree of interconnection and of interdependency of the electricity system in terms of flows and the size of the region which shall cover at least one capacity calculation region (recital 16 of the Regulation).

Moreover, "[…] where the control area of a TSO is part of various synchronous areas, the transmission system operator may participate in two regional coordination centres" (art. 37 of the recast regulation on the internal market for electricity (EU, 2019d)).

Nevertheless, Article 12 of the RPR requires that crises with a cross-border impact are properly prevented or managed. The regulation defines the possibilities to conclude regional/bilateral agreements on concrete cross-border measures (Figure 2):

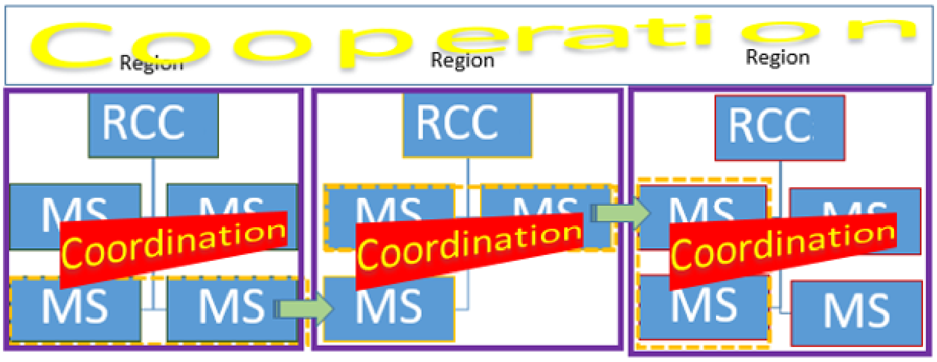
— with all Member States in a region[5], which have the technical ability to provide assistance;

— by creating sub-groups within a region, comprising those Member States which are technically able to provide each other with assistance;

— by means of bilateral measures between those Member States, which are directly connected but not part of the same region;

— with the exception for those Member States in a region, which do not have the technical ability to provide assistance.

Figure 2. The MSs' cooperation framework established under the Risk Preparedness Regulation



Legend:
The Regional Coordination Centres (RCCs) are defined based on regional cooperation structures at technical level;
Subgroup within the region to define concrete measures made of Member States, which have the technical ability to provide (mutual) assistance;
Possibility of bilateral agreements between Member States, which are directly connected but are not within the same region. These MSs have the technical ability of offering each other assistance;
Coordination art. 37 of the recast regulation (2019/943);
Cooperation art. 38 of the recast regulation (2019/943).

Source: authors' elaboration

Box 2. Cooperation and coordination between national and regional authorities.

Risk preparedness is carried out by a combination of national actors (who hold ultimate responsibility for declaring a crisis event), and regional actors (who have the task to promote optimal regional resource use in a crisis and improve the overall regional system operation). The interplay of various actors brings benefits but may lead to challenges.

The cooperation should extend beyond the Energy Union borders.

Existing regional cooperation structures, i.e. Regional Coordination Centres provide the foundations for the cooperation arrangements.

[5] The term "region" is left general here, in consideration of considered the dynamic development that regional security coordinators (RSC) are undergoing. Regional coordination centres (RCCs) will evolve from RSCs experience as required by the clean European package" ((ENTSO-E, 2019c) page 6).

3 A new system of measures for the prevention and management of electricity crises: the risk preparedness plan

The risk preparedness plan is the set of national, regional and bilateral measures and procedures necessary to prevent, prepare for, and manage electricity crises (Table 7). The RPR provides the template of the risk preparedness plan (ANNEX I to the Regulation). The main actors involved in the drafting of the plan are the competent authority of each MS in consultation with relevant DSOs, TSOs, the relevant producers or their trade bodies, the electricity and natural gas undertakings, the relevant organisations that represent the interests of industrial and non-industrial electricity customers, and the regulatory authority where it is not the competent authority. The MSs' cooperation framework is complemented with existing or newly established institutions, like the regional coordination centres. The regional measures are defined based on the information retrieved from the regional crisis scenarios, the regional risk assessments, and the seasonal and short-term adequacy assessments. Finally, the plan shall also include the foreseen post-crisis activities, like the monitoring and reporting of the occurrences, to gather the lessons learnt and improve, when necessary, future risk preparedness plans.

Table 7. Regional / bilateral measures. An overview of relevant elements

Coop. framework	Regional risk assessment		Regional / bilateral measures		Post-crisis
MSs competent authority & RCC	**Regional electricity crisis scenarios (ENTSO-E)**	**Short term Resource Adequacy Assessment**	**Prevention / preparation for / mitigation**	**Management of the emergency & restoration**	**Ex-post reporting and monitoring**
• R/CA responsible for the coordination • MSs belonging to each RCC, sub-groups within the RCC and between RCCs • TSOs from EU and non-EU MSs • Solidarity based on tech. ability to cooperate • Cooperation when cost-efficient solution • Effectiveness	• ENTSO-E/RCCs identify the most **relevant crisis scenarios for each region** and submit to TSOs, R/CAs, RCCs • Ranking of scenarios • **Trigger for each scenario** • Interdependencies across MSs • Basis for the short term risk assessments	• Regional / national scope • **(RCCs) week/day ahead according to ENTSOE methodology** • better definition of the magnitude of the crisis when cross-border resources are accounted • Prob. trans. capacity outages, unplanned outages of generation • Prob. of a (simultaneous) crisis (ENS, LoLP) • Basis for the regional cooperation and coordination	• **Common platform to share information** • **Pre-agreed mechanisms to cooperate** • **National procedures** may be taken into account when cross-border impact • emergency tests • ENTSOE/EC/ACER can provide support in the definition of agreements	• **Early warning** (adequacy issue from i.e. seas. assessment) • **Declaration of crisis** (imminent elec. shortage for category of users entitle to receive special protection) • **Request of assistance** • Non-mkt based are exhausted • Tech. ability to offer assistance • Legally binding rights / obligations • Fairness	• the trigger • adopted preventing and alleviating measures and their cross-border impact • Assistance foreseen and effectively activated • economic impact of the crisis and the measures • ENS, voluntary and forced demand disconnection and their justification • Possible improvement to the RP plan/ grid

Source: authors' elaboration

3.1 Risk assessment. The combined tools of risk scenarios and adequacy assessment

The RPR puts together two important tools for the electricity risk assessment: the national and regional crisis scenarios and the seasonal and short term adequacy assessments. The methodologies for both types of assessments were approved by ACER in March 2020 (ACER, 2020a). ENTSO-E or, if delegated, the regional coordination centres identify the most relevant risk scenarios for each region. This categorization will be useful for each regional coordination centre to assess, on the one side, the week-ahead to at least day-ahead assessments for the identification of possible adequacy issues in the region, for the preparation of risk-reducing actions, and on the other side for the establishment of regional measures and agreements within and between regional coordination centres.

The geographical scope of the regional crisis scenarios may or may not coincide with the geographical scope of the RCCs. The regulation of the internal electricity market (articles 37 and 38, see (EU, 2019d)) and the guidelines for system operation (art. 81.4 (European Commission, 2017b)) address the case in which a potential crisis/adequacy issue impacts countries that belong to different RCCs. The regulation and the SO GL define the conditions for RCCs/RSCs to coordinate to assess correctly the risk and define appropriate actions.

An example of threats going beyond individual RCC geographical areas is the one related to the floods on the Danube River. The Danube River Basin is the second largest river basin of Europe, covering 801 463 km2 and territories of 18 countries. Periods of droughts or floods could impact several countries at the same time. The International Commission for the Protection of the Danube River (ICPDR) is an International Organisation consisting of 14 cooperating states and the European Union with the aim of strengthening coordinated actions along the Danube River Basin, which includes its tributaries and ground water resources.

Another example of regional crisis scenarios going beyond the geographical scope of the RCCs may be provided by gas fuel shortages, a Carrington storm, or a pandemic. The heat wave in summer 2019 affected the Nordics (Sweden had to stop some nuclear power plants) but also Germany, Belgium, The Netherlands, and the UK. ENTSO-E is responsible of the seasonal pan-European adequacy assessments (see also sections 3.1.2 and 3.3.1). In case an adequacy issue is detected, the affected MSs could use the results to decide whether to launch an early warning informing the European Commission, all the TSOs part of the regional coordination centre, and the competent and regulatory authorities of the adequacy issue, and gather information on a possible electricity crisis (see also paragraph Risk management. From early warning to request of assistance), or to perform a closer analysis through the monthly adequacy assessment (voluntary) and/or week/daily adequacy assessment performed by RCCs.

The International Foundation Big Data and Artificial Intelligence for Human Development developed the European Extreme Events Climate Index (E3CI[6]), an ensemble of indices about the areas affected by different types of weather-induced hazards and the severity of such events. Currently, based on the corresponding index developed for North America (Actuaries Climate Index, ACI; actuariesclimateindex.org), E3CI includes five components returning information about main hazards: cold and heat stresses, droughts, extreme precipitations, extreme winds. Moreover, these components are combined into a single index, providing a general overview of the hazards. The data is released at Country level but it will be made available on different Administrative unit levels in the future. The E3CI applications can support Member States in a wide area comprising both scientific and technical use cases to link the occurrences of relevant weather events to their impacts, particularly in terms of economic and insurance losses. Such an information can be useful to complement the tools already in use by the competent authorities dealing with risk assessment and risk management.

In this chapter, we highlight the key elements of each tools and describe how they all contribute to the identification and assessment of a crisis and their role as monitoring tools for the prevention and management of the (risks of) electricity crises.

Box 3. Regional and national risk scenarios.

The RPR combines the use of multiple tools for the analysis of the risk of electricity crisis at national and regional level and for different time horizons.

The geographical scopes of the regional crisis scenarios may or may not match with the geographical scope of the RCC/SOR. There could be crisis scenarios beyond RCCs geographical scope.

This may envisage the need of improving the scope of the regional assessments performed by RCCs to effectively assess the risk of electricity crisis. If so, the results of the assessment could be used to evaluate the risk associated to the regional crisis scenarios and to define the regional/bilateral measures in the risk preparedness plan.

3.1.1 Regional / national crisis scenarios

The approved methodology for the identification of regional crisis scenarios requires ENTSO-E to collate and combine those national crisis scenarios candidates submitted by TSOs that are likely to be caused simultaneously or consequently by the same (or a combination of) initiating event(s), or have a significant cross border relevance (art. 8.1 of the methodology). For example, if a certain crisis is Likely and has Critical

[6] IFAB, E3CI: European Extreme Events Climate Index, https://www.ifabfoundation.org. Other interesting information and tools can be found in https://www.atlas.impact2c.eu/en/ ; https://www.eea.europa.eu/publications/adaptation-in-energy-system ; and https://climate.copernicus.eu/ .

LOLE impact and major EENS impact, it would be defined as Critical. For the purpose of combining and computing the consequences across multiple Member States, a numerical value (rating) is assigned to each scenario rating. In Table 8, the scenario rating is shown in parenthesis under each type of scenario.

Table 8. Example of crisis scenario rating (impact/likelihood/score) for a crisis X in a Member State

Member State	Impact of the crisis		Likelihood of the crisis (rating)				
	EENS%	LOLE	Very likely	Likely	Possible	Unlikely	Very unlikely
MS 1	Disastrous	Minor	Disastrous (10)	Critical (5)	Major (2)	Major (2)	Minor (1)
MS 2	Major	Critical	Critical (5)	Critical (5)	Major (2)	Minor (1)	Minor (1)
MS 3	Insignificant	Minor	Major (2)	Minor (1)	Minor (1)	Insignificant (0)	Insignificant (0)

Source: authors' elaboration on (ACER, 2020)

The crisis scenario rating of each Member State, together with the corresponding cross-border dependency rating (CBD), is then used to build the national and the regional rating. The scenarios are then ranked considering their probability and Expected Energy Not Served (EENS) and/or Loss of Load Expectation (LOLE), including also the national ratings of the strength of the cross-border dependencies (art. 9 and 10 of the methodology) (Table 9). Finally, ENTSO-E submits the so-defined regional electricity crisis scenarios to the TSOs, RCCs, competent authorities and national regulatory authorities and the Electricity Coordination Group and to ACER. RCCs that are requested to perform short term adequacy assessment may take into account the information provided in the regional crisis scenarios.

Table 9. Construction of regional rating from hypothetical national ratings of three Member States

Scenario name	Member State 1			Member State 2			Member State 3			Regional rating
	A	B	C	D	E	F	G	H	I	
	Scenario rating	CBD	National rating (A*B)	Scenario rating	CBD	National rating (D*E)	Scenario rating	CBD	National rating (G*H)	C+F+I
Scenario	1	1.2	1.2	5	2	10	2	1	2	13.2

Legend: CBD: cross-border dependency.
Source: authors' elaboration on (ACER, 2020)

The short term and seasonal adequacy assessment (STSAA, see below for a brief description) complements the information provided by the regional crises scenarios with the assessment of possible adequacy issues. The two tools together contribute to the definition of risk-informed resilience investment decisions. New investments may be triggered by the results of the overall risk assessment and target the reinforcing the transmission and distribution grid resilience in more vulnerable regions to severe-weather impacts like hardening the electric infrastructure or building underground lines; improvement the operation and maintenance (O&M) activities such as tree trimming, replacement of old equipment; improve the accessibility of the affected electric infrastructure facilities to the restoration crews in a post-disaster situation; improvement of the flexibility capacity – like installing protective devices to shelter against possible interruptions - and flexibility services; demand side programs; installation of microgrids, distributed generation, energy storage; and reinforcement of distribution grids (Larsen, 2016).

Box 4. Cooperation for investment aiming at increasing energy security.

The increasing frequency and/or intensity of extreme weather and climate events in many regions of Europe combined with the aging electric power infrastructure puts the system at high risk of outages. Risk-informed resilience investment decisions may be taken also in coordination with MSs facing the same type of hazards. The RPR, in fact, not only triggers further and stronger cooperation among MSs to improve system security and resilience by establishing regional measures in the case that assistance is requested. The Regulation also indirectly incentivises the establishment of regional cooperation platforms, and the coordination on joint investment programmes to enhance energy security, so to reduce risk levels and generate benefits for all parties of the agreements. For example, costly investments in outage recovery equipment can be shared by MSs in an agreement, so that costs for individual utilities could be reduced. Dependence and system vulnerability indicators can provide the right information on the identification of the parties of regional agreements and on the type of investment to be jointly undertaken. If this analytical approach proves to be efficient in negotiating agreements for international investments in commodities like oil and gas (Costantini, 2007), where geopolitics plays a relevant role not only for security of supply but also for political stability, some authors (Van der Vleuten, 2010) have shown how events like the 'European blackout' are a confirmation of the transnational security threat stemming from electricity grids, and strengthen the argument according to which a certain regulatory environment and economic gains would push cooperation in sharing emergency power generating capacity investments also in the electricity sector.

(Mukherjee, 2018) provide an interesting insight on how to leverage a multi-hazard risk estimation method to link the complex relationships between the characteristics of a country experiencing outages (in terms of land-use information, electricity consumption patterns, climate variations, etc.) and outage intensities, showing that the extent of prolonged outages is predominantly dependent on the types of severe weather events. Once it is known what are the most risky and disastrous events (in terms of hours of outages, type of grid infrastructure, etc.), the regional spread and the number of affected customers, risk-informed resilience investment decisions can be reached which are tailor-made and effective.

Recent studies on the American power system (LaCommare, 2018) have highlighted severe weather as the leading cause of power outages and show how customers have invested in backup generators, both in the residential and commercial/industrial sectors while utilities' spending on vegetation management, storm hardening, including tree trimming, and undergrounding of distribution lines to reduce exposure to environmental hazards have also increased.

3.1.2 Adequacy and the short-term and seasonal adequacy assessment

Regulation (EU) 2019/943 foresees a European resource adequacy assessment (Article 23) and a national resource adequacy assessment (Article 24) to identify adequacy concerns according to the approved methodology (ACER, 2020e) and to assess the need of capacity mechanisms. In case of adequacy issues, Member States shall develop and publish an implementation plan with a timeline for adopting measures to eliminate any identified regulatory distortions or market failures, in particular:

- removing regulatory distortions:
- removing price caps
- introducing a shortage pricing function for balancing energy
- increasing interconnection and internal grid capacity
- enabling self-generation, energy storage, demand side measures and energy efficiency
- ensuring cost-efficient and market-based procurement of balancing and ancillary services;
- removing regulated prices.

The details of this plan are relevant for the regional agreements, as they reflect the investment plans that the MS experiencing adequacy issues intends to put in place to improve its security of supply. Also, it is important to remark that article 16 of the RPR establishes that measures taken to prevent or mitigate electricity crises shall comply with the rules of the internal electricity market, and that non-market rules are a last resort tool to be used only in exceptional cases where market-based measures alone are not sufficient, or when they are exhausted. The removal of market failures and distortions is important to reduce the non-market measures to a minimum part of the risk preparedness plans.

