



# **Luxembourg risk preparedness plan for the electricity sector in accordance with article 10 of the Regulation (EU) 2019/941 of the European Parliament and of the Council of 5 June 2019 on risk-preparedness in the electricity sector and repealing Directive 2005/89/EC**

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## Introduction

The electricity sector is in a process of change due to the increasing shares of renewable energies and decentralised market players. Meanwhile, power grids in Europe are closely meshed and markets are coupled with one another, which enables significant efficiency gains but also creates dependencies, last but not least for the risk of electricity supply crises. Against this background, the prevention and management of possible crisis scenarios requires efforts on the national as well as on the regional level. Consequently, ***Regulation (EU) 2019/941 of the European Parliament and of the Council of 5 June 2019 on risk-preparedness in the electricity sector and repealing Directive 2005/89/EC***<sup>1</sup> (hereafter ‘the Regulation’) lays down rules for cooperation between Member States with a view to preventing, preparing for, and managing electricity crises in a spirit of solidarity and transparency and in full regard for the requirements of a competitive internal market for electricity. The Regulation requires EU member states to adopt and publish their risk preparedness plans after a consultation process on national, regional and European level. The present document is Luxembourg’s risk preparedness plan in accordance with article 10, paragraph 8 of the Regulation.

## Competent authority

According to the national law on the organisation of the electricity market, the competent authority responsible for the implementation of the Regulation and the preparation of the present plan is the Minister responsible for Energy of the Luxembourg government.<sup>2</sup>

## The regional context

The **Pentalateral Energy Forum** (“Penta”) is the framework for regional cooperation in Central Western Europe, consisting of Austria, Belgium, France, Germany, Luxembourg, The Netherlands, and Switzerland. The forum aims to work towards improved electricity market integration and security of supply. Jointly, Penta countries cover more than a third of the EU population and more than 40% of EU electricity generation. The initiative aims to allow energy policy to evolve from a purely national focus to a regional approach. It allows for political backing to a process of regional integration towards a European energy market. To this end, the Ministers for Energy of the Pentalateral countries regularly meet in order to discuss energy policy matters and give guidance on this regional cooperation. The work program is implemented by the transmission system operators (TSOs), ministries, regulatory authorities, the European Commission and the market players who regularly meet in different support groups. This collaboration is formalized through the Memorandum of Understanding of the Pentalateral Energy Forum, signed on 26 June 2007 in Luxembourg.

Security of supply in the electricity sector has always been one of the most important pillars of collaboration within the Pentalateral Energy Forum. To this end, at the beginning of 2020, the Forum received a mandate to work on a well-coordinated regional framework in light of the Regulation (EU) 2019/941 of the European Parliament and of the Council of 5 June 2019 on risk-preparedness in the electricity sector (Risk Preparedness Regulation), while at the same time building further on its Memorandum of Understanding (MoU) of 26 June 2017 on emergency planning and crisis

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<sup>1</sup> Here and in the following, reference documents appear in ***bold italic*** for better traceability. An overview of all reference documents is provided in Annex B.

<sup>2</sup> *Loi modifiée du 1er août 2007 relative à l'organisation du marché de l'électricité*, article 9bis.

management for the power sector. Penta therefore established a network of risk preparedness experts with representatives from ministries, regulatory authorities and TSOs from all Penta countries within the framework of Support Group II, mainly focusing on security of supply. Competent Authorities and their representatives, as depicted in the table below, actively contributed to the work.

The first two steps that were taken to work on this well-coordinated regional framework was the drafting of a common chapter that was added to the draft Risk Preparedness Plans and that was presented to the Electricity Coordination Group. This was followed by the signing of a new MoU of the Pentalateral Energy Forum on Risk Preparedness in the Electricity Sector on 1 December 2021 in Brussels by the Ministers representing the countries in the Pentalateral Energy Forum. Both documents aim to provide an answer to the requirements as regards regional and bilateral measures pursuant to article 12 and 15 of the Risk Preparedness Regulation. Furthermore, the MoU provides a basis for the work that will be done in the following years on risk preparedness in the Penta Region.

Country	Competent authority	Contact details
Belgium	Federal Minister of Energy	<a href="https://www.belgium.be/en">https://www.belgium.be/en</a> Email: <a href="mailto:be-riskpreparedness@economie.fgov.be">be-riskpreparedness@economie.fgov.be</a>
Germany	Federal Ministry for Economic Affairs and Energy	<a href="https://www.bmwk.de/Navigation/EN/Home/home.html">https://www.bmwk.de/Navigation/EN/Home/home.html</a> Email: <a href="mailto:buero-VIII B2@bmwe.bund.de">buero-VIII B2@bmwe.bund.de</a> ; <a href="mailto:riskpreparedness@bmwe.bund.de">riskpreparedness@bmwe.bund.de</a>
France	Directorate General for Energy and Climate	<a href="https://www.ecologie.gouv.fr/">https://www.ecologie.gouv.fr/</a> Email: <a href="mailto:ccr.pole-dgec@developpement-durable.gouv.fr">ccr.pole-dgec@developpement-durable.gouv.fr</a>
Luxembourg	Minister responsible for Energy	<a href="https://meco.gouvernement.lu/fr.html/">https://meco.gouvernement.lu/fr.html/</a> E-Mail: <a href="mailto:secretariat.energie@eco.etat.lu">secretariat.energie@eco.etat.lu</a>
Netherlands	Ministry of Climate Policy and Green Growth	<a href="https://www.rijksoverheid.nl/ministeries/minist erie-van-klimaat-en-groene-groei d.nl">https://www.rijksoverheid.nl/ministeries/minist erie-van-klimaat-en-groene-groei d.nl</a> Email: <a href="mailto:secretariaatenergiemarkt@minezk.nl">secretariaatenergiemarkt@minezk.nl</a>
Austria	Federal Ministry of Economy, Energy and Tourism	<a href="https://www.bmwet.gv.at/">https://www.bmwet.gv.at/</a> Email: <a href="mailto:mailto:stabst-krima-el@bmk.gv.at">mailto:stabst-krima-el@bmk.gv.at</a> <a href="mailto:energielenkung@wirtschaftsministerium.at">energielenkung@wirtschaftsministerium.at</a>
Switzerland	Swiss Federal Office of Energy	<a href="https://www.bfe.admin.ch/">https://www.bfe.admin.ch/</a> Email: <a href="mailto:contact@bfe.admin.ch">contact@bfe.admin.ch</a>

Table 1: Competent authorities in the Penta region

All further information regarding the regional cooperation within the Pentalateral Energy Forum is to be found under section 7 of this document.