Table 10. Seasonal and short-term (season - 6 months/month/week/day ahead) adequacy assessment (STAA)

Objective	**Actors / geographical scope**	**Assessment**	**Indicators**
To detect possible short-term risks that might occur in the following six months that are likely to result in a significant deterioration of the electricity supply situation. If the seasonal resource adequacy assessment shows concrete risk of a serious crisis, the competent authority of the affected MS issues an early warning to the Commission, the MSs in its region, and the MSs with which it has bilateral agreements. When launching the early warning and / or declaring an imminent electricity crisis, the MS should prepare a technical document on the origin and causes of the crisis, including the theoretical maximum electricity quantities they may request. The latest seasonal and short-term adequacy assessments can be used as "a good starting point for the analysis of the potential electricity quantities." (EU recommendations 2020/775)	ENTSO-E performs Seasonal (winter and summer) - Pan-EU - adequacy assessment to alert MSs and TSOs to risks related to the security of electricity supply that may occur in the following six months (art 9 of the Regulation) RCCs carry out week-ahead to at least day-ahead adequacy assessments in accordance with Regulation (EU) 2017/1485 and applying the methodology defined in art. 8 of the Regulation National TSOs conduct national, seasonal, and short term week-ahead to at least day-ahead adequacy assessments applying the same methodology Member States (belonging to different RCCs) that are part of a regional or bilateral agreement may conduct regional short-term adequacy assessment to investigate the risk associated to crisis scenarios that affect the MSs part of the agreement.	(a) the uncertainty of inputs such as the probability of a transmission capacity outage, the probability of an unplanned outage of power plants, severe weather conditions, variable demand, in particular peaks depending on weather conditions, and variability of production of energy from renewable sources; (b) the probability of the occurrence of an electricity crisis; (c) the probability of the occurrence of a simultaneous electricity crisis. Moreover, these assessments shall first ensure risk awareness for all relevant stakeholders and support system operation by identifying what the adequacy risks are and when these risks exist. It can also support system operation planning to mitigate those risks (e.g. maintenance planning). The same methodological principles may be applied for national short-term and seasonal adequacy assessments (ENTSO-E 2020 Short-term and Seasonal Adequacy Assessments Methodology)	EENS[7], LOLE[8], Loss of Load Probability ('LOLP')[9], Relative EENS[10] and Adequacy Probability Metric ('APM') are defined for a "'given time period'. The 'time period' is adapted taking into consideration the timeframe of each typology of adequacy assessment (See paragraph (28) point (a) of ACER"s approval of the STSAA methodology of ENTSO-E) (ACER, 2020b)

Source: authors' elaboration

[7] Expected Energy Not Served (EENS) in a given geographical zone and for a given period, is the energy (MWh) which is expected not to be supplied due to a lack of market-based resources retaining sufficient transmission grid operational security limits. This indicator describes the magnitude of adequacy issues expressed in energy for an analysed season.

[8] Loss of Load Expectation (LOLE) in a given geographical zone and for a given period is the expected number of hours during which a lack of market-based resources is expected to cover the demand needs with sufficient transmission grid operational security limits. This indicator is very useful to give an overview of adequacy over longer periods and is commonly used in adequacy assessments such as the mid-term adequacy forecast.

[9] Loss of Load Probability (LOLP) in a given geographical zone and for a given period, is the probability to have a lack of market-based resources to cover the demand needs with sufficient transmission grid operational security limits. This indicator represents the likelihood of adequacy issues in an analysed period.

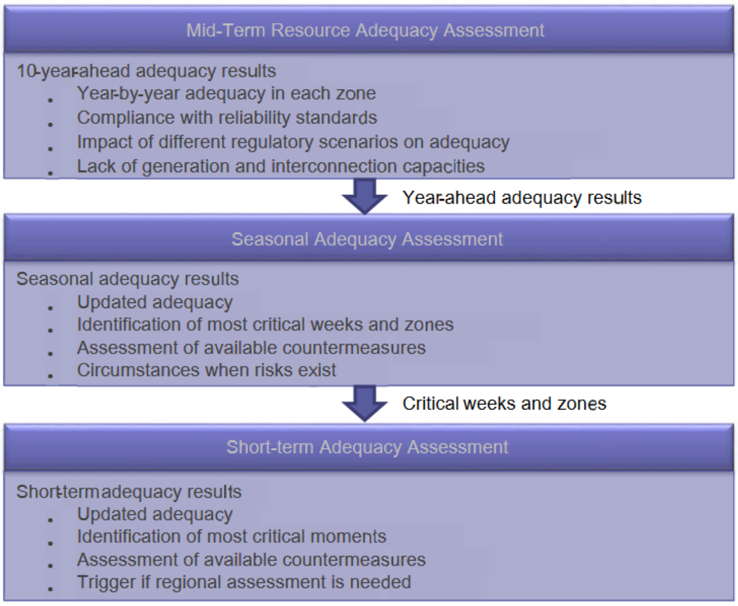
[10] Relative EENS is a more suitable metric to compare adequacy across geographical scope, as it represents the percentage of total demand (MWh) which is expected not to be supplied during the analysed period.

As it is clarified in the Regulation (EU) 2019/943 on the internal market for electricity (EU, 2019d), "*the methodology for the long-term [European] resource adequacy assessment [ERAA] (from ten-year-ahead to year-ahead) set out in this Regulation has a different purpose than the short-term and seasonal adequacy assessments [STSAA] (six months ahead) as set out in Article 9 of Regulation (EU) 2019/941 on risk preparedness for the electricity sector (11). Medium to long-term assessments are mainly used to identify adequacy concerns and to assess the need for capacity mechanisms whereas seasonal adequacy assessments are used to alert to short-term risks that might occur in the following six months that are likely to result in a significant deterioration of the electricity supply situation. In addition, regional coordination centres also carry out regional adequacy assessments on electricity transmission system operation. Those are very short-term adequacy assessments (from week-ahead to day-ahead) used in the context of system operation*". The ERAA assessment for SY+1 may refer to the results of the STAA performed pursuant to Article 9 of the RPR ((ACER, 2020e) article 3, annex I). The main features of the STAA are summarised in Table 10. In 2019, ENTSO-E launched the pan-European IT tools for Outage Planning Coordination and Short-term Adequacy Assessment, two of the five mandatory services provided by Regional Security Coordinators (RSCs) and Transmission System Operators (TSOs) for electricity under the European Commission Regulation establishing a guideline on electricity transmission system operation. They are aimed at increasing the operational security of Europe's power system (ENTSO-E, 2020a).

The Methodology shall be adopted by ENTSO-E in the form of winter and summer outlooks with the purpose of alerting Member States, transmission system operators, and all other relevant stakeholders of adequacy-related risks that might occur in the following six months. Regional Coordination Centres (RCCs) will use STSAA —as required by Article 9 of the RPR—to perform week-ahead to at least day-ahead adequacy assessments to continuously monitor adequacy.

Seasonal adequacy assessments provide a link between one-year-ahead European Resource Adequacy Assessment (ERAA), and the short-term and seasonal adequacy assessment (STSAA) (Figure 3). The ERAA methodology has the same foundation as the STSAA methodology, whereas STSAA has a reduced data uncertainty, and shall consider, when available, weather forecast (ACER, 2020b).

Figure 3. Information flow between mid-term and short term adequacy assessments



Source: (ACER, 2020b)

The outcomes from the short-term pan-European adequacy assessment can be refined in regional and national studies, which can incorporate a higher granularity and local sensitivities. In case major contingencies or input updates (e.g., rescheduling of maintenance) are foreseen after the seasonal adequacy assessments

(Winter Outlooks and Summer Outlooks) and in case ENTSO-E, RCC(s), or TSO(s) estimate that this could cause an adequacy risk, a month-ahead adequacy assessment will be performed[11].

Moreover, TSOs are required to take this methodology as reference when carrying out any other type of national short-term adequacy assessments, especially the week-ahead to at least day-ahead generation adequacy forecasts provided for in the SO GL. This continuous intra-year monitoring is necessary to ensure that mitigating actions could be taken to respond to changing operational conditions, weather patterns and occurred contingencies. When the assessments show they can pose a risk for adequacy, dedicated measures can be taken to mitigate the risk, for instance planned generation or network outages can be rescheduled.

Moreover, when an electricity crisis with a cross-border impact seems imminent - according to the EC's Recommendations - short-term adequacy assessments represent a good starting point for the analysis of the theoretical maximum electricity quantities that a MS in need of assistance may request when launching an early warning of electricity crisis or when declaring a crisis and the request of assistance (see EC's Recommendations section 2.2.2).

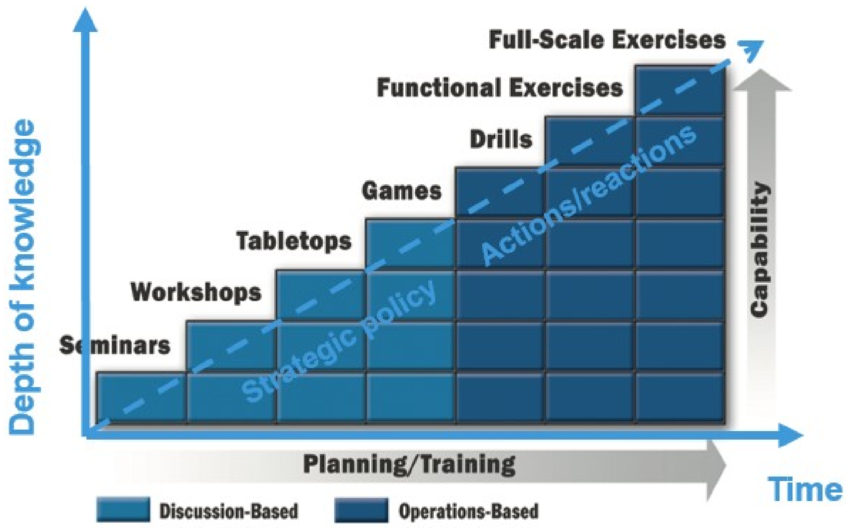
3.1.3 Electricity crisis simulations and exercises

The Regulation foresees the performance of annual / biennial - regional / national emergency tests (i.e. real time response simulations of electricity crises) accompanied by a report on the results with the indication of procedures agreed and the actors involved and the measures adopted as a result of those tests. In summary, the benefit of the simulation crisis exercises is to check the suitability of risk-preparedness plans and to identify the elements of the plans that is crucial to sustain or improve.

3.1.3.1 How to organise a crisis simulation exercise

Among the regional and bilateral measures foreseen in the risk-preparedness plans, the regulation includes procedures for carrying out annual or biennial tests of the risk-preparedness plans (Art. 12). Crises have long incubation times, thus in order to avoid that numerous warnings remain undetected or ignored, it is important to recognise triggering events and possible cascading effects. Electricity crisis simulation exercises are useful to collect knowledge on how to detect the first signs of a crisis at various stages of development and build a resilient system.

Figure 4. Example of simulation exercise: Building Block Approach



Source: (Poljanšek, 2019)

[11] Page 4 of (ACER, 2020b).

3.1.3.2 *The joint electricity crisis exercise of the Pentalateral energy forum (Pentex 2018)*

Tabletop exercises are one of the many possible simulations that can be carried out to improve the knowledge on regional crises and on the most effective cooperation measures. In 2018, the Pentalateral energy forum carried out the joint electricity crisis exercise (Pentex 2018), a joint tabletop exercise of a regional electricity crisis and regional cooperation. This joint exercise represents a good example of coordinated actions to mitigate and manage a possible regional electricity crisis.

The goals of the exercise were:

- bring relevant networks operators, representatives of ministries and national regulators together & support cooperation and collaboration
- share knowledge and practices
- identify potential crisis situations for the region
- test coordination & communication abilities in case of electricity shortage/load shedding
- identify best practices
- set a good example for future operations

The PLEF members acknowledged that national decisions can impact the cross-border electricity market, neighbouring countries and all region. The results of the crisis exercise showed the importance of common actions and shared principles when defining cooperative regional measures:

- The adoption of the "Market-First"-Principle as a cost-efficient measure aimed also at limiting the potential spillovers from strictly national non-market-based decisions;
- The importance of carrying out regional Generation Adequacy Assessment for the identification of adequacy issues and to target an efficient planning and usage of resources (existing and future interconnection and generation capacities);
- The adoption of principles of solidarity, mutual trust, and shared responsibility, including a list of measures which are accepted or not in crises to better define a joint coordination of national and regional measures;
- Predefined non-market-based measures such as load shedding or curtailment when managing the crisis;
- Definition of the relevant national and regional authorities and crisis coordinators needed for the flow of information during early warning and crisis declaration;
- Identification of potential crisis situations for the region and elaboration of a report describing the nature, likeliness, and possible cross-border impacts of these risks, with a comparison of national risk preparedness measures and definition of adequate national and regional mitigation measures also for crisis declaration and early warning systems;
- Exploring potential benefits of further coordination and/or information exchange among the Pentalateral countries.

Pentex 2018 set the basis of the discussion on the national emergency plans for the seven countries involved. Among other resolutions coming from this first exercise of regional crisis simulation, the parties agreed on using those plans as the basis of the regional emergency plan under the RPR. Most of the elements that are already part of this voluntary agreement are relevant for the establishment of regional agreements for mutual assistance under RPR. However, compliance with the Regulation and adherence to the EC's Recommendations would require the scope of this voluntary cooperation to be broader and include other elements. The RPR explicitly foresees that these include at least:

- the economic compensations for the provision of “assistance energy” in case of crisis;
- the categories of electricity users entitled to receive special protection against disconnection in each MS part of the agreement;
- the compensations – if any - to forcibly curtailed customers established at the national level;

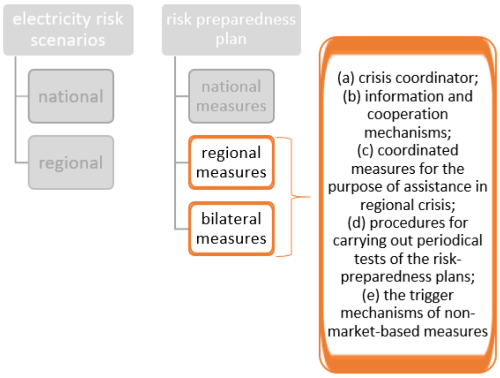
- the short-term adequacy assessment;
- agreements on periodical crisis simulation exercises;
- creation of legal rights and obligations under national or international law.

It should furthermore be noted that the legal form of the existing agreement, which is voluntary and based on a memorandum of understanding, does not comply with the RPR which specifically requires the establishment of legally binding rights and obligations on the parties for the provision or request of assistance in case of electricity crises. Agreements under memorandum of understanding should be complemented by national binding measures that ensure the application of the provisions of the memorandum of understanding.

3.2 Risk prevention and mitigation. Pre-established regional/bilateral measures

Article 12 of the RPR identifies the main elements of the regional and bilateral measures to be included in the risk preparedness plan (Figure 5).

Figure 5. Main elements of regional / bilateral measures to be included in the risk preparedness plans



Source: authors' elaboration

The first element is the designation of a **crisis coordinator** that can be a single person or a team composed of the relevant national electricity crisis managers (TSOs, the national regulatory authority and electricity undertakings) or an institution tasked with acting as a contact point. This body has the task of coordinating all technical aspects and operational measures during the early warning and declaration of crisis phases, and when assistance is applied (coordination across the relevant TSOs, NEMOs, DSOs, national emergency coordinators, competent authorities, and entities involved in delivering the electricity). The crisis coordinator is in charge of the implementation of the plan. In case the assistance is requested, the MS in need will activate the agreements set out in regional and bilateral agreements. A key element of the plan is the identification of the trigger mechanisms of non-market-based measures, to be activated in accordance with Article 14 and 16(2) of the RPR (this aspect is further analysed in section 3.4).

3.2.1 National measures relevant to regional arrangements (article 11 of the Risk Preparedness Regulation)

National measures should be based on national crisis scenarios – i.e. identification of the main triggers of an electricity crisis – and define tailor-made preventive measures. National measures should describe the contribution of market (demand-side response and other flexible capacity) and non-market-based measures for handling electricity crises. The Regulation recognises that national measures adopted to manage national electricity crises may have a cross-border impacts, and for this reason they should be duly taken into account also in the regional measures and agreements.

Box 5. Link between the National Energy and Climate Plans and the Risk Preparedness Plans.

Interestingly, among the initiatives undertaken at the national level with respect to electricity market integration, the national energy and climate plan (NECP) of Belgium identifies some "indicators of the urgency of action" to monitor the level of integration of the system, both for the infrastructure and the market:

- price differential in the wholesale market exceeding an indicative threshold of EUR 2/MWh between Member States, regions, or bidding zones;
- nominal transmission capacity of interconnectors below 30% of peak load;
- nominal transmission capacity of interconnectors below 30% of installed renewable generation.

3.2.1.1 Demand response

Among national market-based measures, demand side response plays a relevant role in providing flexibility to the system and in improving its reliability. Demand side response potential is present, in various degree, in all economic sectors (Table 11).

Table 11. Main processes and industrial sectors with some degree of DR potential

Residential	**Industrial**	**Commercial**
Air-conditioning	Paper machines	Air-conditioning
Washing machines	Non-metallic minerals	Ventilation
Tumble Dryers	Non-ferrous metals	Refrigeration
Dishwashers	Chemical and petrochemical	Storage water heater
Water heaters	Iron & steel	Storage heater
Refrigerators and freezers	Wood products	Wastewater treatment
Heating systems and electric boilers	Air Separation	Pumps in the water supply
Transport	Cement Mills	Cold storages
	Wastepaper processing	Transport

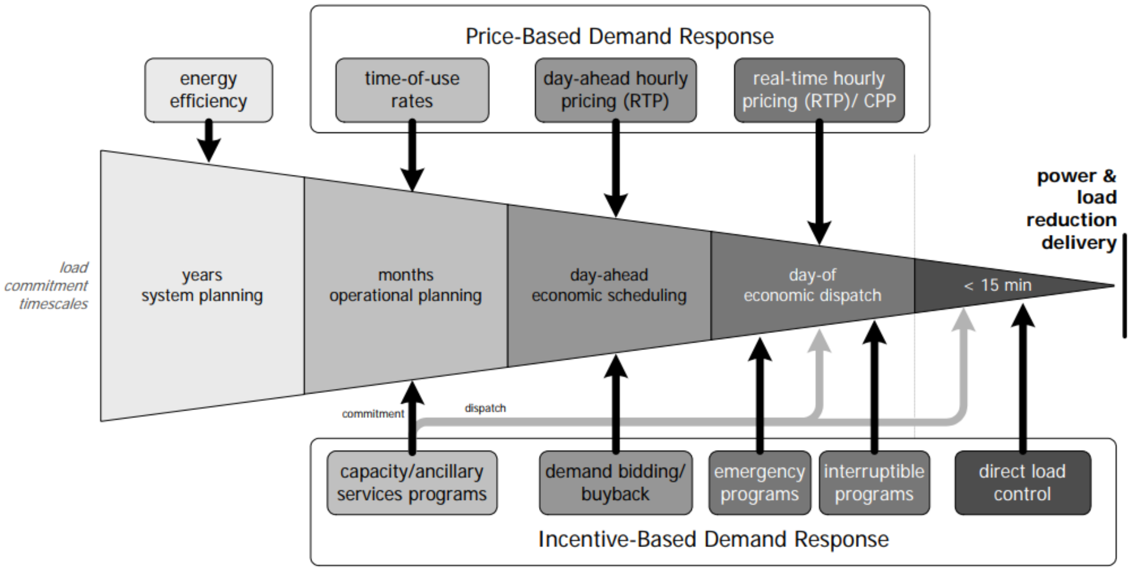
Source: (Dranka, G.G. and Ferreira, P.,, 2019)

The deployment and potential of demand side technologies among the European MSs ((Srivastava, 2018), (Gils, 2014), (Söder, 2018)) is diverse and their level of system integration varies MS by MS. (Dranka, G.G. and Ferreira, P.,, 2019) review different categories of demand response and assess their theoretical, technical, economic, and achievable potential, where "achievable" is to be interpreted as "realisable and socially acceptable". In this section we address the role of demand side technologies in energy security without the ambition to be exhaustive, given the fact that the level of adoption of those technologies in Europe is in continuous evolution.

Demand response can improve the reliability of the system operation in mitigating the intermittent effects of renewable energy resources. Some authors (Lynch, 2019) assess the role of demand response participation in capacity markets in mitigating fluctuating prices and market power, and rationalise the need for capacity investments in generation, transmission, and storage for system security. Moreover, (Aghaei, 2016) show the contribution of demand response to provide security in case of failure of generation units by helping system operators to schedule day-ahead generating units in a more reliable manner.

Demand response options can be deployed at all-time scales of electricity system management (Figure 6) *and can be coordinated with the pricing and commitment mechanisms appropriate for the timescale of their commitment or dispatch. For example, demand response programs designed to alert customers of load response opportunities on a day-ahead basis should be coordinated, for example, with a day-ahead market. Like generation resources, the actual delivery of customer load reductions occurs in real time* (DOE, 2006).

Figure 6. The multiple roles of demand response in the electricity system



Source: (Energy, 2005).

Reducing demand in response to system reliability problems enhances the operators' ability to manage the electric grid and reduces the potential for forced outages, cascading, or full-scale blackouts. Demand response also impacts the overall cost-efficiency and the adequacy of the system. Selectively curtailing service to customers that place lower values on loss of service, and voluntarily elect to participate in an emergency demand response program is less expensive, less disruptive and more efficient than forced curtailment. In the medium and long run, this leads to lower need for generation capacity build up serving peak demand that occurs on just a few hours per year.

Box 6. Importance of interruptible loads during stress situations

In the Continental Europe Synchronous Area Separation on 8 January 2021, the activation of 1.7 GW of interruptible loads in France and Italy which were disconnected according to their contractual duties show their effectiveness in the frequency stabilization in the North-West area immediately after the separation (ENTSO-E, 2021a).

On the other side, non-market-based measures such as forced demand disconnection, or the provision of extra supplies outside normal market functioning, should be activated only as a last resort, when all possibilities provided by the market have been exhausted, so to limit the market distortions and costs of state intervention (negative spillovers). The risk preparedness plan should specify the triggers, conditions, and procedures for their implementation. In this respect, the RPR states that the conditions for the activation of those measures should also be based on "the situation or opportunities coming from neighbouring counters", thus reinforcing the importance and benefits of regional cooperation also in the definition of purely national measures and procedures.

Also in case of a simultaneous electricity crisis, a "coordinated and pre-agreed approach [among MSs] would ensure a consistent response, reduce the risk of negative spillover effects" and avoid undue curtailment of cross-border flows and cross-zonal transmission capacities. Examples of pre-agreements come from two (voluntary) existing cooperation agreements, the PLEF and the North Sea cooperation framework, that foresee a number of coordinated national actions aimed at strengthening regional cooperation (see the agreement on non-market-based measures in crisis situations in The joint electricity crisis exercise of the Pentalateral energy forum (Pentex 2018)). Non-market-based measures shall also be mentioned (and agreed upon) in the regional agreements as part of the set of arrangements to be put in place for the prevention, preparation, and management of regional crises (see section Technical arrangements

Highlights on the role of electricity storage in outages preparedness and recovery[12]

- A microgrid system is a collection of controllable and physically close generators, consisting of power electronics equipment for system control and coordination, electricity storage (ES) (batteries but also supercapacitors and flywheels), and distributed generators (gas engine generators, renewable generators, fuel cells and combined heat and power systems) managed in careful collaboration with local loads. By relying on a variety of generators, a microgrid system avoids many of the single-point-of-failure issues of the traditional electricity grid. (IEC, 2014).
- Among storage technologies, supercapacitors are energy storage devices that can provide large amounts of power for very short periods of time, with a longer lifecycle in this application than traditional batteries. Flywheels are energy storage devices based on high-speed rotating mass and provide fast response. Being part of a micro grid system or as a standalone plant, ES technologies can contribute to resilience against large-scale electrical disasters, or to the recovery from these.
- According to the experience of the great east Japan earthquake in 2011, data centres - equipped with a range of back-up systems such as uninterruptible power supply (UPS) and generators - are considered to be one of the best examples of an industry with relatively mature plans for disaster preparation and recovery. For example, after the Great East Japan Earthquake, no critical damage to data centres was reported (IEC, 2014).
- To ensure a secure, reliable, and efficient electricity system, point (d) of Article 40(1) of Directive (EU) 2019/944 includes ancillary services provided by energy storage facilities - together with demand side management (DSM) services – among the available resources under the responsibility of the TSOs[13]. On the other side, the RPR mentions "any supply- or demand-side measure that deviates from market rules or commercial agreements […]" as non-market measures to mitigate an electricity crisis. The question now would be: are energy storage facilities to be included among the resources that can be used under the RPR? In general, this will depend on the storage national ownership rules and on the effects that the implementation of the recast Electricity Directive (2019/944) and Regulation (2019/943) will have on the implementation and transposition by national authorities of the European provisions on the design of energy and ancillary services markets as well as capacity mechanisms for the entry and participation of storage. This issue is rather relevant for countries where hydro resources are very important in the energy mix.
- The study on the contribution of energy storage to security of supply (Christopher Andrey (Artelys), 2019) reveals "*that in 2030 […] for the provision of daily flexibility, storage technologies such as batteries or pumped storage appear to be relevant solutions. Up to 97 GW of electricity storage (batteries and pumped hydro storage) would be necessary for the EU-27, with a large development of stationary batteries*". However, *"an optimal use of the flexibility of [demand-side response, i.e.] electric vehicles and of decentralised space heating could reduce the need for stationary batteries by half (67 GW vs 34 GW)".*
- From the assistance request point of view, the requesting MS - according to Section *2.2.2. Technical information in the early warning and declaration of crisis of the EC's Recommendations* - should inform other MSs - among other things - about the specific characteristics of its own system, included "*the state of the […] storage capacity*" as a resource that contributes to the security of the national system.
- From the assistance provision point of view - see section 1.1 of the EC's Recommendations - *"[…] the assistance mechanism includes an obligation for the other Member States* (who have the technical ability to provide assistance) *within the regional / bilateral agreement to cooperate in a spirit of solidarity to prevent and manage electricity crises.* The possibility of the helping MS of counting also on its own energy storage resources when assessing the ability to provide assistance to a MS in need in case of crisis depends on storage national ownership rules.
- The important aspects that are required to understand the applications of rapid responsive energy storage technologies for frequency regulation (FR) are modelling, planning (sizing and location of storage), and operation (control of storage) (Akram, 2020).

[12] We add here a separated paragraph on ES. The reason why we keep ES separated from DSM comes from the fact that in the electricity sector these two concepts are independent as their principle of functioning, constraints and regulations are different.

[13] *[…] the transmission system operator shall be responsible for ensuring a secure, reliable and efficient electricity system and, in that context, for ensuring the availability of all necessary ancillary services, including those provided by demand response and energy storage facilities, insofar as such availability is independent from any other transmission systems with which its system is interconnected.*

3.2.2 Regional measures (article 12 of the Risk Preparedness Regulation)

The regional measures cover all the five steps that configure a possible critical event, from the preventive measures, to the early warning and the crisis declaration until the request of assistance and the management of the crisis (Figure 7). According to the EC's Recommendations, the implementation and enforcement of regional and bilateral agreements should preferably be based on existing (adapted) national measures, laws, and practices.

Figure 7. Prevention, preparation for and management of critical event and corresponding relevant information

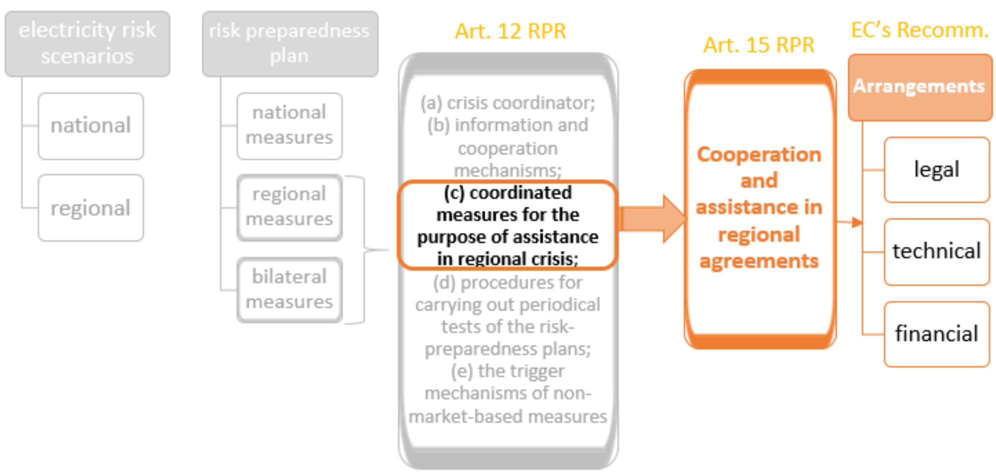
1-Measures to prevent and prepare for an electric crisis
2-Adequacy issues is detected, Causes of the crisis, Impacts on internal electricity market
3-Market-based measures are exhausted; activation of non-market measures
4-Non-market measures exhausted; imminent risk of disconnection of users entitled to received special protection ; assistance as cost-efficient option
5-Legal, technical and financial agreements (art. 15 RPR and EC's Recommendations)

Source: authors' elaboration

Among the relevant information to be included in the risk preparedness plan there are:

- clearly defined and pre-agreed procedures for the activation of cooperation, included preventing and mitigating measures;
- the mechanisms and procedures for the activation of the cooperation, included information flows and platforms for the information exchange;
- the possible causes of the imminent outage and its impacts;
- the activation mechanism of non-market measures once the market can no longer prevent a further deterioration of the outage.

Figure 8. Technical, legal and financial arrangements in case of request of assistance



Source: authors' elaboration

The risk preparedness plan shall also include the necessary technical, legal and financial arrangements for the management of a crisis in case of request of assistance. Those measures are defined in article 15 of the RPR and in the European commission's recommendations on technical, legal and financial arrangements between Member States for the application of the assistance mechanism (Figure 8).

The assistance can be requested when:

— Non-market measures are exhausted and there is an imminent risk of disconnection of users entitled to receive special protection against disconnection, and when assistance is the cost-efficient option.

— The management of the crisis will follow the legal, technical and financial arrangements pre-defined in the cooperation agreement (see section Regional cooperation agreements and provision of assistance).

The Regulation's objective is to facilitate cooperation among MSs to cope with a situation in which the potential risk of a significant electricity shortage or an impossibility to supply electricity to customers is present or imminent. Regional cooperation aims at exploiting the potential for more efficient and less costly measures for the prevention, preparation for, and management of electricity crises, in a context of interlinked electricity markets and systems. To this end, the Regulation established new tools and entities (see chapter Risk assessment. The combined tools of risk scenarios and adequacy assessment).

Box 7. Regional measures in the risk preparedness plans.

Regional agreements for mutual assistance in case of an electricity crisis that are voluntarily undertaken by each MS should build on the information provided by the regional crisis scenarios (article 8 ENTSO-E's methodology as approved by ACER (ACER, 2020a). The measures established in the risk preparedness plan when agreed in a regional agreement should be adequate to the cross-border dependencies and impacts showed in the regional crisis scenarios (artt. 7.2, 9.2, and 11 of the methodology). Those elements all together should provide the MSs that are part of the agreement with adequate information and tools to prevent, prepare for, and manage a risk of an imminent electricity crisis.

3.3 Risk management. From early warning to request of assistance

3.3.1 Early warning

The early warning to the Commission is issued in case the results of a seasonal adequacy assessment or other qualified source provider show a concrete, serious, and reliable information that an electricity crisis may occur in one MS.

The information flow in this case starts from the competent authority of the MS experiencing this potential adequacy issue warning the Commission, the competent authorities of the Member States within the same region or within directly connected regions.

The early warning communication shall include the following information:

— the causes of the possible electricity crisis,

— the measures planned or taken to prevent an electricity crisis;

— the possible need for assistance from other Member States, including:

- the theoretical maximum electricity quantities they may request, in terms of energy and power; the uncertainty around this quantities,
- the status and limit of cross-zonal capacity and the specific characteristics of the MS system, included the state of interconnectors if relevant (in case of outage), the level of hydro reservoirs and its expected evolution, storage capacity, demand-side response possibilities, possibility of fuel shortages etc.
- the possible period when assistance will be required
- the trigger for the assistance.

— the possible impacts of the measures on the internal electricity market.

Box 8. Early warning.

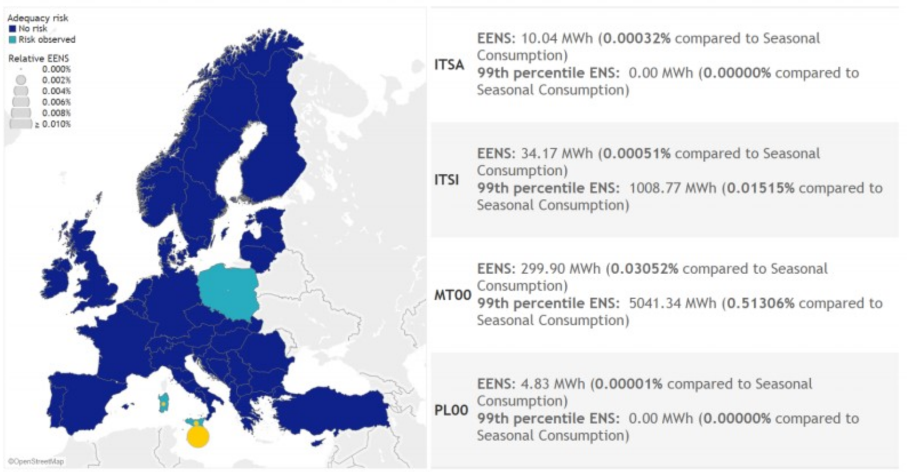
In the early warning to the European Commission, MSs experiencing a critical situation shall inform also about the estimated theoretical maximum shortage of electricity that may be caused by an imminent electricity crisis. This information is retrieved from the seasonal and short-term adequacy assessment that computes reliability indicators, like the expected energy non-served (EENS) expressed in GWh/target time frame, the loss of load expectation (LOLE), expressed in hours/target time frame, Loss of Load Probability (LOLP), the Relative EENS, and Adequacy Probability Metric (APM). The monitoring of the results of repeated adequacy assessments will provide improved information on the quantities that may be requested under the regional cooperation agreements for assistance.