## 1. Electricity crisis scenarios

In Luxembourg's law creating a High Commission for National Protection (hereafter 'HCPN'), a crisis is defined as follows<sup>3</sup>:

*Any event, which, by its nature or effects, is detrimental to the vital interests or essential needs of all or part of the country or the population, which requires urgent decisions and coordination at the national level of the actions of the Government, the administrations,*

<sup>3</sup> Loi du 23 juillet 2016 portant création d'un Haut-Commissariat à la Protection nationale, article 2 (2)

*the services and bodies under the authority of the public authorities, and, if necessary, also at the international level.*

Against the background of this definition, and according to articles 6 and 7 of the Regulation, relevant regional and national electricity crisis scenarios shall be identified as a basis for establishing the risk preparedness plan.

The identification of the relevant electricity crisis scenarios followed the ENTSO-E methodology developed in accordance with article 5 of the Regulation. In 2024, the methodology was updated by ENTSO-E and approved by ACER<sup>4</sup>. Key improvements to the methodology include:

- A top-down process for the identification of the regional electricity crisis scenarios, starting with the original 31 scenarios from 2020 and merging, adding or removing certain scenarios.
- A stronger focus on extreme scenarios with regional impact.
- A closer involvement of Member States and competent authorities.
- A more pragmatic approach to the analysis of the scenarios, with ENTSO-E to undertake quantitative methods and model-based simulations where seasonal adequacy tools can be applied.

The methodology considers different classes of hazards being the initiating event for a crisis scenario:

- Natural hazards
- Accidental hazards beyond the (n-1)-security criterion and exceptional contingencies
- Consequential hazards, especially consequences of malicious attacks or fuel shortages

The crisis scenarios derived from these initiating events are ranked according to assessments of the likelihood (based on the expected frequency of occurrence of an initiating event, or a combination of multiple initiating events) and impact considering the indicators expected energy not served (EENS) and loss of load expectation (LOLE). For both indicators, a classification with a five-step scale is used. The combination of the rating with respect to both parameters results in an overall rating of each scenario in a bandwidth between “low” and “very high”.

Details of the methodology can be found in the ENTSO-E document ***Methodology to Identify Regional Electricity Crisis Scenarios in accordance with article 5 of the Regulation of the European Parliament and of the Council on risk-preparedness in the electricity sector and repealing Directive 2005/89/EC.***

## 1.1 National crisis scenarios

Based on the proposal of possible electricity crisis scenarios by ENTSO-E, a detailed qualitative assessment of experts from the national TSO, regulator, and the Ministry identified six national crisis scenarios as particularly relevant with respect to impact and likelihood from a Luxembourgish perspective. As depicted in the following Figure 1, all six scenarios have a “High” risk rating.

It should be noted that the identification of six particularly relevant scenarios does not imply that all other scenarios are irrelevant or even impossible to occur. Indeed, as will be depicted from 2 onwards,

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<sup>4</sup> ACER decision No 02/2024 of the European Union Agency for the Cooperation of Energy Regulators of 8 March 2024 on the amendment of the methodology for identifying regional electricity crisis scenarios.

most parts of the present risk preparedness plan apply to any electricity crisis, independent of the specific scenario.

★ Most relevant national scenarios

[id]	Scenario name	Related 2020 scenario name(s)	Initiating/contributing hazards/factors
★ W.SS	Severe summer	Dry period, Forest fires, Heatwave	●
★ W.SW	Severe winter	Cold spell, Winter incident	●
★ W.ST	Severe storm	Storm, Multiple failures caused by extreme weather	●
W.IL	Heavy ice loading	(new)	●
W.FL	heavy flooding	Precipitation and flooding, Multiple failures caused by extreme weather	●
W.DF	Dunkelflaute (extremely low wind/solar)	(new)	● ■
W.FE	Unusually big demand / RES forecast errors	Unusually big RES forecast errors	● ■ ■ ▲
N.EQ	Earthquake	Earthquake	● ▼
N.VE	Volcanic eruption	Volcanic eruption	● ▼
N.SW	Space weather	Solar storm	● ▼
S.FF	Fossil fuel shortage	Fossil fuel shortage	● ▼ ■ ▲
S.NF	Nuclear fuel shortage	Nuclear fuel shortage	▼ ■ ▲
★ T.LA	Large nuclear/industrial accident	Industrial/nuclear incident	● ■ ■ ▲
T.SD	Serial technical defects	Serial equipment failure	▼ ■ ■
H.PA	Pandemic	Pandemic	● ▼ ■
H.IA	Industrial action, strikes, riots	Strike, riots, industrial action in power supply chain	▼ ■ ■
H.IM	Unforeseen interaction of energy markets	Unexpected/unforeseen interaction of energy market rules	● ▼ ■ ■
★ M.AA	Physical attack on critical assets	Physical attack on critical assets	▼ ■ ▲
★ M.AC	Physical attack on control centres	Physical attack on control centres	▲
M.AE	Attack on entities not connected directly to the grid	Cyber-attack on entities not connected to the grid	▲
★ M.CA	Loss of ICT systems to cyber-attack	Loss of ICT systems for real-time operation, Cyber-attack on entities connected to the electrical grid	▲
M.UA	Unauthorised action by personnel	Threat to key employees, Insider attack	■ ▲
M.AS	Targeted political malicious actions by adversarial states	(new)	▲