Since 2009, ENTSO-E carries out winter and summer adequacy assessments to alert MSs and TSOs to risks related to the security of electricity supply that might occur in the following six months. ENSOE delegates Regional Security Coordinators (RSCs) to monitor adequacy closer to real-time. For Summer Outlook 2020 report, ENTSO-E implemented the new methodology for seasonal and short-term adequacy assessment (STSAA) required by the Clean energy for all Europeans package, and the Regulation on Risk Preparedness in the Electricity Sector (EU) 2019/941. The main improvement of this methodology compared to the previous one is the adoption of a probabilistic approach to the analysis of risk (see also Table 10 for an overview of the main elements of STSAA). Moreover, and this is the real novelty of this harmonised Pan-European methodology, moving from a seasonal to a short-term time frame (i.e. month-ahead or week-ahead) and the closer to real time forecast (up to at least day-ahead), the inputs on forecast are refined thus the uncertainty around stochastic variables is dramatically reduced. This is what emerges also from the conclusion to the 2020 summer report.

The report shows a rather favourable adequacy situation in all Europe. Adequacy concerns – the risk to rely on non-market measures – associated with some extreme scenarios (high unplanned outages combined with low renewable generation) are identified for Malta and other two islands of the Mediterranean Sea (Sicily and Sardinia) and in Poland (Figure 9).

The 2020-2021 Winter Outlook (ENTSO-E, 2020b) assess with some detail the risk related to the COVID pandemic that has introduced unprecedented uncertainty into the European power system on the demand, that is expected to decrease if pandemic grows, and on the slower maintenance works due to sanitary measures, hence decreasing available supply and network capacities.

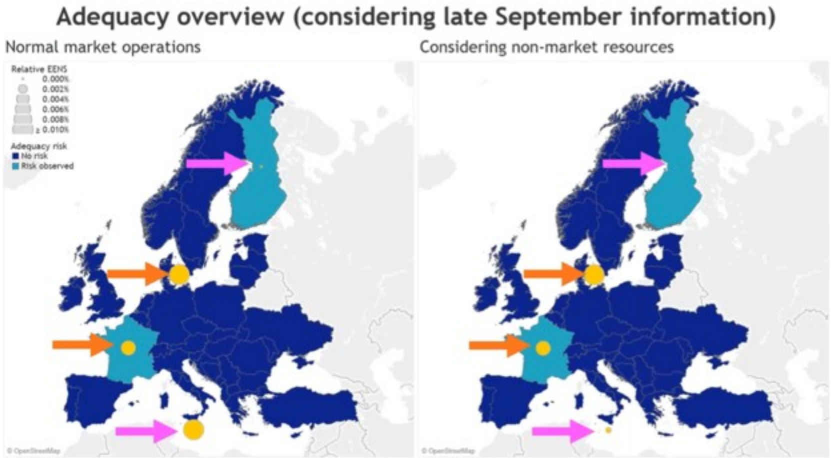
Figure 9. ENTSO-E adequacy risk overview in summer 2020



The map includes EU and non-EU countries that are simulated by EMTSO-E models.
Source: ENTSO-E 2020 summer outlook available at https://www.entsoe.eu/outlooks/seasonal/

Another interesting information is the estimated impact of non-market-based resources – i.e. strategic reserve and demand side response if activated by TSOs – managed by TSOs when adequacy issues arise (Figure 10).

Figure 10. ENTSO-E Winter Outlook 2020-2021 – adequacy assessment with normal market operation (left map) and with the utilisation of non-market-based resources (right map).



NB. As ENTSO-E pointed out during the presentation on 1st December 2020, some updates arrived after September 2020 slightly changed the results of the assessment. In particular, Energinet revised the outages in the network, which produced a decrease in the adequacy issue. The nuclear outages in France were also rescheduled and produced a decrease of the risk in November, but the risk remained for January and February 2021.

Source: ENTSO-E webinar, "Winter Outlook 2020/2021 Public Presentation" held on 01/12/2020

The figure shows how adequacy issues detected in two regions (Malta and Finland) decrease when TSOs deploy non-market-based resources. Those results do not allow for an assessment of the possible cross-border impacts of non-market-based measures adopted to prevent a further deterioration of the adequacy issue. Moreover, it would be interesting to know what is the avoided economic loss from a reduced ENS due to the implementation of those top-down actions by the TSOs and what is the difference of VOLL in the two Member States in the two situations.

Once a risk situation is identified in a seasonal time frame, STAA can be used to monitor the risks that are likely to result in a deterioration of the electricity supply situation with a closer time-frame (i.e. one month/week/day ahead). This approach is also reflected in the conclusions of ENTSO-E's 2020 summer outlook for the monitoring of the adequacy in Malta (MT00), which has highest Loss of Load Probability (LOLP) exceeding 5%. There the situation should have been monitored continuously throughout summer closer to particular weeks – especially in tighter supply situations.

Many actors participate to this monitoring activity. The RPR requires ENTSO-E to carry out short term adequacy assessments following the new methodology. The regional coordination centres (RCCs) and TSOs shall carry out week-ahead to at least day ahead adequacy assessments in accordance with Regulation (EU) 2017/1485 on the basis of the same methodology (Figure 11). This risk analysis should support the relevant authorities on the timely detection of possible electricity crisis, assessment of the causes, the plans in place for prevention and mitigation (i.e., for instance, maintenance planning) and the available options for assistance.

"Explanatory note on STSAA" ENTSO-E[14]

Short-term adequacy assessments, namely week-ahead to at least day-ahead, refine the inputs based on forecasts, thus dramatically reducing the uncertainty of seasonal adequacy assessments. Those assessments can include ad-hoc regional studies with detailed network models to validate risks and evaluate counter-

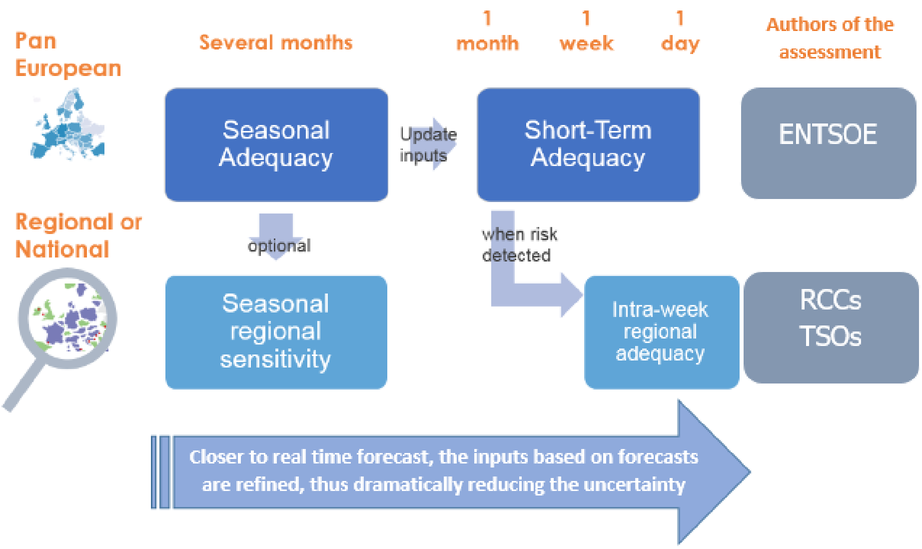
[14] ENTSOE 2020. Short-term and Seasonal Adequacy Assessments Methodology. Explanatory note page 4

measures to mitigate adequacy problems detected in the pan-European phase of the assessment. This provides insight into the circumstances and contingencies under which risks would be credible. Furthermore, TSOs can trigger a regional assessment when internal congestions can be anticipated, even if no risk is detected.

Very often in month-ahead adequacy assessments, information does not change significantly compared with the seasonal adequacy assessment. Therefore, the latest seasonal adequacy assessment already covers the risks of most possible resource availability changes. Furthermore, the uncertainty of the month–ahead study compared with the seasonal adequacy assessment does not decrease as is the case with week-ahead adequacy assessments.

On the other hand, in some rare occasions, a significant change of resource availability might occur. An example of such a change could be an extension of the planned outage of a big generation unit or of an interconnection which will prevent this unit to come back to operation. Such a significant change of resource availability may have an impact on adequacy in a timeframe larger than the week-ahead timeframe. Therefore, month-ahead adequacy assessments might be performed if TSO estimate that the situation has changed significantly compared to the seasonal adequacy assessment and if TSOs estimate this impact to go beyond the week-ahead horizon.

Figure 11. The combined use of seasonal and short-term adequacy assessments



Source: Own adaptation on ENTSO-E 6/1/2020. Short-term and Seasonal Adequacy Assessments Methodology–Explanatory note (page 4).

Box 9. Coordination of RCCs in the regional risk and adequacy assessments

To ensure that all possible risks of supply shortage are adequately addressed, the regional scope of the risk assessment should take into account the regional scope of the regional crisis scenarios developed by ENTSO-E, following the provision of art. 5 of the RPR. This aspect is also mentioned in art 81.4 of the SO guideline stating "When performing a regional adequacy assessment, each regional security coordinator shall coordinate with other regional security coordinators". When a regional crisis impacts countries that belong to different RSCs, these all together shall coordinate among them to assess correctly the risks. When the technical ability to provide assistance is present among those MSs belonging to different RSCs/RCCs a regional agreement would set the basis for a prompt, effective and efficient response to the risk of crisis.

3.3.2 Electricity crisis declaration

When confronted with an electricity crisis, the competent authority of the MS in crisis shall consult with the TSO concerned on the decision to declare an electricity crisis and inform the competent authorities of the Member States within the same region or of directly connected Member States, as well as the Commission.

With the crisis declaration, the MS in crisis should provide the following information:

- The causes of the deterioration of the electricity supply situation.
- The reasons for declaring an electricity crisis.
- The measures planned or taken to mitigate the crisis.
- Measures can be market-based or non-market-based, and they shall not alter the level of competition. In case market-based measures alone are not sufficient to prevent a further deterioration of the electricity supply situation, non-market-based measures shall be activated and shall be necessary, proportionate, non-discriminatory, and temporary.
- The need for any assistance from other Member States. In case the assistance mechanism is triggered, the coordinated measures - legal, technical, and financial arrangements - set out in the risk preparedness plan will rule the assistance (see section "2.3.2 Regional cooperation agreements and provision of assistance").

3.4 Regional cooperation agreements and provision of assistance

In the RPR, MSs shall act and cooperate in a spirit of *solidarity* to prevent or manage electricity crises. The main elements of the regional cooperation are:

- the parties: MSs that have the necessary technical ability to offer each other assistance;
- the form: pre-agreed legally binding regional or bilateral measures;
- the final goal: protecting public safety and personal security.

The RPR does not set binding rules on the implementation of the regional / bilateral cooperation arrangements for the provision of assistance, and leaves Member States the freedom to define the key elements (legal, technical, and financial) that should be included in the regional agreements. The EC's Recommendations provides guidance on how to implement the assistance and cooperation prescription of Article 15 of Regulation (EU) 2019/941 with the aim to provide certainty and security to all the parties involved in making the assistance mechanism work. The assistance agreed by the assisting MS is limited to specific conditions, such as:

- the maximum available cross-zonal capacity of the providing MS;
- the amount of electricity necessary for the purpose of protecting the public safety and personal security of the citizens in the providing MS;
- the operational security of the providing MS's electricity network.

These agreements shall define:

- The legally binding rights and obligations of the parties. According to the EC's Recommendations (section 2.1.6), to establish such agreements, any pre-agreed legally binding regional or bilateral measures or existing regional (i.e. voluntary – therefore not internationally legally binding) arrangements (i.e. included MoUs) can be used if national binding measures are defined in a way that make the existing arrangements enforceable at national level. This might include existing regional or bilateral treaty provisions, contractual arrangements between TSOs, or specific licensing conditions for electricity entities, provided they are overseen by the relevant competent authorities (paragraph 2.1.6 of EC Recommendations). Different provisions in electricity can be used as a basis and can be considered as a starting point to ease the discussions among the parties of the agreement. MSs may want to refer to contractual arrangements already in place between the national TSO and the neighbouring TSOs. Non-binding legal instruments alone (such as a memorandum of understanding) would not be sufficient for the implementation of Article 15(6);

— The trigger for the suspension of market measures. In this regard, a starting point should be to consider ENTSO-E report assessing the level of harmonisation of the rules for suspension and restoration of market activities (ENTSO-E, 2020d); and assess the areas identified in that report that could benefit from harmonisation.

— The triggers of the assistance;

— The categories of users entitled to receive special protection against disconnection in each MS;

— The Willingness To Pay (WTP) of users entitled to receive special protection against disconnection (an optional element), which may be used as a benchmark value to be compared with the costs of the assistance to finally determine if the assistance is the cost-efficient solution to the crisis;

— The compensation for the assistance, included the methodology to calculate it;

— The value of lost load of forcibly curtailed costumers that can be used to determine the compensation if this is foreseen by national rules, and if there is no further adequate information that can be retrieved from the market to assess this compensation.

3.4.1 Legal arrangements

Legal arrangements should be clear, transparent and effective so that stakeholders know the rules and procedures for cross-border assistance and should provide a minimum information on:

— requesting MS, TSO, and NEMO, and corresponding entity in charge and contact person(s);

— expected deficit in terms of energy and power, duration of this gap, and the (scope/geographic area) extent of the crisis;

— the preferable interconnector or delivery points, where relevant (for example, for mobile generators);

- for some particular technical tools (request to reactivate mothballed power plants, transfer of mobile generators, activation of strategic reserves, etc.), a request to indicate the timing of the first possible delivery and the anticipated duration of the provision of supplies (indicating the anticipated period during which the assisting Member State will provide assistance),
- a reference to pay compensation for assistance.

The possible triggering events to request assistance should be specified in each risk scenario and can be distinguished between:

— operational (loss of controllability, lack of balance between generation and demand, lack of reserves or inability to supply electricity due to physical damage to parts of the systems);

— non-operational (external security threats).

Moreover, the **conditions for triggering assistance** should be:

— All national market measures are exhausted or insufficient to offer the electricity necessary to protect public safety and personal security;

— All national measures in the requesting Member State's risk-preparedness plan are exhausted (this includes the pre-agreed non-market measures, included those that can have a cross-border impact).

— In relation to any existing or imminent situation, *non-market measures* (with a cross-border impact) *are expected to be necessary to avoid or minimise impacts of the electricity crisis*[15] (section 2.1.4 of the EC's Recommendations).

— In relation to an existing or imminent situation in which a MS cannot ensure protection against disconnection for the categories of electricity users defined by national laws, or for the purpose of

[15] Non-market measures that have a cross-border impact should be agreed beforehand to avoid inefficiencies and spillover in the system (see section National measures relevant to regional arrangements (article 11 of the Risk Preparedness Regulation).

protecting public safety and personal security, in case the MS has not defined this special category of users.

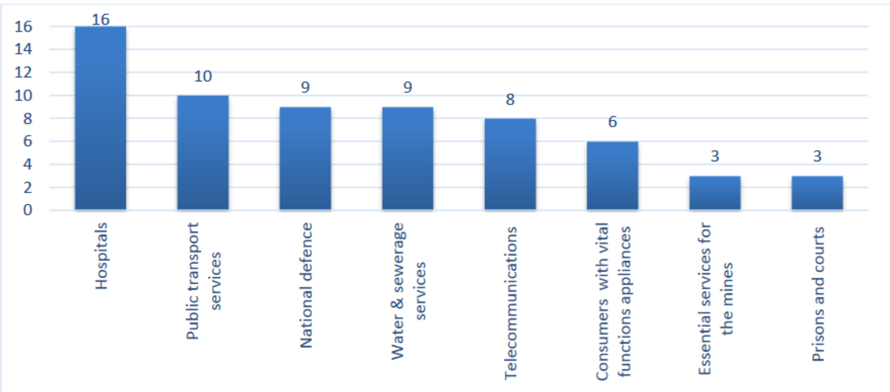
Differences across MSs in the implementation of national rules, like market and non-market measures, or in the definition of categories of electricity users entitled to receive special protection can play a decisive role in defining the moment/condition in which the assistance is triggered. To avoid that those differences benefit one MS on the expenses of the other parties of the agreement, the triggering events and conditions for the assistance need to be agreed upfront in legally binding regional agreements.

Within the framework of the public safety and personal security, each Member States should establish special measures to ensure continuity of power supply in light of:

— national, regional or local critical need
— public health and safety issues
— the potential for catastrophic damage or a high risk of significant safety issues (due for example to environmental risks)
— potential exposure to security threats
— technical capabilities for selective disconnections (EC's Recommendations 2.13).

In this respect MSs are allowed to specify in the risk preparedness plan the categories of users entitled, according to national law, to receive special protection against disconnection in relation also to the duration and scope of the possible electricity crisis, as the list of this category of users may vary according to those parameters. A categorisation of consumers' categories in 16 Member States is provided in Figure 12. Note that the users entitled to receive special protection against disconnection can be consumers but also critical energy facilities. Note that the RPR does not impose an obligation on the MSs to define those category of users. However, these definitions are relevant with respect to the triggering event for assistance, as we have seen above, but also with respect to the decision on whether to call for assistance (see the discussion about value of lost load (VoLL) and willingness to pay (WTP) in Financial arrangements).