● Weather / Natural ▼ Supply chain ■ Technical ■ Human ▲ Malicious attacks

		Likelihood					
		Extremely Unlikely	Very Unlikely	Unlikely	Possible	Likely	Very likely
Impact	LOLE						
EENS%							
Disastrous	Disastrous	Medium	Medium	High	T.LA	Very high	Extremely high
Disastrous	Critical	Medium	Medium	High	Very high	Very high	Extremely high
Critical	Disastrous	Medium	Medium	High	Very high	Very high	Extremely high
Disastrous	Major	Medium	Medium	High	High	Very high	Extremely high
Major	Disastrous	Medium	Medium	High	High	Very high	Extremely high
Disastrous	Minor	Medium	Medium	High	High	Very high	Extremely high
Minor	Disastrous	Medium	Medium	High	High	Very high	Extremely high
Disastrous	Insignificant	Medium	Medium	High	High	Very high	Extremely high
Insignificant	Disastrous	Medium	Medium	High	High	Very high	Extremely high
Critical	Critical	Low	Medium	Medium	High	Very high	Extremely high
Critical	Major	Low	Medium	Medium	High	Very high	Very high
Major	Critical	Low	Medium	Medium	High	Very high	Very high
Critical	Minor	Low	Medium	Medium	High	High	Very high
Minor	Critical	Low	Medium	Medium	High	High	Very high
Critical	Insignificant	Low	Medium	Medium	High	High	Very high
Insignificant	Critical	Low	Medium	Medium	High	High	Very high
Major	Major	Low	Low	Medium	H.M.AC M.AA	High	W.SW W.ST
Major	Minor	Low	Low	Medium	Medium	High	High
Minor	Major	Low	Low	Medium	Medium	High	High
Major	Insignificant	Low	Low	Medium	Medium	High	High
Insignificant	Major	Low	Low	Medium	Medium	High	High
Minor	Minor	Low	N.EQ N.VE	T.SD	S.NF W.IL	S.FF W.DF	Medium W.SS W.FL
Minor	Insignificant	Low	Low	Low	Medium	Medium	High
Insignificant	Minor	Low	Low	Low	Medium	Medium	High
Insignificant	Insignificant	Low	Low	M.AE	H.IA	H.IM H.PA W.FE	Medium W.SW

Figure 1: List of crisis scenarios and Luxembourg's assessment of corresponding national risks

The identified national crisis scenarios cover the different classes of hazards that may initiate a crisis, i.e. natural, accidental and consequential hazards. The impacts were studied in combination with a detailed contingency analysis to identify the most critical infrastructures and to determine the foreseeable actions to be taken. The scenarios most relevant to Luxembourg's electricity supply security (i.e. those with a "high" risk) are:

- Scenario M.CA. Loss of ICT systems to cyber-attack
- Scenario M.AA. Physical attack on critical assets

- Scenario M.AC. Physical attack on control centres
- Scenario T.LA. Large nuclear/industrial accident
- Scenario W.SW. Severe winter
- Scenario W.ST. Severe storm

The detailed descriptions of the scenarios have been omitted from the public version of the plan to ensure confidentiality of critical information.

## 1.2 Regional crisis scenarios

For information regarding the regional crisis scenarios and regional cooperation, please refer to the Penta Common Chapter in section 7 at the end of this document.

## 2. Roles and responsibilities

### 2.1 The government and public authorities

The **government** is the decision-making entity in case of an electricity crisis. Several government members are involved explicitly in crisis management.

In its role as the competent authority in the sense of the Regulation, **the Minister responsible for energy** is in charge for the identification of relevant national electricity crisis scenarios (article 6), the establishment of the risk preparedness plan as well as its consultation and publication (article 10-12), the issuing of early warnings and declarations of an electricity crisis to the European Commission and the Member States in the region (article 14), and the ex-post evaluation of an electricity crisis (article 17).

In terms of operational crisis management, the highest decision-making power lies with the **Prime Minister** as depicted in the Government's crisis emergency response plans (see section 3 below).

The most important **public authorities** having distinguished roles and responsibilities in electricity crisis management are the following:

#### High Commission for National Protection (HCPN)

At the national level, the missions of the HCPN can be divided into four groups:

- coordinating counter-terrorism measures,
- preventing and managing crises of any kind affecting the vital interests or essential needs of all or part of the country or population,
- protecting critical national and European infrastructures, including in the framework of the EU Critical Entities Resilience Directive where energy figures on top of the list of essential services,
- contributing to the definition and implementation of the national cyber-security strategy.

At international level, the HCPN represents the country at European Union fora, NATO, Benelux, and any other international organisation dealing with the management of crises and civilian emergency response plans. With Luxembourg's neighbours, it is responsible for establishing and maintaining contact with the organisations in neighbouring countries that have similar or identical responsibilities to those of the HCPN.



The head of the HCPN, the High Commissioner, acts as a link between government, private organisations and the public in any kind of crisis.

#### Government commissioner for energy

According to the law on the organisation of the electricity market, the Government Commissioner for Energy is responsible, amongst other tasks, for the monitoring of the national energy supply situation.

#### Institut Luxembourgeois de Régulation (ILR)

By law, the ILR's objectives in relation to electricity include

- to promote a competitive internal market in electricity and natural gas that is secure and environmentally sustainable and effective market opening for all customers and suppliers in the Community, and to ensure appropriate conditions for the effective and reliable operation of the electricity and natural gas systems, taking into account long-term objectives;
- ensuring that customers benefit from the efficient functioning of the market, promoting effective competition and helping to ensure consumer protection;
- to help ensure the most cost-effective, non-discriminatory, secure, reliable, efficient and consumer-oriented systems;
- help ensure high quality public service, contribute to the protection of vulnerable customers and the compatibility of the necessary data exchange mechanisms to allow customers to switch suppliers;
- facilitate access to the network.