Figure 12. Protected customers categories in 16 MSs. On the vertical axis it is represented the number of Member States that adopt each protected costumers' category



Source: (European Commission, 2016)

3.4.2 Technical arrangements

Despite the fact that the RPR distinguishes between MSs having or lacking the technical ability to provide assistance (recital 16 and articles 2(17), 12(1), and 15(2) of the RPR), the EC's Recommendations further specify this aspect. Some technical constraints impairing ability to provide assistance may or may not vary with time or other factors. By way of example, some technical solutions and arrangements can be made for some parts of the infrastructure in a given Member State, but not for others, depending on the related technical constraints. In addition, the costs of the assistance may be so high in the providing MS that the MS in need may decide not to ask for assistance. This case can happen when VoLL under critical conditions is exceeded. Finally, electricity crises may be very different, so that the same MS may be able to provide assistance in some cases but not in all of them, considering also its own limitations for offering assistance.

For the assistance mechanism to work in practice, the parties of the agreements should define some minimum technical provisions and conditions on:

— the technical capability and constraints of the relevant electricity infrastructure

— the maximum theoretical amount of electricity relevant for assistance

— an assessment of the technical constraints that would make assistance difficult, included the limitations inherent to the MS providing assistance (section 2.2.5.1 letters (b) and (c)) of the EC's Recommendations)

— the mutually acceptable solutions to be applied in order to secure the necessary cross-zonal capacity if the assistance mechanism is triggered.

Box 10. Coordinated capacity calculation during a crisis situation

During the critical grid situation in January 2017, there were extraordinary coordinated capacity calculation processes (from D-2 to intraday) between RTE and REE to guarantee the maximum exchange capacity between both Spain and France (ENTSO-E, 2017).

Operational technical solutions:

Operational cooperation is a very useful tool in the recovery phase of a crisis when the crisis has implied a physical damage to some parts of the system. Some examples of technical cooperation are:

— Support with repair crews and other technical personnel or equipment. For example, technical support with personnel and equipment (drones, helicopters) for a rapid assessment of the damage in the electrical infrastructure and the accessibility of the specific sites with damaged equipment (after earthquakes or flooding, it is usual that roads have been also damaged by the natural event

— Support with mobile generators or small mobile transformers to restore critical loads.

— Support with spare parts for repair.

Another activity where operational cooperation is interesting is in the *ex-post analysis of the crisis*. For example, cyberattacks will probably need very high qualified and experienced specialists.

Box 11. Example of operational support: 4.2.3 Explosion in Cyprus, 2011

On 11 July 2011, a series of explosions at the Evangelos Florakis naval base on the south coast of Cyprus caused 13 deaths and 65 injured along with extensive material damage. In particular, it severely impaired and put out of service the Vasilikos power plant, which contributes 50% of Cypriot power generation capacity and 60% of energy production. The severe reduction in generating capacity resulted in power outages and curtailments, as the electricity authority was no longer able to meet peak summer demand. The damage to the plant also disrupted the drinking water supply, as desalination plants had their power cut.

On 13 July, following the damage at the plant and the related power shortages, Cyprus made a request for assistance through the EU Civil Protection Mechanism. The request explained that Cyprus urgently needed high-capacity generators in order to boost power production and power desalination plants. In addition, Cyprus requested expert assistance in the fields of damage assessment and repair for the Vasilikos plant, as well as for health and safety issues. Several Participating States offered generation capacity to the Cypriot electricity authority. Cyprus accepted the Greek offer of generators able to provide 70 MW of electric power as the one which best fitted their needs. Rapid transport of assistance resources was facilitated through EU co-financing. A multinational EU civil protection team composed of experts from eight participating Member States assisted the Cypriot authorities in managing the situation providing technical expertise, including in the areas of damage assessment and restoration, health and safety, and structural engineering.

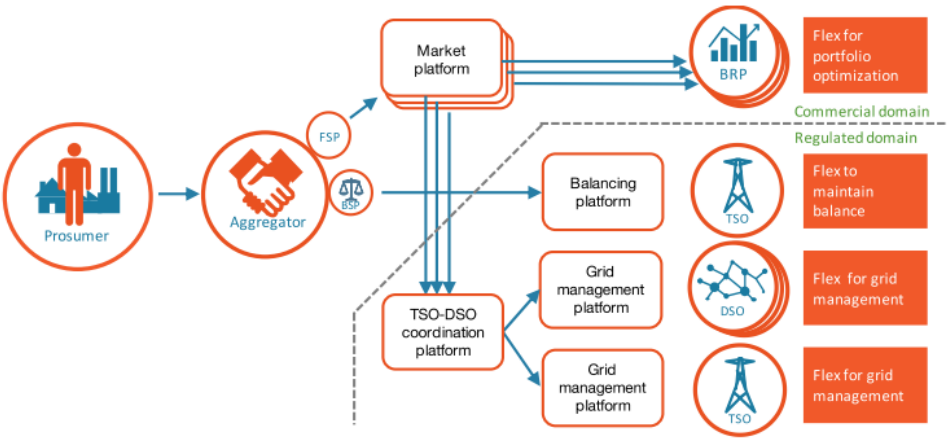
Market-based technical solutions:

The Regulation advocates the use of market-based measures, to the furthest possible extent, to solve electricity supply issues in relation to an existing or imminent crisis. In this respect, the Regulation proposes a number of options that would strengthen and prolong the use of market measures to alleviate or delay as much as possible a crisis:

- The development of coordinated mechanisms or platforms that allow for voluntary demand-side response sharing and the sharing of other flexible capacity. Several market players in Europe are currently developing flexibility market platforms. Some examples come from the power exchanges that develop those platforms with their customers that can provide flexibility. Some examples in Europe16 are EPEX SPOT local flexibility market launching the "enera project" for improving energy infrastructure resilience, cost efficiency of the grid and renewable integration through innovative business models. The electricity trading platform Amsterdam (ETPA) that is currently developing the IDCONS platform a Dutch DSO and TSO initiative for buying congestion products in a coordinated way. NODES is an Independent Market Operator providing a marketplace for local flexibility for DSO or TSO grid or for a balance responsible party (BRP) that needs to rebalance its portfolio.

The new regulatory framework brought about the clean energy for all Europeans package (CEP) is the driver of this transformation, opening up opportunities to a wider spread used of market-based instruments in the power system, like a supported role for Demand Response and aggregation, new requirements for TSO/DSO coordination, market-based redispatch, flexible assets to be owned by market participants. Organised power markets set up new opportunities for TSOs/DSOs operation and coordination (balancing and grid management platforms). Market operators, energy traders / suppliers, aggregators and private citizens organised in energy communities can have a new role as owners and managers of platforms offering their (large) customers direct access to futures and spot markets without the need to become a balance responsible party (BRP). Market facilitation platform (i.e. data exchange / data hub) can contribute by easing the access to information. Several proposals for flexibility markets have assumed aggregators fully interacting with the electricity markets and DSOs contracting services with power system actors (Figure 13). These interactions are still not allowed in many European countries, and several research papers analyse the European regulation to identify the most important enablers that may pave the way towards the full exploitation of distributed energy resources for flexibility, culminating in the establishment of (local) flexibility markets (Minniti, Haque, Nguyen, & Pemen, 2018), and (Radecke, Hefele, & Hirth, 2019).

Figure 13. Market platform as gateway to ancillary services



Source. USEF 2019. White paper. Flexibility platforms

Taking a closer look at the specific case of the balancing market, the proposals for new forms of (voluntary) markets for redispatch have been analysed under various perspectives. Balancing market platforms designed

[16] https://www.usef.energy/app/uploads/2018/11/USEF-White-Paper-Flexibility-Platforms-version-1.0_Nov2018.pdf

according to historical national specificities (generation portfolios, significant presence of internal congestions and level of interconnections with foreign markets) can significantly differ from one country to another (ENTSO-E, 2016). The wide variety of designs within a single EU Internal Electricity Market is perceived as an important barrier for their integration and the cause of unnecessary complexities for cross-border trade. Regulation (EU) 2017/21952 (Electricity Balancing Network Code – EB NC) establishes an EU-wide standardised set of technical, operational, and market rules to govern the functioning of electricity balancing markets in order to ensure an optimal management and coordinated operation of the European electricity transmission system (European Commission, 2017e). The EB NC is applicable to TSOs, DSOs, balancing responsible parties (BRPs), and balancing service providers (BSPs).
As a step towards a harmonised European electricity balancing market and based on the EB NC, TSOs are required to implement four European platforms for the exchange of balancing energy from:

- ✓ Replacement Reserves (RR);
- ✓ Frequency Restoration Reserves with manual activation (mFRR);
- ✓ from Frequency Restoration Reserves with automatic activation (aFRR);
- ✓ Imbalance Netting (IN).

To achieve the implementation of these four platforms required by the EB NC, European TSOs have established the following implementation projects:

— the Trans-European Replacement Reserves Exchange (TERRE) is the lead project on the design and implementation of the RR platform

— the Manually Activated Reserves Initiative (MARI) is the lead project on the design and implementation of the of the mFRR platform

— the Platform for the International Coordination of Automated Frequency Restoration and Stable System Operation (PICASSO) is the lead project on design and implementation of the aFRR platform.

— the International Grid Control Cooperation (IGCC) is the lead project on the design and implementation of the IN platform.

Table 12. Status submission of the methodologies for market-based allocation and allocation of cross-zonal capacity for the exchange of balancing capacity based on economic efficiency analysis by each CCR

CCR	Market-based* article 41 of the EB regulation	Inverted Market-based* article 41 of the EB regulation	Economic efficiency analysis article 42 of the EB regulation
Nordic	Y	N	N
Hansa	Y	N	N
Core	Y	N	Y
Italy North	Y	Y	Y
Greece-Italy	Y	Y	Y
South-West Europe	N	N	N
Channel	N	N	N
Baltic	Y	N	N
Ireland and the UK	N/A	N	N/A
South-East Europe	N	N	N

Source: ENTSO-E 2020 Balancing report (last update 19/12/2019)

In addition to these, the Frequency Containment Reserves exchange platform (FCR cooperation) is also being voluntarily implemented across Europe by a certain number of countries and TSOs (ENTSO-E, 2020c).

- **Unlimited wholesale prices fluctuation** in accordance with supply and demand, as long as the operation of the electricity markets does not cause further deterioration of the electricity crisis[17], is a widely agreed measure for improving market price signals. Strictly associated to this is the case of renewable generation, whose supporting scheme is slowly changing in many MSs. For example, in Germany all new contracts for RES generation do not enjoy feed-in tariff/premium payments when electricity market prices are negative for 6 consecutive hours, thus reducing the extra benefit previously enjoyed coming from a negative price and a still paid subsidy[18].
- **Imbalance settlement prices after a crisis** should reflect the cost to consumers of any disconnections to supply. This prevents implicit price caps in the balancing rules acting as a disincentive for investments in flexible and reliable capacity that can help avoid electricity crises;
- **Cross-border access to infrastructure should be maintained for as long as is technically and safely possible** in accordance with Regulation (EU) 2019/943. Depending on the technical constraints in each Member State, arrangements should ensure that **cross-zonal capacity** and demand-side offers, where appropriate, are fully accessible to market players across the border. This will delay the need to curtail electricity users in the Member State facing supply difficulties. The EB NC (Article 38) prescribes TSOs to define the allocation process of cross-zonal capacity (CZC) for the **exchange of balancing capacity** or **sharing of reserves** through the establishment of cooperation between two or more TSOs. The TSOs have defined the allocation methodologies based on three processes: co-optimised allocation (article 40 of the ER) defined by all TSOs, and market-based allocation (ENTSO-E, 2019a) and allocation based on economic efficiency analysis (articles 41 and 42 of the ER, (ENTSO-E, 2019b)) that are voluntarily developed by every CCR.
- Effective cooperation among MSs already from the **early stages of the electricity crisis**.

The reference documents for market-based solutions are:

- The system operation guidelines Commission Regulation (EU) 2017/1485) (i.e. points 2, 3, and 4 of article 18 ruling alert, emergency, and blackout states of the transmission system, points 2 and 3 of article 52 ruling the case of load curtailment).
- The network code on emergency and restoration[19] Commission Regulation (EU) 2017/2196 that must be followed in the event of emergency, blackout, and restoration states.
- The guideline on electricity balancing (Regulation (EU) 2017/21952). A coordinated deployment of reserves is envisaged in article 5.3 (b) and (o) of the EB Regulation that foresees for the geographical area concerning two or more TSOs exchanging or mutually willing to exchange balancing capacity, the establishment of common and harmonised rules and process for the exchange and procurement of balancing capacity pursuant to Article 33(1). In this respect, agreements between TSOs for exchanging reserves are already in place between Load Frequency Control blocks. Some examples can be found in the annual report on balancing published by ENTSOS (ENTSO-E, 2020c).

An indicative and non-exhaustive list of technical solutions[20] that can be described in the technical arrangements may include:

— Preventive arrangements (i.e. development of re-dispatching products for extreme events or modification of the duration of a planned outage or contracts for additional generation under specific conditions).

— Arrangements just before the crisis when there is evidence that the crisis could happen (in the preparation phase).

— Arrangements during the disruption to limit or shorten the effects of the crisis.

[17] See Rules related to price caps and technical bidding limits as set out in Article 10 of Regulation (EU) 2019/943.
[18] https://energypedia.info/wiki/Feed-in_Premiums_(FIP)
[19] ACER intends to issue reports on the implementation of the Regulation (the first is expected in 2021). https://acer.europa.eu/en/Electricity/OPERATION-CODES/Pages/Monitoring.aspx
[20] Each technical solution should provide the following information: Capability (GWh/week), whether or not it has already been verified in practice, start-up time from decision to effect, potential duration, entity responsible for each measurement, dependency on other measures, side effects, and any other remarks.

Box 12. Example of measures during the winter 2018-2019 in Belgium

The delay of some nuclear power plants to be online after a prolonged maintenance produced an estimation of a lack of available generation resources in the Belgian bidding zone for the winter 2018-2019. After several national measures (re-entry into the market of strategic reserves, increase of the rated capacity of gas generators, revision of maintenance planning , emergency generators and DSM), Elia estimated a remained gap of 700-900 MW, launching an early warning to request structural imports need. The Pentalateral Energy Forum launched a standing group on Electricity scarcity. The initial assessment was that under normal conditions there would be enough production capacity in the region to fill the gap in Belgium although there were doubts about the adequate transmission capacity to ensure the imports to Belgium. Some regional measures were launched to overcome this constrain:

- ensure an optimal day-ahead flow-based market coupling;
- seasonal thermal limits of key power lines. Currently, Elia is using Dynamic line Rating to optimise the capacity of transmission lines;
- regional coordination (through CORESO) on PST taps;
- optimization of intraday capacity calculation process;
- coordinated short-term adequacy and critical grid situation process at the Regional Security Center (CORESO).

Non-market technical solutions

The risk preparedness plan shall include information on the trigger for the activation of non-market-based measures in each MS. According to article 16 of the RPR, non-market technical solutions can be distinguished between:

Transaction curtailment

— Transaction curtailment including curtailment of already allocated cross-zonal capacity via forward capacity allocation for long-term transmission rights. Long-term cross- zonal capacity curtailment rules are established in title 9 of the harmonised allocation rules (ACER, 2019). They are allowed in a coordinated manner following liaison with all directly concerned TSOs, in the event of *force majeure* or in an emergency situation where the TSO must act in an expeditious manner and re-dispatching and countertrading[21] are not possible.

— Limitation of provision of cross-zonal capacity for capacity allocation (Article 16.2 and 16.3 of the Electricity Regulation (EU, 2019d) and the rules adopted to implement that provision (see (ACER, 2020d)) and Emergency and Restoration network code (European Commission, 2017c), or limitation of provision of schedules (System Operation guideline, (European Commission, 2017b)) after the outcome of the day-ahead or intra-day markets is known.

— In exceptional cases where cross-zonal capacity has been offered to the market but has remained unused, TSOs should be entitled to utilise that capacity.

Market suspension

The market operation can be suspended only for reasons listed in Article 35-36 of Regulation (EU) 2017/2196 establishing a network code on emergency and restoration (European Commission, 2017c).

A TSO may temporarily suspend one or more market activities laid down in paragraph 2 where: (a) the transmission system of the TSO is in blackout state; or (b) the TSO has exhausted all options provided by the market and the continuation of market activities under the emergency state would deteriorate one or more of the conditions referred to in Article 18(3) of Regulation (EU) 2017/1485; or (c) the continuation of market activities would decrease significantly the effectiveness of the restoration process to the normal or alert

[21] Common methodologies for coordinated redispatching and countertrading: status by June 2020. All methodologies have been approved by relevant regulatory authorities in all regions but the CCR Core. https://acer.europa.eu/en/Electricity/MARKET-CODES/CAPACITY-ALLOCATION-AND-CONGESTION-MANAGEMENT/IMPLEMENTATION/Pages/REDISPATCHING-AND-COUNTERTRADING.aspx

state; or (d) tools and communication means necessary for the TSOs to facilitate market activities are not available.

- the following market activities may be suspended pursuant to paragraph 1:
- the provision of cross zonal capacity for capacity allocation on the corresponding bidding zone borders for each market time unit, where it is expected that the transmission system shall not be restored to the normal or alert state;
- the submission by a balancing service provider of balancing capacity and balancing energy bids;
- the provision by a balance responsible party of a balanced position at the end of the day-ahead timeframe, if required by the terms and conditions related to balancing;
- the provision of modifications of the position of balance responsible parties;
- the provision of schedules referred to in Article 111(1) and (2) of Regulation (EU) 2017/1485 and,
- other relevant market activities, the suspension of which is deemed necessary to preserve and/or restore the system.

Article 6 of the national implementation of the network code on emergency and restoration (Regulation 2017/2196) establishes that "each TSO shall ensure the consistency [of the national system defence and restoration plans] with the corresponding measure in the plans of TSOs within its synchronous area and in the plans of neighbouring TSOs belonging to another synchronous area [...] or with TSOs not bound to this regulation".

ENTSO-E has published in December 2020 a report assessing the level of harmonisation of the rules for suspension and restoration of market activities (ENTSO-E, 2020d); where ENTSO-E reports the areas identified that could benefit from harmonisation. It is desirable that regions work on these areas to avoid undesired effects in neighbouring countries in case of market suspension in one Member State.

3.4.3 Financial arrangements

The importance of defining a fair and adequate cost of the assistance provided by the helping MS is at the basis of the correct functioning of the assistance mechanism.

As a general principle, to avoid the misuse of the assistance measure, the financial arrangements should not introduce perverse incentives, which could themselves trigger the need for assistance. For example, if the cost of assistance is "too low", this incentivises undersupply of domestic security of supply (SoS), so to increase the odds of actually fulfilling those very conditions (moral hazard). At the same time, section 2.1.4 of the Recommendations states that "the risk of misuse of the assistance mechanism by an unjustified assistance request is very small because of the strict conditions that must be fulfilled before the assistance mechanism is triggered". However, "when assistance is provided across borders, [...] compensation for assistance is obligatory" (sections 2.3. "Financial arrangements" of the EC's recommendations), and it is supposed to cover no more than the total costs actually incurred, consisting in the cost of energy and the adequately assessed share of fixed costs borne by the providing MS[22].

A number of elements need to be taken into account when defining the cost of the assistance.

Price of the kWh of electricity provided under assistance, as determined:

- on the last balancing market or intra-day market session,
- or the costs associated to administrative pricing/forced curtailment (if the MS providing assistance will curtail some of their customers),

[22] There are cases where the premium covers the 'insurance value' of the freed-up electricity.

— or alternatively the price of the last known electricity trade where a premium may be considered in order to fill the gap – if such a gap exists – between the last known price and the curtailed customers' value of lost load (VoLL)[23] (see also Annex 4 for a numerical example of the calculation of VoLL);

— or the price of call options sold in the derivative markets.

ACER monitors the implementations of common methodologies for redispatching and countertrading cost sharing. The status of the implementation by June 2020 shows that all methodologies have been approved by relevant regulatory authorities in all regions but the CCRs Core, Italy North, and SEE[24].

When available balancing products are purely national, therefore not accessible by requesting MSs, or in case of unavailability of any balancing product in the market (as in case of simultaneous crises), or when the balancing price is not available, a methodology for calculating the reference price would be needed.

Article 59 of the harmonised allocation rules[25] for long-term transmission rights establishes how transaction curtailment including curtailment of already allocated cross-zonal capacity via forward capacity allocation for long-term transmission rights must be compensated (or article 72 of Regulation 2015/1222 establishing a guideline on capacity allocation and congestion management)).

Administrative shortage pricing

The objective of scarcity pricing is to increase energy prices above the marginal cost of the marginal unit under conditions where the system is short on generation capacity. Regulation (EB) 2017/2195 article 44.3 requests TSOs to introduce a shortage pricing function in the settlement mechanism. The objective is to reach an effective scarcity pricing to encourage market participants to react to market signals and to be available when market most needs them. This idea is further highlighted under the Electricity Market Regulation article 20 where it is stated that the implementation plan for market reforms should contain the introduction of this shortage pricing function.

Box 13. Example of administrative-shortage pricing

— In 2016 Elia (the Belgium TSO) launched a study on the design of a scarcity pricing mechanism for remuneration of reserve in scarcity situation and on the desirability of this scarcity pricing implementation for Belgium[26]. The scarcity price-adders shown in the study are calculated according to the model conceptualised in the CREG/UCL study (Papavasiliou A., 2019) (cf. chapter 7. Implementation) that - under specific assumptions - assesses the risk of scarcity and assigns a value to these moments that is linked to the loss of load probability and the VoLL.

— The scarcity price adders is calculated according to this formula:

scarcity price-adder = (VoLL - real-time energy price) * LoLP

where:

— VoLL (Value of Lost Load) is a fixed input parameter, set at €8300/MWh.

— The real-time energy price is approximated by the MIP (Marginal Incremental Price) (cf. Imbalance Prices).

— The LoLP (Loss of Load Probability) is to be interpreted as the probability of incurring loss of load, estimated based on the distribution of historical system imbalances (cf. System imbalance, SI), taking into account the remaining capacity after resources have been activated to clear the imbalance of the present interval (cf. Available Remaining Margin, ARM).

— It is interesting to notice that since October 2019 Elia publishes ex-post scarcity prices one day after operations based on the Available Reserve capacity during the previous day.

[23] If the compensation to forcibly curtailed customers is based on VoLL of the assisting country, those amounts paid in an emergency may differ across countries. According to the results of the study by (Shivakumar, et al, 2017), VoLL is a country-specific value.

[24] Visit ACER web site on redispatching and countertrading here.

[25] See Acer's decision on Harmonised allocation rules for long-term transmission rights in accordance with Article 51 of Commission Regulation (EU) 2016/1719 establishing a Guideline on Forward Capacity Allocation available here.

[26] The public consultation on Elia's findings regarding the design of a scarcity pricing mechanism for implementation in Belgium can be consulted here.

The European Commission has published several opinions of these implementation plans inviting Member States to implement such scarcity pricing schemes no later than 1st January 2022. The Commission also recommends that the scarcity pricing function "should be triggered by the scarcity of reserves in the system and it should be calibrated to increase balancing energy prices to the Value of Lost Load when the system runs out of reserves". An interesting discussion on how to implement this functions is found in (Papavasiliou, 2020).

While avoiding double counting, **other costs actually incurred** should be taken into account, including:

- Transmission costs;
- The economic damage incurred by the forcibly curtailed costumers of the providing MS for the electricity curtailment, only if this cost is not already reflected in the electricity price that the requesting MS had to pay and according to national procedures[27] (see Annex 3 for some examples of assessment tools and approaches). The relevant methodology for the calculation of those costs needs to be included in the arrangements.
- Cost of judicial proceedings in the assisting Member State.

Box 14. Economic signals under crisis

According to the EC's Recommendations, a VoLL calculation can be used to determine the price of the ***customers being forcibly curtailed in the Member State providing assistance***. The value reflects the benefits that the <u>specific consumer group</u> has lost as a result of being curtailed. The recommendations clarify the fact that the VoLL should refer to the specific consumer group being affected by the electricity crisis. When different consumer groups are affected, then different VoLLs will be calculated. Finally, the recommendations refer to Article 11 of Regulation (EU) 2019/943 for the methodology for calculating VoLL (a numerical example on the calculation of VoLL is provided in Annex 4), as developed by ENTSO-E and approved by ACER[28]. The different sectors' weights for computing the VoLL are to be taken from national plans, and MSs willing to sign regional agreements should discuss the identity of users entitled to received special protection against disconnection/weights and their VoLL as key part of assistance agreements.

The recommendations also point out that "a premium may be considered in order to fill the gap – if such a gap exists – between the last known price [balancing market price or intra-day market price, whichever is higher; alternatively, the price of the last known electricity trade or measure with or without a premium may also be a pointer] and the curtailed customers' VoLL.

The assessment methodology for VoLL recognises its variability according to time, place, subject, frequency, period of advance knowledge, and duration, but may seem ill-equipped to gauge VoLL as severity levels grow in the disruptions of vital economic activity, and possibly of law & order that one may envisage for major electricity crises. This is due, in particular, to the latter being intrinsically related to the provision of key public goods, instead of the private ones more readily captured through the last available market price.

The willingness to pay (WTP) is the maximum amount that each Member State is willing to pay for electricity in a crisis situation. Section 2.3.1 of the EC's Recommendations states that this amount" would likely be the VoLL for categories of electricity ***users who are entitled to receive special protection against disconnection***". The WTP becomes the benchmark value for the request of assistance by the MS in need, so that if the costs of the assistance go beyond this value, the cost-efficient decision for the MS in need would be not to activate the assistance mechanism. This method is valid as a decision-making tool as long as there are other viable alternatives to the assistance, and with respect to the specific characteristics of each electricity crisis.

[27] "Any compensation paid to customers who are curtailed in an emergency – whether this stems from the obligation to provide cross-border assistance, or a national emergency – should be the same as that set out in national law".

[28] ACER Annex I Methodology for calculating the value of lost load, the cost of new entry and the reliability standard in accordance with Article 23(6) of Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity.

Other considerations

Electricity users entitled to receive special protection against disconnection should have robust business continuity arrangements in place to maintain adequate supply of services in the event of an electricity crisis, rather than relying only on the arrangements under the risk-preparedness plans (EC's Recommendations section 2.1.3).

All electricity users entitled to receive special protection against disconnection should also reduce their load as much as possible in the event of an electricity crisis. If the situation deteriorates and the risk of shortfall of supply to these electricity users is imminent, priority should be given to preventing loss of life and to minimising the risk of disasters that could involve loss of life or major damage (EC's Recommendations section 2.1.3).

To avoid "different treatment of curtailed consumer groups within a country when assistance is provided across borders", the MS may create a centrally managed fund financed by the compensations received for providing assistance in case of a regional crisis. The fund would be centrally managed by the providing MS.

The structure of the markets can vary across MS. This means that some markets can be more articulated or sophisticated in one MS rather than in the other. For example, the balancing market sessions can be arranged differently between MSs, in a way that some specific energy services are traded in the Intra-day or instead the balancing markets. MSs with more sophisticated intra-day or balancing markets may be in a better position to not only provide the needed services, but also adequately price them even in the event of a crisis. On the other side, adequate market design is fundamental to define optimal pricing of assistance energy to a MS in need in the event of a crisis.

Different approaches to determining the electricity price may be used and agreed upon in the arrangements. However, it is important that the arrangements are clear about the agreed approach and the circumstances under which it would apply, and that they identify any known parameters that would be used (e.g. the premium, if the last known trade plus premium is chosen).

Payment of the compensation for assistance

The regional measures in the risk preparedness plan shall include also the methodology for the calculation of the compensation. The Recommendations give an indication of possible methodologies to be implemented (section 2.3.3):

- simple sum of all the applicable elements described in the section above;
- time value of money: payment should be made promptly. However, Member States may agree on an interest rate to be applied to the compensation once a realistic period has elapsed after the provision of assistance, and once the exact amount of the compensation has been calculated and agreed;
- agreement between Member States using different currencies on the currency in which compensation should be calculated and paid, including the relevant exchange rate.

According to the recommendations, <u>the regulatory authority (NRA) of the MS providing assistance should lead or be involved in the calculation of the compensation</u>, <u>with the support of the TSO in providing information on the quantities delivered or to be delivered in case of assistance</u> ("Subject to the technical and legal constraints in each Member State, national regulatory authorities are best placed to lead, or at least be involved in, the process of calculating compensation costs. The TSOs should preferably be in charge of dispatching the necessary electricity quantities in a cost-efficient manner". Recommendations (EU) 2020/775 paragraph 2.1.5).

The payment procedure should be established and defined between the relevant authorities that are part of the agreement.

Moreover, from the Recommendations (EU) 2020/775 we know that "the entity in the Member State that is in charge of providing assistance could also be in charge of collecting claims for electricity and additional costs, verifying and channelling them to the entity in the Member State that benefited from assistance. In this context, a one-stop-shop approach would be useful. The Member States are advised to identify and agree on which entity is in charge of collecting and channelling claims for compensation for curtailment" (Recommendations (EU) 2020/775 paragraph 2.1.5).

The request of assistance should include the information on "*a reference to the commitment by the requesting Member State to pay compensation for assistance*" (last point of paragraph 2.1.2 of the Recommendations (EU) 2020/775).

The Recommendations (EU) 2020/775 state: *Making provision for a mediator in the regional and bilateral arrangements concluded between Member States might reassure all parties concerning payment and the calculation of compensation costs. The mediator would help resolve any disagreements about the amount of the compensation to be paid* (paragraph 2.1.5 of the Recommendations (EU) 2020/775).

The provider Member State determines how to handle these funds received as compensation for the assistance to the MS in need, and how they fit with existing rules for imbalance settlement (paragraph 2.3 of the Recommendations (EU) 2020/775).

3.5 Ex-post reporting and monitoring activities

A very important part of the regional agreements under risk preparedness are the ex-post reporting and monitoring activities. This section of the plan shall include:

- a description of the event that triggered the assistance
- the measures to prevent and alleviate the crisis that have been adopted before the crisis and their cross-border impact
- a description of the assistance that was foreseen according to the pre-agreed measures and the assistance that was effectively activated
- the economic impact of the crisis and of the regional measures
- the occurred ENS, voluntary and forced demand disconnection and their justification
- finally, the possible improvements to the RP plan/ and to the grid.

Starting from 2013 ENTSO-E publishes annual reports on incidents in the pan-European power system, the Incident classification scale (ICS) and the methodology adopted in the report[29] (Figure 14).

The Incident Classification Scale has four levels of increasing severity, ranging from anomalies up to significant or widespread incidents. It is compliant with the system state definitions listed in Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation. The latest methodology for the incident classification scale (ENTSO-E, 2019d) details the procedure for the investigation of scale 2 and scale 3 incidents.

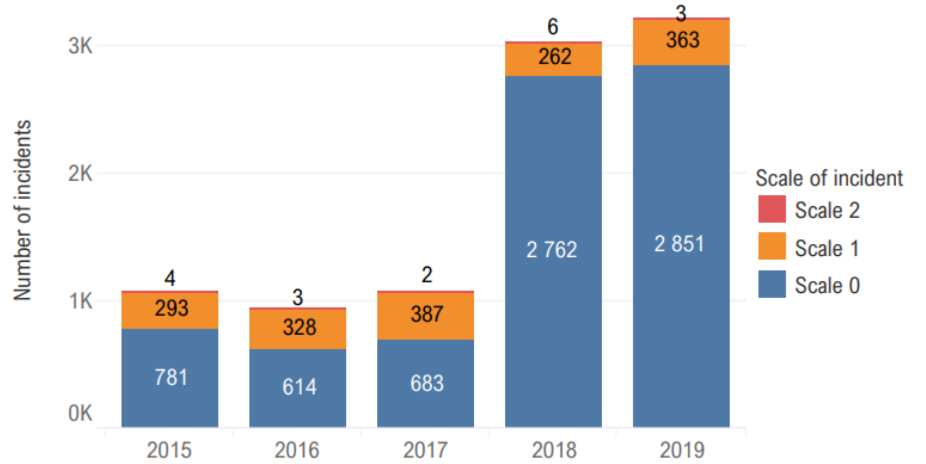
Another ENTSO-E's activity is to provide technical descriptions of recent critical events. In May 2017 ENTSO-E published a report on the situation in January 2017 in Continental Europe (ENTSO-E, 2017), which resulted in system adequacy and network security issues due to a cold spell in several countries. The report combines the information published in the seasonal outlook, describing the detected adequacy risks associated to reduced available generation capacity in some EU MSs, with the exceptional severity of the cold spell that took place in January 2017 and the complexity of the system operation caused by this extreme event. The report also describes the actions undertaken by the TSOs in the affected areas, and the other countries' support with measures to alleviate the consequences. A rather detailed analysis of the market during the event is given in section 5. This report is a very good example of useful ex-post information that can be taken as reference by MSs reporting on various categories of incidents.

29 https://www.entsoe.eu/network_codes/sys-ops/annual-reports/

Figure 14. (a) Incident Classification Scale (b) The annual number of incidents per scale from 2015–2019

Scale 0 Noteworthy incident		Scale 1 Significant incident		Scale 2 Extensive incident		Scale 3 Major incident / 1TSO	
Priority/Short definition (Criterion short code)		Priority-Short definition (Criterion short code)		Priority-Short definition (Criterion short code)		Priority-Short definition (Criterion short code)	
#20	Incidents on load (L0)	#11	Incidents on load (L1)	#2	Incidents on load (L2)	#1	Blackout (OB3)
#21	Incidents leading to frequency degradation (F0)	#12	Incidents leading to frequency degradation (F1)	#3	Incidents leading to frequency degradation (F2)		
#22	Incidents on transmission network elements (T0)	#13	Incidents on transmission network elements (T1)	#4	Incidents on transmission network elements (T2)		
#23	Incidents on power generating facilities (G0)	#14	Incidents on power generating facilities (G1)	#5	Incidents on power generating facilities (G2)		
		#15	N-1 violation (ON1)	#6	N violation (ON2)		
#24	Separation from the grid (RS0)	#16	Separation from the grid (RS1)	#7	Separation from the grid (RS2)		
#25	Violation of standards on voltage (OV0)	#17	Violation of standards on voltage (OV1)	#8	Violation of standards on voltage (OV2)		
#26	Reduction of reserve capacity (RRC0)	#18	Reduction of reserve capacity (RRC1)	#9	Reduction of reserve capacity (RRC2)		
#27	Loss of tools and facilities (LT0)	#19	Loss of tools and facilities (LT1)	#10	Loss of tools and facilities (LT2)		

(a)



(b)

Source: ENTSO-E 2020. (a) Incident Classification Scale Methodology 2020. (b) ICS 2019 Annual Report. The 2014 to 2017 data was reported according to a previous version of the methodology, Therefore, the results for individual years cannot directly be compared against each other (ENTSO-E, 2019e).