These objectives are complemented by general policy objectives, both European and national, such as maintaining or even increasing competitiveness, respect for the environment, consumer protection, security and quality of supply.

#### Corps grand-ducal d'incendie et de secours (CGDIS)

The CGDIS is responsible for civil protection with the following main missions:

- assistance for people who are in need due to accidents, disasters, fire or other damaging events,
- fire prevention and protection,
- combating pollution from radioactive, nuclear, biological or chemical substances,
- protecting property in the event of fire, disaster or other damaging events,
- international assistance in the event of disasters outside the Grand Duchy, and
- ensuring medical emergency services.

Depending on the type and scale of the crisis, CGDIS may be supported by other national services such as the national armed forces, national road administration, etc.

## Police grand-ducale

The police are a national service responsible for ensuring internal security. It ensures respect for and contributes to the protection of individual rights and freedoms and acts through preventive, proactive, dissuasive, and repressive actions.

In carrying out their administrative police duties, the Police ensure

- maintaining public order,
- the execution and respect of general and municipal police laws and regulations,
- the prevention of offenses, and
- protection of people and property.

Further tasks result from their judicial police duties. In addition, and pursuant to article 42 of the law on the police grand-ducal, the national armed forces intervene to assist the Police in their missions upon requisition by the competent authorities in the cases provided for by the law.

## Municipalities

Communes in Luxembourg hold general administrative police powers and are therefore responsible for maintaining public order under the Decree of 14 December 1789 on the Constitution of Municipalities. Public order is typically defined by public safety, tranquility and hygiene. Specific duties related to emergency assistance to the population, carried out by the CGDIS as the operational arm of the communes or the State, are based on the 1790 decree.

These decrees assign administrative police responsibilities to municipal authorities, while the internal distribution of these powers is defined by municipal law. The municipal council manages all matters of communal interest and holds the primary regulatory authority in administrative policing. The college of mayor and aldermen has exceptional regulatory powers in urgent situations. The mayor is responsible for enforcing national and local police laws and regulations, issuing individual decisions such as permits, prohibitions, or orders.

Overall, the communes' obligations to safeguard people and property stem directly from their administrative police responsibilities.

## Information and press service (SIP)

The SIP is the body responsible for circulating communications from the Luxembourg Government. It is attached to the Ministry of State and is under the direct authority of the Prime Minister. The main missions of the SIP are as follows:

- ensuring the communication of information about State activities to the press, the media, the public and interested parties,
- defining and implementing the Government's communication policy with regard to Internet and the social media,
- keeping the Government informed of current affairs dealt with in the press and the media,
- publishing and circulating documents and information of all kinds,
- defining and implementing a policy of promoting open data and access to information, and

- facilitating the work of journalists and media representatives.

## 2.2 System operators

Based on the European and national legal framework, and specifically pursuant to article 9 of the national law on the organisation of the electricity market, the transmission, distribution and industrial system operators have far-reaching responsibilities for security of supply and the reliability of the electricity system. They are responsible for the planning, execution, maintenance and operation of high, medium and low voltage power grids, and obliged, jointly with producers and suppliers, to guarantee the security of supply of electricity to end customers within economically justifiable limits.

## 2.3 Final customers

While final customers are rather “passive” in terms of crisis management, they may nevertheless have an important role through their activity in terms of instantaneous electricity demand and production that impacts the balance and thus stability of the electricity system. Specifically, guidelines or legally binding instructions may be given by public authorities and followed by final customers, such as voluntary or mandatory demand reductions during a specific period in time.

Furthermore, final customers bear responsibility for their own preparation for a possible interruption of supply by means of business continuity plans. This is particularly relevant for critical infrastructures which have an obligation to establish such plans according to national legislation.

## 3. Procedures and measures in the electricity crisis

To illustrate the general logic of the development of a crisis, Figure 2 shows the different crisis levels as defined in the Regulation as well as the corresponding timeline.

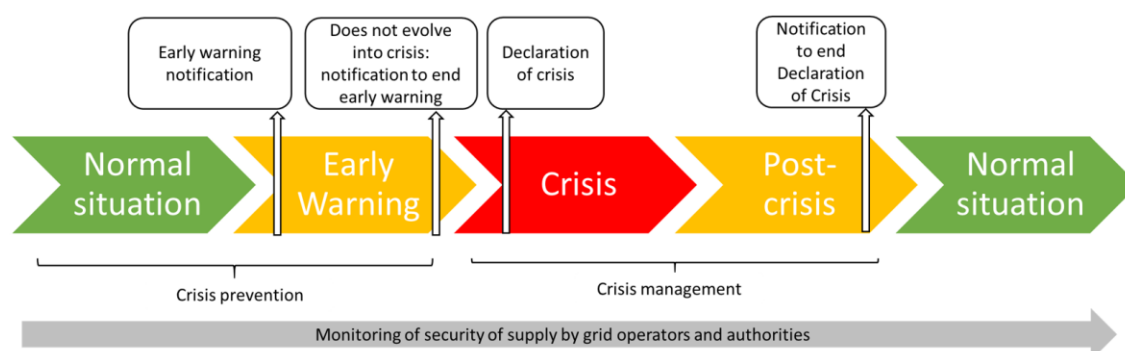


Figure 2: Timeline of a crisis scenario

**Normal system operation** is defined as a time during which the system is operating within a range of normal conditions, without extraordinary measures taken by neither the system operators nor the authorities. System operators, authorities and other entities active in the electricity market deploy and further develop preventive measures to ensure the system remains in normal conditions.