4 Conclusions

Many European and non-European countries have documented their experience in managing severe electricity crises. Cooperation among countries started as voluntary agreements, often based on existing procedures implemented by the TSOs for emergency prevention and management, for establishing cooperation to coordinate actions in the event of future electricity crises. Among others, the following practices and initiatives have been acknowledged as important: increasing coordination with neighbouring TSOs, close cooperation with national DSOs, establishment of central sources of information for all the countries affected by a critical event, the introduction of a harmonised methodology for monitoring the crisis and managing its evolution, and finally the utilisation of common, and shared weather monitoring and forecasts.

The increase in the number and type of threats that can hamper the electricity supply calls for the development of new ways to deal with them.

The Risk Preparedness Regulation objective is to formalize and facilitate the cooperation among Member States, in order to cope with a situation in which the potential risk of a significant electricity shortage or an impossibility to supply electricity to customers is present or imminent. The main elements are: the solidarity principle, with the final goal being to protect public safety and personal security; a common EU-framework for the identification of regional crisis scenarios and the definition of national, regional, and bilateral measures to be included in the risk preparedness plans; legally binding rights and obligations of the parties of the assistance agreement, that set technical., legal and financial arrangements to ensure a fair agreement on the assistance.

Member States are required to draft a risk preparedness plan to use in the event of a crisis. Our study identified a number of crucial elements and stages of the implementation to help Member States in the preparation, implementation and adoption of the plan.

Review of the risk preparedness plans after submission. The plans will be subject to a twofold review. The first review aims to ensure consistency between Risk Preparedness Plans of countries within the same region or with bilateral agreements. The second review is a deeper analysis of the plans against the requirements of the Regulation.

The importance of existing measures of crisis prevention and management. The risk preparedness plans shall complement existing measures already in place within the system operation guideline and the network code for emergency and restoration. The RPR also recalls other EU legal frameworks that establish tools for the preparation and management of crises or platforms for cooperation between MSs, some of them beyond the energy field. At national level is important that the competent authority coordinates also with these other relevant structures. In the same way, it is important that the first risk preparedness plans build on existing cooperation structures and provide clear and transparent mechanisms of cooperation to increase its efficiency in case of need.

The phases of an electricity crisis. The risk preparedness plans cover all the steps associated with coping with a critical event, from the preventive measures, to the early warning and the crisis declaration, the request of assistance, the management of the crisis, up to the recovery and the collection of lessons learnt without neglecting the importance of informing and alerting the public, requiring also an efficient communication flow.

The "market-first" principle. Markets shall keep working also during electricity crisis, providing right economic signals. Non-market measures shall be used only as a last resort and when the market alone can't cope with the crisis. It is important to have a forward-looking vision considering the National Energy and Climate plans, the resource adequacy assessment and the market reform plans develop under this framework.. All resources (interconnection capacity, storage and demand response) and not only generation have an important role in case of crisis. It could be relevant to consider the administrative shortage pricing required by the Electricity balancing network code when setting the price of providing assistance.

The cooperation among MSs. The regional and bilateral measures are the means for the prevention, preparation for, and management of electricity crises when more than one Member State is directly or indirectly affected by a crisis. In this study, we summarizes the key elements for defining regional and bilateral measures under the RPR. The MSs' cooperation framework is redesigned to benefit from the establishment of the regional coordination centres. The risk assessment is broaden with regional crisis scenarios complementing the national ones and short-term and seasonal adequacy assessments are harmonised to monitor and measure adequacy issues within a short time frame. The regional measures are defined in article 15 of the RPR and further elaborated in the European Commission's recommendations on technical, legal, and financial arrangements between Member States for the application of the assistance mechanism. Relevant information items to insert in the risk preparedness plan include:

- Legally binding rights/obligations of the parties;
- Clearly defined and pre-agreed procedures for the activation of cooperation, included prevention and mitigation measures, the information flows and the platforms for the information exchange;
- The possible causes of the imminent outage and its impacts;
- The triggers of the assistance;
- The activation mechanism of non-market measures once the market can no longer prevent a further deterioration of the outage.
- The trigger for the suspension of market measures;
- The categories of users entitled to receive special protection against disconnection in each MS;
- The financial agreement and clear transparent rules on how to calculate the economic compensation.

Practical tools and tested methodologies. The scientific literature provides a variety of methodologies to simulate an electricity crisis and assess its economic impacts. In the annexes of the report, we give examples of publicly available tools for the economic impact assessment of blackouts, and a short review of other methodologies. Being able to quantify the economic impacts of an electricity crisis is a relevant information not only for the definition of adequate financial compensation for the assistance in cooperation agreements. This type of assessment becomes a signal for investments for the prevention, mitigation and management of electricity crises. Investments can be undertaken by one MS to reduce the risk to incur in costly assistance requests or can be jointly planned and carried out by two or more MSs that share the same electricity risk to abate high investment costs and enjoy the mutual benefits of the investment. In the report, we also briefly discuss examples of setting up simulation exercises with the parties of a cooperation agreement to improve the knowledge on regional crisis and to identify the most effective cooperation measures. The regulation foresees that the performance of those simulations is reviewed on annual/biennial and regional/national basis and a report is drafted including the indication of agreed-upon procedures, the actors involved in the simulation, and the indication of the measures adopted as a result of those tests.

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List of abbreviations

ACER	Agency for the Cooperation of Energy Regulators
BRP	Balance Responsible Party
BSP	Balance Service Provider
BZ	Bidding Zone
CBD	Cross Border Dependency
CCR	Capacity Calculation Region
CCT	Crisis Communication Tool
CEP	Clean Energy Package
CESEC	Central and South Eastern Europe Energy Connectivity
DSO	Distribution System Operator
EAS	European Awareness System
EB NC	Electricity Balancing Network Code
ECG	Electricity Coordination Group
EENS	Expected Energy Not Served
ENTSO-E	European Network of Transmission System Operators for Electricity
ENTSO-G	European Network of Transmission System Operators for Gas
ERAA	European Resource Adequacy Assessment
ES	Electricity storage
EU	European Union
E3CI	European Extreme Events Climate Index
FCR	Frequency Containment Reserve.
aFRR	automatic Frequency Restoration Reserve
mFRR	manual Frequency Restoration Reserve
GAA	Generation Adequacy Assessment
IGCC	International Grid Control Cooperation
IN	Imbalance Netting
JRC	Joint Research Centre
LOLE	Loss of Load Expectation
LOLP	Loss of Load Probability
MARI	Manually Activated Reserves Initiative
MS(s)	Member State(s)
NECP	National Energy and Climate Plan
NRAPM	Negative Reserve Active Power Margin
NOAA	National Oceanic and Atmospheric Administration (US department of commerce)
PICASSO	Platform for the International Coordination of Automated Frequency Restoration and Stable System Operation
PLEF	Pentalateral Energy Forum
PV	Photovoltaic system

RCC/RSC	Regional Coordinator Centre/Regional Security Centre
RES	Renewable Energy Source
RoCoF	Rate of Change of Frequency
RPR	Risk Preparedness Regulation
RR	Replacement Reserve.
SNSP	System Non-Synchronous Penetration ratio
SO GL	System Operation Guideline
SOR	System Operation Region
SoS	Security of Supply
STSAA	Short-Term and Seasonal Adequacy Assessment
TERRE	Trans-European Replacement Reserves Exchange
TSO	Transmission System Operator
UCED	Unit Commitment and Economic Dispatch
UPS	Uninterruptible Power Supply
WMO	World Meteorological Organization

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Annex 1. Assessment of risk preparedness plans.

The main objective of the risk preparedness plans is to be effective in the event of a crisis. To this end, the plans are subject to a twofold review. In a first stage, the draft plans submitted by the competent authorities will be consulted by the competent authorities of the MSs in the same region and with bilateral measures and to the ECG. These consulted parties may issue recommendations to **ensure consistency** between the plans. After the adoption of the plans, the European Commission will assess the plans and issue a non-binding opinion, considering the following:

- taking duly into account the recommendations set out by the ECG;
- if the plan is consistent with the electricity crisis scenarios and effective to mitigate their risks;
- if the plan is consistent with the plans of neighbouring MSs;
- it does not distort competition and the effective functioning of the market;
- it does not endanger the security of supply of other MSs;
- it complies with the risk preparedness regulation and other provisions of Union Law. In particular, if the plan comply with the rules set in articles 11, 12 and 16 of the risk preparedness regulation.

The plans shall follow the template provided in the annex of the RPR. The main elements are as follows:

- General information
    - Name of the competent authority responsible for the preparation of this plan;
    - Member States in the region.
- 1. **Summary of the electricity crisis scenarios**
- 2. **Roles and responsibilities of the component authority**
- 3. **Procedures and measures in the electricity crisis**
    - 3.1. National procedures and measures;
        - Describe the mechanisms used to inform the public about the electricity crisis;
    - 3.2. Regional and bilateral procedures and measures.
- 4. **Crisis coordinator**
- 5. **Stakeholder consultations**
- 6. **Emergency tests**

For the updates of the plan: briefly describe the tests carried out since the last plan was adopted and the main results. Indicate which measures have been adopted as a result of those tests.

Annex 2. Case study

Australia. We will show here the arrangements and rules governing electricity crisis in Australia and the changes after the South Australia blackout on the 28th September 2016. Australia has several similarities with the electricity system in Europe (i.e. zonal wholesale prices).

There are two different electricity markets, the NEM (National Electricity Market) which interconnects the six eastern and southern states and territories and delivers around 80% of all electricity consumption in Australia. Western Australia and the Northern Territory have their own electricity systems and separate regulatory arrangements (WEM). In what follows we will refer only to the NEM system. The main events of the blackout in South Australia on 28 September 2016 were:

- Pre-event situation: on 27 September 2016, AEMO (Australian Energy Market Operator) received information about the potential severe weather front for the following day in South Australia State. In particular tornadoes with wind speeds 190 – 260 km/h were expected.
- Event: the predicted weather front produced multiple transmission system faults. Between 16:16 and 16:18 h two tornadoes damaged a single circuit 275 kV transmission line and a double circuit 275 kV transmission line 175 km apart. The three lines tripped and a sequence of faults in quick succession resulted in six voltage dips over a two-minute period. As a result, nine wind farms reduced their power generation as a protection feature was activated. These produced a 456 MW deficit in wind power generation over a period of less than seven seconds. The energy deficit was covered by an increase in power flowing through the Heywood interconnector. Eventually, this interconnector also tripped. The South Australia system became islanded from the rest of the NEM. The large generation-load imbalance made it impossible to maintain the islanded system frequency and as a result all generation of the islanded system was lost (16:18). The blackout resulted in South Australia's regional electricity market being suspended at 16:25 of 28th September.
- Restoration: started at 19:00 but the transmission grid was divided in two, isolating the north of the state.
- The South Australian spot market resumed at 22:30 on 11th October 2016

Prices under market suspension: AEMO must determine the spot price and ancillary service prices in a suspended region according to clause 3.14.5 of the National Electricity Rule (NER) as follows:

- Spot prices are determined in accordance with a pre-published "suspension pricing schedule". These prices are calculated ex-ante and published in an automated way for each region on a rolling basis. The price for each 30-minute trading interval in the billing week, is calculated as the average price in the region on each corresponding trading interval over the previous four billing weeks. Separate pricing schedules are calculated for weekdays and weekend days to reflect differences in typical supply and demand patterns on these days. While these prices are not linked to the dispatch pattern of generation during the market suspension, AEMO requests that generators continue to bid their plant into AEMO's systems. This ensures that, while respecting system security constraints, participants in the market zone suspended continue to be dispatched as close as possible to economic merit.
- Suspension prices in one region can affect spot prices in any neighbouring regions that have energy flow towards the suspended region in any trading interval. AEMO must retrospectively calculate and apply price adjustments for those regions. This is not done in an automated way and it is performed manually afterwards. As a general rule, prices in those regions must not exceed the suspension price, scaled by the average loss factor applicable to the energy flow from their region towards the region with the suspended market.

The lack of detailed procedures on how to operate the power system under extended periods of market suspension was identified as an issue. This issue particularly relates to:

- merit order principles applicable when the dispatch engine is not usable or when directions are required,
- management of reserves and frequency control ancillary services,
- management of export limits and negative settlement residues,
- principles and processes for resuming market operation after suspension.

Some actions were taken after this event in order to:

- implementing rigorous weather monitoring processes and review criteria under which weather events are classified
- standardising notifications for market participants during abnormal weather conditions
- inertia provision and correct operation of inverter-connected facilities
- simplify market suspension procedures and at the same time provide detailed procedures on how to operate the power system under extended periods of market suspension:
  - reduce suspension market pricing complexity,
  - allow to return to dispatch pricing as soon as possible. The reason is that administrative pricing is based on historical price averages so it does not reflect the stress situation of the system. As soon as possible come back to more informative price schemes,
  - differences in price scaling arrangements. Frequency reserve pricing adjustment and administrative pricing check against neighbouring countries prices to have the right flow direction in interconnectors.

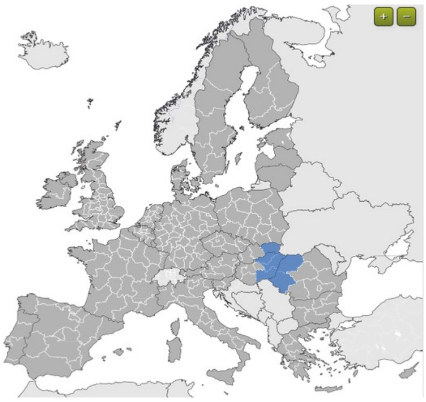
Blackout in Italy in 2003. System integration, coordination, and cooperation brings multiple benefits to the overall integrated energy system. A rather extreme example of the challenges that are brought about when energy systems are not integrated is represented by the case of the blackout in Italy in 2003. In the years before 2003, Italy's electricity imports grew sharply due to the country's significantly higher electric production costs than the rest of Europe. The fact that Switzerland was not integrated with the European electricity market and operation meant that the increasing imports into Italy were also flowing on unscheduled parallel paths through Switzerland. This meant that loads on cross-border transmission lines often deviated from scheduled exchanges with ever-growing amounts flowing on the Swiss transmission lines. The resulting power flows were not always well coordinated between the European system and Switzerland. This lack of system integration was among the causes of the failure to prevent the accident occurred on a 380 kV interconnection between Switzerland and Italy in the night of 28th September 2003[30].

[30] DGA Consulting 2016. International comparison of major blackouts and restoration.

Annex 3. Economic assessment of an electricity crisis. An example from the blackout simulator

The scientific literature offers various methodologies to simulate an electricity crisis and to assess its economic impacts. The blackout simulator is a tool developed by the university of Linz under the EUFP 7 project SESAME "Securing the European electricity Supply Against Malicious and accidental thrEats" that simulates regional and national electricity crises and assess the economic costs by economic sector[31] (Figure 15 and Figure 16).

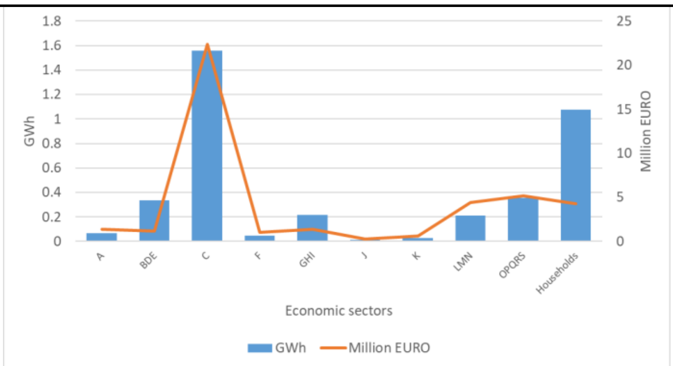
Figure 15. Blackout simulation in Slovakia, Hungary and Romania



Source: own simulation on https://www.blackout-simulator.com/

The tool allows the user to simulate a power blackout in selected regions (NUTS 2), in a specific day and hour of the year and for a pre-defined duration (minimum duration of the blackout is 1 hour). The result of the simulation is an economic assessment of the costs associated to the blackout by economic sectors classified as per NACE 2008 nomenclature. We show the results of a blackout simulation taking place on January the 12, 2021 at noon and for one hour in six regions of Europe, Východné Slovensko (SK), Észak-Alföld, Észak-Magyarország, Dél-Alföld (HU) and Vest and Nord-Vest (RO). The blackout resulted in 3.90 GWh energy not supplied and an economic damage 42.02 million Euro.

Figure 16. Economic costs of the simulated blackout*



Legend:
Economic sectors: A: Agriculture, forestry and fishing; BDE: Mining and quarrying/ electricity, gas, steam and air conditioning supply/ water supply/ sewerage/ waste management and remediation activities; C: Manufacturing; F: Construction; GHI: Wholesale and retail trade/ repair of motor vehicles and motorcycles/ transporting and storage, accommodation and food service activities; J: Information and communication; K: Financial and insurance activities; LMN: Real estate activities/ professional, scientific and technical activities/ administrative and support service activities; OPQRS: Public administration and defence/ compulsory social security/ education/human health and social work activities/ arts, entertainment and recreation/ other services activities; Households.