In accordance with Article 2, paragraph 18, of the Regulation, an **early warning** means a provision of concrete, serious, reliable information indicating that an event may occur which is likely to result in a significant deterioration of the electricity supply situation and is likely to lead to electricity crisis. Once such a potential yet concrete risk of deterioration is detected, the entities having a role and responsibility assess the situation and take action to address and mitigate the specific risk. Such situations may allow anticipating a risk a few hours, days, or even weeks ahead and to take

corresponding action, as described in detail in Section 3.1.3. Being in a stage of early warning implies measures to be taken that go beyond normal system conditions, however, with the system still being able to be run without last resort measures such as load shedding or even uncontrolled interruption of services (such as a blackout). Nevertheless, the general crisis management may still be activated already at the early warning stage, especially if the materialisation of the specific risk at hand would likely cause negative effects that are broader than just within the electricity sector.

In contrast, and according to Article 2, paragraph 9, of the Regulation, an **electricity crisis** means a present or imminent situation in which there is a significant electricity shortage [...], or in which it is impossible to supply electricity to customers. For instance, a persistent national blackout would clearly meet this criterion. This situation would trigger the actual crisis management and thus the escalation of the appropriate emergency plans to mitigate the impact of the crisis on electricity customers and society at large, and to restore normal conditions as swiftly as possible.

It should be noted that it is possible to move from a normal situation directly into a crisis, i.e., without having declared an early warning in between, and that not every early warning necessarily results in a crisis situation.

In the wake of an electricity crisis, a **post-crisis** phase would likely be used to observe and ensure stability before reaching again a **normal situation**.

Security of supply is being monitored by grid operators and authorities alike during all the phases depicted above.

## 3.1 National procedures and measures

### 3.1.1 Overview

Risk preparedness measures can be structured along the dimensions depicted above, i.e.

- **Crisis prevention measures** prior to the specific knowledge of any concrete incident that might cause an electricity crisis, i.e. in preparation of all types of scenarios
- **Early warning measures** during a situation of imminent concrete risks for a specific crisis to occur and in view of avoiding the crisis to materialise
- **Electricity crisis measures**, including the preparation for an unavoidable specific crisis as well as the mitigation of adverse effects during and shortly after the crisis
- **Communication**, a horizontal element in parallel to the three aforementioned phases

An overview of the national procedures and measures is provided in Figure 3 with the help of the four dimensions depicted above. They are discussed in more detail in sections 3.1.2 - 3.1.5 with the exception of regional measures that are described in Section 3.2.

It should be noted that neither the overview nor the explanations in sections 3.1.2 - 3.1.5 are meant to be fully exhaustive as further procedures and measures may be applied depending on the specific situation. Furthermore, the application of specific measures is not necessarily linked to the specific phases, but may be delayed or brought forward.