Source: own elaboration on results from blackout simulator (*Results are adjusted for inflation)

This simulation tool can provide important information on the economic impacts that can be used as a benchmark value for investment decision in security of supply. Moreover, this value can be also taken into account by Member States that are in the process of deciding upon the benefits of establishing regional agreements with neighbouring countries for assistance in case of electricity crises. The economic damage

[31] https://www.blackout-simulator.com/

associated to a blackout can be interpreted as the avoided costs for the society when adequate investment are undertaken to improve the security of the supply.

The blackout simulator tough does not provide information on "transboundary" effects of a blackout on neighbouring countries; neither it is able to assess the avoided damage in case of an investment is added to the system to improve the security of supply. On the other side, the simulator can be used to replicate pasts (Reichl, 2013a) (Reichl, Johannes, Michael Schmidthaler, and Friedrich Schneider, 2013b), (Schmidthaler M. J., 2014) and (Schmidthaler M. a., 2016) as well as future electricity crises[32].

Another important element of this tool is the disaggregation of the damage associated to the blackout by economic sectors, included the household. The distinction by sectors differs from the categorization implemented in the VoLL methodology approved by ACER, where the types of electricity consumer are: household, commerce or service sector (tertiary), Public service, small-medium enterprise in the industrial sector, large enterprise in the industrial sector and transport sector.

We elaborate on the results of the previous simulation by assessing the relation between the durations of an electricity outages with the associated economic damage (Table 13).

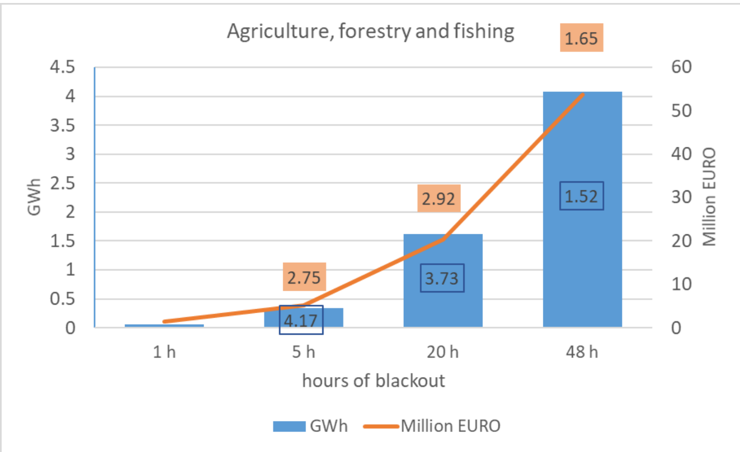
Table 13. Economic damage and energy not supplied in correspondence with different duration of the simulated outage

Duration of the outage	Energy not supplied (GWh)	Economic damage (Million €)*
1 h	3.90 GWh	42.02 million Euro
5 h	19.43 GWh	142.97 million Euro
20 h	67.41 GWh	427.80 million Euro
48 h	166.25 GWh	1,089.16 million Euro

*Results are adjusted for inflation

In Figure 17 we show a non-linear increase of economic damage and energy not supplied for the agriculture, forestry and fishing sector in correspondence with four different durations of the blackout (1 hour, 5 hours, 20 hours and 48 hours).

Figure 17. Increase* of economic damage and energy not supplied with increasing duration of blackout. *Values in the squares represent the change of the results of the simulation in % compared to the previous value.



Source: own elaboration on results from blackout simulator

[32] The data base of the simulator consists of, among others, official statistics about the economic performance of the NUTS regions, populations' statistics, energy consumption statistics, etc. For future scenarios, each of these variables is increased or decreased by the average trend of the respective variable over the last years. Of course, 2020 and 2021 are problematic, as their development does clearly not follow an average development.

Beside the examples above, the blackout simulator allows for a wide range of analysis and use cases:

- assessing the economic impacts of past blackouts (i.e. Italy 2003);
- studying the impacts of a blackout by economic sector to find out what sectors are more affected than others;
- monitoring the impacts in different time horizons (summer/winter; day/night; week days/weekend days (holidays)/ etc..);
- comparing impacts across regions within the same country ;
- comparing impacts in the same sector of different regions/countries;
- assess the relevance of supply security for households.

The assessment of the costs of electricity interruption from other scientific literature. Praktiknjo et al. (2011) reviewed 21 studies on the assessment of outage costs in private European households and attribute the cross-country's differences on three possible factors (Table 14): the method (i.e. surveys or macroeconomic approach), the blackout factors (i.e. the duration of the power outage, the point in time, frequency of reliability problems) and the consumers factors (i.e. dependencies of the individuals regarding the availability of electricity, like personal needs, existing assets and individual preferences, and those dependencies vary for categories of consumers).

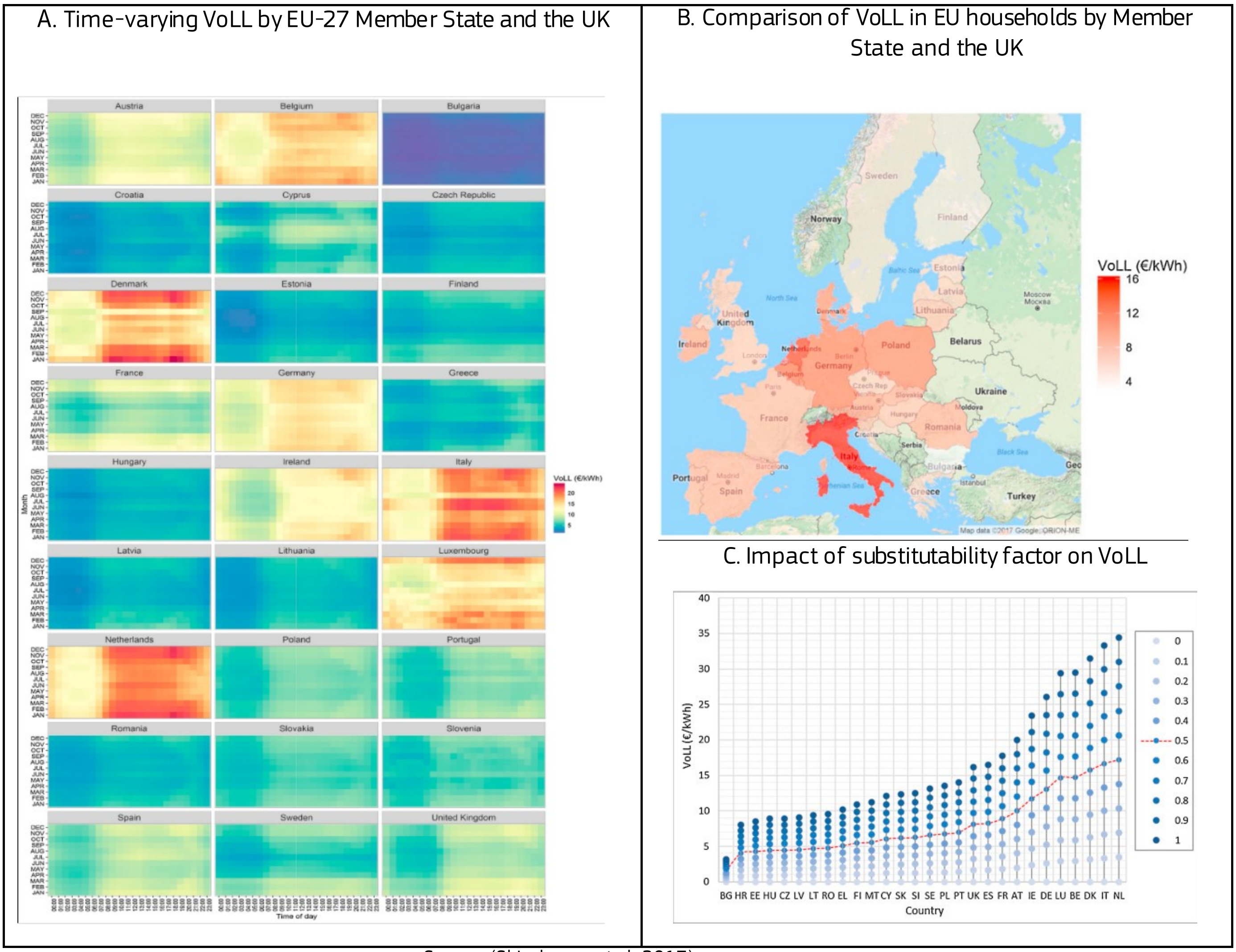
Table 14. Review of studies on the assessment of VoLL

Country (year of the study)	Method	Outage cost (€/kWh)
Austria (2005)*	Macroeconomic	16.63
Austria (2008)*	Survey	5.3
Ireland (2007)	Macroeconomic	68
Italy (2005)	Survey	10.89
Mexico (1999)	Macroeconomic	0.75
Netherlands (2009)	Survey	3.66
Netherlands (2007)	Macroeconomic	16.38
Netherlands (2005)	Survey	21.62
Norway (2000)	Survey	0.55
Norway (2008)	Survey	1.08
Sweden (1985)	Survey	3.57
USA (2002)	Survey	0.18
USA (1990)	Survey	5.72
USA (1978)	Survey	2.46
USA (2003)	Survey	7.8
USA (1982)	Survey	0.48

Legend: study performed by the same author.
Source: Praktiknjo et al. (2011)

In particular (Shivakumar, et al., 2017) assess the costs of outages for the households in the European Union. The authors adopt a harmonized methodology based on a production function approach to compute the average annual VoLL and compare results across EU countries. Results show that the differences in VoLL between EU Member States is significantly large, ranging from 3.2 €/kWh in Bulgaria to 15.8 €/kWh in the Netherlands. The annual average VoLL for the EU was calculated to be 8.7 €/kWh. Figure 18 shows the VoLL VoLL during the year. Countries differ also from the Impact of substitutability factor on VoLL. A sensitivity analysis on the dependency on electricity and VoLL in the target countries is carried out by recalculating VoLL assuming, on one side, that leisure activities are completely independent of electricity (substitutability factor equal to 0) and, on the other side, that leisure activities are completely dependent on electricity (substitutability factor equal to 1) (Figure 18(C)).

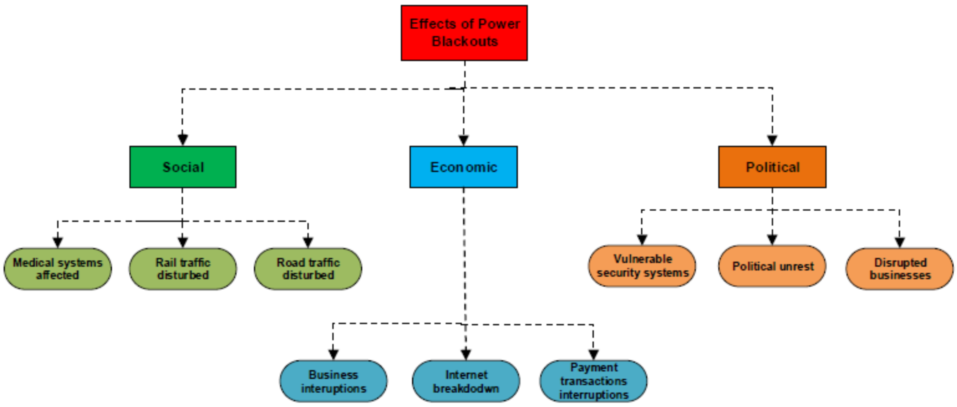
Figure 18. Results of the study on the assessment of the costs of electricity interruption in 22 EU MS and the UK.



Source: (Shivakumar, et al., 2017)

The impacts of blackouts and power outages are not only economic but also social and political (Haes Alhelou, 2019) with possible major consequences on critical social services and infrastructure and risks of political unrest (Figure 19).

Figure 19. Impacts of blackouts and power outages



Source: (Haes Alhelou, 2019).

Annex 4. ENTSO-E methodology for the assessment of VoLL[33]

The VoLL is the maximum electricity price that customers are willing to pay to avoid a supply interruption. Other methods may complement the results of the WPT approach like, willingness to accept an interruption or direct worth method, with a cross check with macroeconomic values. The result of the assessment is given in EUR/MWh. This value will be updated at least every five years, or earlier in case significant changes justify it.

<u>The methodology</u>

The methodology that has been approved by ACER foresees surveying representative sample of costumers:

— estimate sectoral VOLL per consumer type;

— estimate share of load-shedding per consumer type;

— combine sectoral VOLLs with share of load-shedding to drive single VOLL.

The methodology will have to target a minimum consumer segmentation (aggregation allowed to ensure meaningful results, given the available example):

— household

— commerce or service sector (tertiary)

— public service

— small-medium enterprise in the industrial sector

— large enterprise in the industrial sector

— transport sector

— other

The parameters that are taken into account in the assessment of VOLL are:

— duration of the interruption;

— period of occurrence

— pre-notification (consumers informed in advance?)

— other (frequency, etc.).

VOLL is used to estimate the reliability standards (RS), the expected energy not served (EENS) that measures how much energy is unserved and the loss of load expectation (LOLE) that informs on how often does unserved energy happen.

<u>Numerical example for the calculation of sectoral VOLL.</u>

A survey on power interruptions is conducted in Sector X. Consumers are asked to express their WTP for a power interruption of 1 hour during a winter evening with pre-notification.

The results of survey are:

Consumer 1 → 80 €/ 1 h interruption
Consumer 2 → 100 €/1 h interruption
Consumer 3 did not answer.
Consumer 4 protected against disconnection → is ignored
Moreover it is assumed that:

Consumer 1 consumes 4.5 kWh (after DSR activation) over the event and suffer full interruption (ENS=4.5 kWh);
Consumer 2 consumes 10 kWh over the event and suffer full partial interruption (ENS=8 kWh).

[33] Source: ACER webinar on Calculating the value of lost load. Online event, 03/11/2020.

Result of the computation of VOLL

Consumer 1: 80/4.5=17.8 €/kWh
Consumer 2: 100/8 =12.5 €/kWh
Single VOLL: (100+80)/(4.5+8) = 14.4 €/kWh = 14.4 k€/MWh

To combine the sectoral VOLLs into a single value (for the calculation of the RS), weights can be attributed to each sectoral VOLL to reflect the applicable load-shedding process. There are two ways to do this:

- By defining the share of avoided load-shedding (marginal approach) or
- By defining the share of (total) load-shedding (proportional approach).

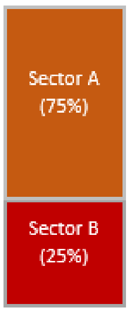
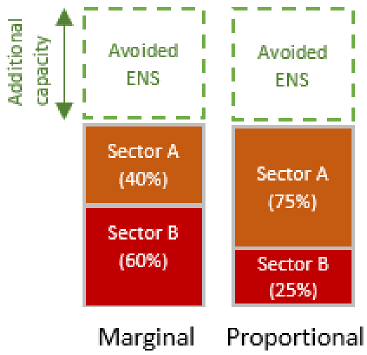
<u>*Graphical example*</u>

A power system made of sector A and sector B experiences a power interruption measured in terms of ENS (phase 1). Sector A suffers 75% of the interruption while sector B suffers 25% of it. Additional capacity is provided to the system to limit the outage and reduce the amount of ENS (phase 2) (Figure 20).

Figure 20. A numerical and graphical example for the calculation of single VOLL

<table>
<tr><th rowspan="2">Initial ENS

(phase 1)</th><th rowspan="2">Additional capacity is added to the system and load shedding is adopted

(phase 2)</th><th colspan="3">Calculation of single VOLL (RS) after additional capacity is added to the system</th></tr>
<tr><th>Avoided ENS (two options)</th><th>ENS decrease</th><th>Single VOLL</th></tr>
<tr><td rowspan="2">
</td><td rowspan="2">
</td><td>Marginal approach *</td><td>100% A
0% B</td><td>$VOLL_A$
(4 k€/MW)</td></tr>
<tr><td>Proportional approach</td><td>75% A

25% B</td><td>$0.75*VOLL_A$
+
$0.25\ VOLL_B$
(3.25 k€/MWh)</td></tr>
</table>

* the additional capacity is entirely used to reduce ENS in sector A. the nominal ENS in sector B remains the same as in the phase 1.

The additional capacity is not enough to avoid the outage therefore the system will apply a load-shedding plan for the remaining amount of ENS. *What is the final single VOLL after the capacity is added and the load-shedding plans are adopted?* Two alternative approaches for system load shedding are considered: the marginal approach and the proportional approach. *How would the different load-shedding plans impacts on the final single VOLL (RS)?*

Let's assume that:

- VOLL in sector A is 4 k€/MWh
- VOLL in sector B is 1 k€/MWh.

After the increase of capacity to the system the single VOLL will be:

- 4 k€/MWh (that results form 1*4 (sector A) + 0*1 (sector B)) in case the implementation of the load shedding plan follows the marginal approach and
- 3.25 k€/MWh (that results from 0.75*4 (sector A) +.025*1 (Sector B)) in case the load shedding plan is implemented following the proportional approach.

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