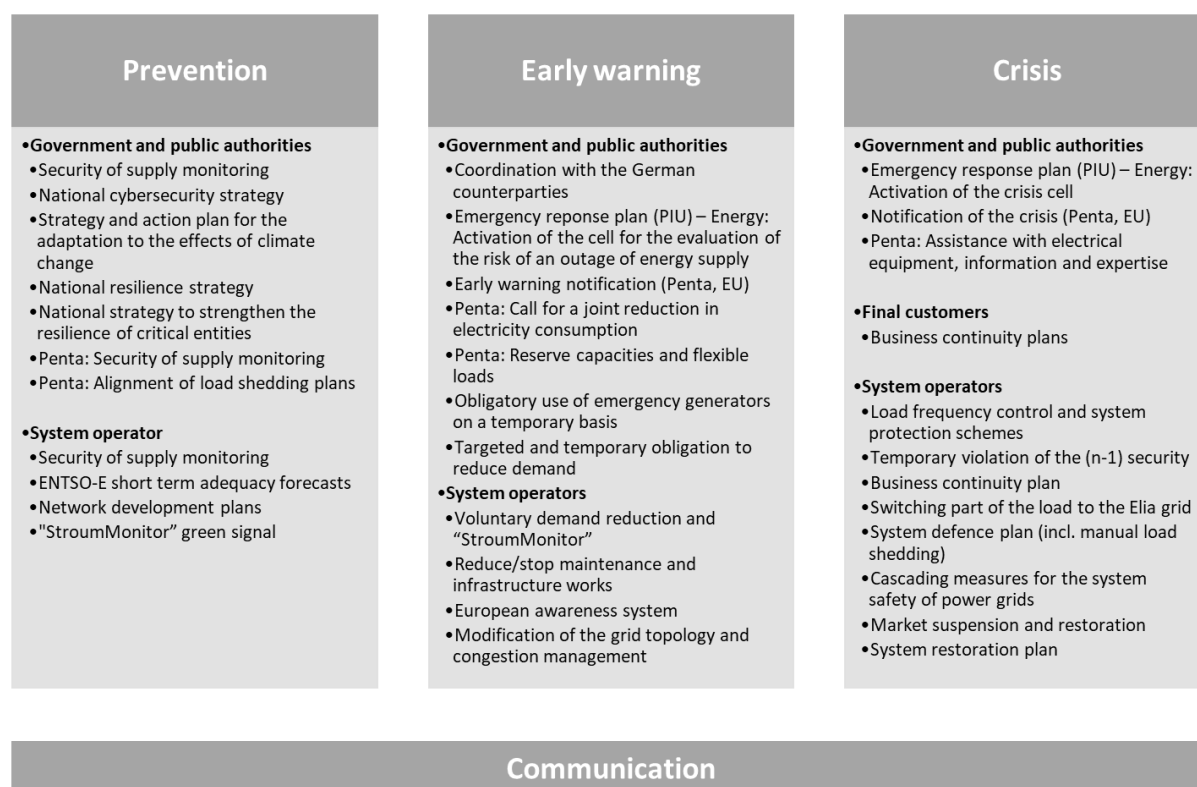


Figure 3: Overview of the national procedures and measures<sup>5</sup>

## 3.1.2 Prevention

### 3.1.2.1 Government and public authorities

#### Report on Security of Supply

Pursuant to article 11 of the law on the organisation of the electricity market, the Government Commissioner's **Report on Security of Supply**<sup>6</sup> provides an analysis of the current situation of supply related to generation and demand, the amount of import capacities and the condition of the grid. Furthermore, it introduces an outlook on the expected development concerning the level of security of supply over the following years. The report is updated every two years and builds upon detailed information from the entire electricity sector. Specifically, system operators submit their inventory as well as their planning for investments in the subsequent decade, allowing for a detailed analysis of Luxembourg's grid infrastructure. The most recent update of the report, which was published in July 2024, included a thorough revision of the report structure, giving a more detailed analysis of the national and regional developments in regard to the security of supply from market and grid perspectives. The report highlighted amongst other things the current and expected national developments in the electricity sector, the future need for flexibility in the electricity system and the importance of the expansion of grid infrastructure for Luxembourg. With Germany, two 220 kV double circuit transmission lines are in place, which are connected to the Amprion grid, with a total import capacity of approximately 2000 MVA. This large import capacity ensures that Luxembourg can cover

<sup>5</sup> Note that original titles for several items are in French

<sup>6</sup> Original title *Bericht über die Versorgungssicherheit im Strombereich in Luxemburg*

its peak electricity consumption even during an unavailability of one of the double 220 kV transmission lines (n-1 security). Considering the geopolitical situation of 2022 and the possibility of an increased demand for heating purposes in the potential absence of other fuels, the large import capacity also allows for an increase in electricity demand in the near future. An upgrade of one of these two lines to 380kV will further enhance security of supply in the country. Nevertheless, depending on the increase of consumption volumes and patterns, further grid expansion is expected to be needed.

### Strategy and action plan for the adaptation to the effects of climate change

The Luxembourg Government's **Strategy and action plan for the adaptation to the effects of climate change in Luxembourg (2025-2035)**<sup>7</sup> identifies the impacts of climate change on a broad range of sectors, and presents a list of measures to adapt accordingly. For the case of energy, the document refers to the following three elements:

- Increased impacts of extreme events → Enhance national risk preparedness, assess and strengthen existing energy infrastructure against vulnerabilities to extreme events, and deepen regional cooperation
- Change in electricity demand → Take measures to raise awareness of energy conservation and deployment of decentralised solar energy and other unused energy sources and enable flexibility sources in the electricity system
- Diversification of the energy supply → Promote a balanced expansion of renewable energy while systematically reducing reliance on fossil fuel imports

### National Cybersecurity Strategy

The **National Cybersecurity Strategy**<sup>8</sup> for the period up to 2025 sets out the guidelines underlying the projects that the Government intends to implement in order to secure cyberspace at all levels. It aims to enable all actors to participate fully in a digital society and to access the new technologies in a secure environment. The measures that will be implemented are designed in the first place to ensure that Internet users are aware and to strengthen their trust in the digital world. Furthermore, they consist in consolidating and strengthening the security and resilience of digital networks and infrastructures. Lastly, the strategy seeks to take account of cybersecurity as a factor of economic attractiveness and to complement the strategy of dynamisation that characterises the digital sector towards the continued development of a high-performance digital economy. It should be noted that a new strategy is currently under development and is expected to be published in 2026.

### National Resilience Strategy

The **National Resilience Strategy** was presented in October 2025. The strategy is aimed at strengthening the country's capacity to anticipate, absorb and overcome major disruptions and to build a more robust and cohesive society. The strategy implementation is coordinated by the High Commission for National Protection (HCPN). It requires a government-wide effort and is based on an integrated, **all-risk**, **pan-societal** and **pan-governmental** approach, in line with the guidelines of the European Union and NATO.

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<sup>7</sup> Original title *Projet de Stratégie et plan d'action pour l'adaptation aux effets du changement climatique au Luxembourg (2025-2035)*

<sup>8</sup> Original title *Stratégie nationale de cybersécurité IV (2021-2025)*

This strategy reflects the mutual interdependence of civil and military preparedness, and is based on eight pillars that form the basis of the concept of national resilience:

1. Defence of democracy, the rule of law and government
2. A resilient society
3. Essential goods and services and critical infrastructure and entities
4. A resilient economy
5. Integrated management of strategic and logistical resources
6. Cyber resilience
7. Civil defence
8. Protection and defence of the national territory and that of allies

### National strategy to strengthen the resilience of critical entities

Luxembourg adopted its National Resilience Strategy in October 2025, built around eight interdependent pillars. While the resilience of critical entities appears across several pillars, it is primarily rooted in Pillar 3, which focuses on essential goods and services as well as critical infrastructures. The **National strategy to strengthen the resilience of critical entities**<sup>9</sup> continues and supports the goals of the National Resilience Strategy, following a whole-of-government, all-sector, all-hazards approach.

To be fully effective, this strategy also incorporates the broader European and international context. At EU level, protecting critical infrastructure and ensuring the resilience of critical entities is key to safeguarding the internal market. Within NATO, civil preparedness is seen as a core component of national resilience and a crucial enabler of collective defense.

The Critical Entities Resilience Strategy was developed in line with Article 4 of EU Directive 2022/2557 on the resilience of critical entities. The strategy was finalised and approved by the Government Council in December 2025.

#### 3.1.2.2 System operators

##### Security of supply monitoring

The main preventive measure of system operators is to ensure a fully functional, adequate and resilient supply system. Pursuant to article 9 of the law on the organisation of the electricity markets, system operators are, jointly with producers and suppliers, obliged to ensure the security and quality of supply, both in the short as well as in the long-term.

##### Network development plans

For the long-term, and in accordance with **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**, they elaborate **Network Development Plans** at least every two years. The plan shall contain efficient measures aiming to guarantee the adequacy of their respective system and its

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<sup>9</sup> Original title : Stratégie nationale pour renforcer la résilience des entités critiques

security of supply. The network development plan of TSO Creos plays a particularly important role to ensure security of supply in the long-term.

### Short-term adequacy forecasts

The process of **short-term adequacy forecasts** represents a complementary preventive measure. This forecast comprises a regional check and update of short-term active power adequacy diagnosis for shorter timeframes than seasonal outlooks such as the one prepared half-yearly by ENTSO-E. The short-term adequacy forecast perform an analysis of detailed information on production, consumption and available grid capacities. It is executed by the TSO or the Regional Coordination Centre (RCC), respectively.

In addition to the short-term adequacy forecasts, the TSO performs regular demand and production previsions on weekly, 2 days ahead, day ahead, intraday, 15-minute and real-time schedules. The TSO is in contact with the RCC on a daily basis and regular contact is maintained with TSOs of the directly interconnected countries (Amprion, Germany & Elia, Belgium & RTE, France). The regular contact with Amprion is particularly important because of the strong import dependence from Germany. Due to this strong dependence, Amprion alerts Creos as soon as possible if a shortfall, an imbalance or an N-1 grid security violation is to be expected.

In general, the TSOs and the RCC can detect a threat of a shortfall by analysing for example:

- The weather forecasts
- The production prospects
- The information from the energy markets.

Further details on the cooperation between TSOs and the RCC is provided in section 3.2.2.3.

## 3.1.3 Early Warning

### 3.1.3.1 Government and public authorities

#### Coordination with the German counterparties

In addition to the procedures followed by the TSO and competent authority to monitor security of supply on a continuous basis, the general state of the system and interconnections as well as the balance between supply and demand within the German-Luxembourgish electricity market is monitored jointly with the respective German counterparties. The measure makes it possible to remain vigilant and, if necessary, to take anticipatory measures in the event that supply problems are becoming more likely to occur.

#### Emergency response plan

The **Emergency response plan for an outage of energy supply<sup>10</sup>** represents the Government's plan for emergency intervention in case of an electricity crisis that may be caused by any of the national crisis scenarios depicted in section 1 or any other scenario affecting security of supply. It determines the required bodies for the crisis management, the definition of emergency measures and procedures for

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<sup>10</sup> Original title *Plan d'intervention d'urgence (PIU) "Rupture d'énergie"*



their activation, as well as procedures of information flows among authorities as well as with the public.

Besides the emergency response plan for an outage of energy supply, there are eleven such emergency response plans in total, which are regularly reviewed and updated<sup>11</sup>. For the scenarios “nuclear accident” and “cyberattack” that were identified as particularly relevant for Luxembourg (cf section 1), specific response plans are in place, i.e. **Emergency response plan in the event of a nuclear accident**<sup>12</sup> and **Emergency response plan for an attack against or the outage of information systems**<sup>13</sup>, respectively. Other emergency response plans may affect the electricity sector and involve actors from the sector, irrespective of the question whether the corresponding scenario has been identified as particularly relevant for the context of risk preparedness in the electricity sector in Luxembourg for the sake of this present plan (cf Figure 1). For instance, for the case of flooding, dedicated risk management and emergency response plans exist that include several elements related to energy and electricity in particular<sup>14</sup>.

In order to be able to deal with the fact that crisis situations may unfold from different angles and fall into the field of more than one emergency response plan, the same general approach and structure is applied to all of them. This allows complementing coherently certain measures or crisis bodies by elements of adjacent emergency response plans (for instance, in case of an electricity supply shortage caused by a cyber-attack). While the structure deliberately foresees a certain level of flexibility in order to be able to respond to the situation-specific needs and requirements, it is nevertheless to be expected that the emergency response plan for an outage of energy supply is the pivotal element in case of a large-scale electricity outage. The main elements of this plan are as follows:

In order to evaluate the extent, origin and likely duration of the outage of energy supply, the situation is continuously assessed by the **cell for the evaluation of the risk of an outage of energy supply (CERR)**. The cell is responsible for following the evolution of the situation and for informing the **crisis cell** about its assessment. It is composed, amongst others, of experts from the High Commission for National Protection (HCPN) and the Ministry of the Economy, and is chaired by a representative of Creos.

Creos invites the partners mentioned above to a technical briefing, which takes place as soon as possible after the notification of a potential shortfall. During the technical briefing, Creos gives more information on the following elements:

- The cause;
- The estimated impact of the shortfall;
- The expected duration;
- The size of the shortfall and;
- The day on which the actual shortfall is to be expected.

During this technical briefing, the most appropriate measures (refer to figure 3 for a non-exhaustive list of potential measures) to avoid or to limit the expected electricity shortfall and the need for the activation of the crisis cell will be discussed.

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<sup>11</sup> The eleven emergency response plans are Nuclear Emergency; Extreme Weather Conditions; Chemical, biological, radiological or nuclear substances; Terrorism; Influenza and pandemics; Flooding; Power Cut; Ebola; Drinking water; Cyber; and Mass casualties.

<sup>12</sup> Original title *Plan d'intervention d'urgence (PIU) en cas d'urgence nucléaire*

<sup>13</sup> Original title *Plan d'intervention d'urgence (PIU) "Cyber"*

<sup>14</sup> Cf *Hochwasserrisikomanagementplan-2021-2027*

Depending on the severity of the shortfall or the timescale, a shortened procedure can be applied and the crisis cell can be activated immediately.

#### Early warning notification

The competent authority gives an early warning notification to the Commission and competent authorities of Member States within the same region in accordance with article 14 of the **Regulation (EU) 2019/941**, following a substantiated indication of a specific risk, detected by the TSO and subsequent recommendation of the cell for the evaluation of the risk of an outage of energy supply or on its own initiative.

#### Obligatory use of emergency generators

The obligatory use of emergency generators during an expected shortfall is as an effective measure to address an electricity shortfall through reduced grid demand. In application of this measure, the consumer essentially disconnects from the grid before the expected shortfall and runs its system in an islanded mode. Data centres for example have been identified as a potentially important contributor in this measure as their high redundancy allows them to operate in an islanded mode while still maintaining a high operational security.

The measure would be introduced via the means of a grand-ducal regulation and would be announced early enough for concerned parties to be able to prepare and respond. Given the technical and procedural possibilities to predict such shortfalls, a typical period of notification would be in the range of 1-7 days. Operators of critical infrastructures are excluded from this measure.

#### Obligatory demand reduction

Obligation of targeted and temporary reduction of demand aims at reducing overall demand before proceeding to administrative manual demand disconnection. The measure is envisaged especially for state and municipal actors, e.g. through mandatory reduction of public lighting, shutting down of computers, or closing of certain public buildings (sports hall, etc.).

#### 3.1.3.2 System operators

##### Voluntary demand reduction and “StroumMonitor”

Voluntary measures aim to encourage all energy consumers to strive for a reduction in their energy consumption, including electricity. For instance, a campaign launched in the context of the war in Ukraine and corresponding energy crisis, four categories of energy consumers were addressed:

1. State actors
2. Municipal actors
3. Companies
4. Citizens

While the campaign was focused on savings in natural gas, it was from its outset not limited in scope and also comprised electricity savings measures due to strong interdependencies between the two sectors. For instance, municipalities undertook significant efforts to reduce electricity consumption in the field of public lighting, and recommendations were provided regarding the use of heat pumps.

To trigger **voluntary demand reduction**, an electricity monitor (StroumMonitor) was developed by Luxembourg's TSO Creos to alert and launch **saving appeals to final costumers**. These saving appeals can be activated to address different levels of severity by means of a traffic light system. Specifically, a call for reduction of demand can be communicated during specific hours where a shortfall in electricity is expected with the objective to avoid as far as possible the activation of more severe options such as manual load shedding. The saving appeal is communicated through a website widget, which is easily accessible for the general population. Figure 4 shows an example of the layout of the StroumMonitor.



Figure 4: Electricity monitor "StroumMonitor" layout (illustration only)

In the widget, the green signal is the default signal of the StroumMonitor. It means that the level of electricity consumption is lower than the available production for the day and that we have sufficient margins. The orange signal is calculated according to available margins based on ENTSO-E's Short-Term Adequacy Forecasts (STA). It is activated when the available electricity reserves are low, i.e. when the available production is very close to the expected consumption level. The red signal is activated when there is not enough electricity to cover all needs.

In addition, the widget also indicates peak hours according to production and consumption forecasts on a daily basis to incentivize enhanced flexibility and peak load shaving.

To support the saving appeals, a dedicated website may be created, which describes easy-to-apply saving measures for both individuals and companies. The general advice would be to avoid high power applications during times of tension and shift them to less stressed times. The message may be echoed and reinforced through dedicated communication channels (communiqué de presse, etc.) to achieve a reduction of electricity consumption in anticipation of the expected shortfall and to avoid the activation of manual load shedding or even a complete blackout.

To reinforce the message, the TSO/DSO may also contact certain industries directly to inform them of the situation and to inquire if a reduction in demand can be arranged for the predicted day of the shortfall.

#### Reduce / stop maintenance and infrastructure works

This measure can be implemented by the TSO and/or the DSOs following the anticipation of a major physical problem on their network. It consists of reducing scheduled maintenance interventions, as well as infrastructure works on specific network elements during the early warning period. This measure can go, if necessary, to the cancellation of all scheduled maintenance interventions and infrastructure works. This measure ensures maximum availability of the transmission and distribution network and thus reduces the short-term risk of electricity shortages.

## European Awareness System

The European Awareness System (EAS) was launched in April 2013 and serves as an important collaborative tool for ENTSO-E TSO members. The EAS allows TSOs to share and monitor real-time information on the transmission systems across Europe, and react quickly with assistance or system measures if an area appears to be under stress, both in the prevention and resolution of disturbances.

## Modification of the grid topology and congestion management

Regular modification of the grid topology and the application of congestion management procedures in the capacity calculation region pursuant to **Commission regulation (EU) 2015/1222 of 24 July 2015 establishing a guideline on capacity allocation and congestion management** are standard procedures to control the grid load. The unavailability of transmission lines or generation units, for instance caused by a physical or cyberattack, severe accidents or extreme weather situations may cause overloads of the transmission and distribution grids.

**Modification of the grid topology**, e.g. by changing the interconnection of lines in substations and/or coupling or decoupling of busbars, is a measure that can be taken rapidly and mostly remotely with the aim to avoid unacceptable loadings of assets that may cause further outages.

Topological measures may be supplemented by applying **congestion management** in a grid convenient way, such as redispatch of power production from one location to another. Due to the small size and the properties of the national energy supply system, congestion management potential in Luxembourg is very limited.

### 3.1.4 Electricity Crisis

#### 3.1.4.1 Government and public authorities

##### Emergency response plan

If the assessment done in the CERR during the early warning phase showed that an imminent crisis or present crisis is unavoidable, the **crisis cell** according to the **Emergency response plan for an outage of energy supply** is activated.

- The **crisis cell** is activated by the Prime Minister and Minister of State in case of an imminent or present crisis. The cell is responsible for directing, coordinating and monitoring all measures for managing the crisis with the aim to restore normal conditions. Members of the crisis cell are representatives of the relevant ministries, administrations and services depending on the nature and scope of the crisis. The crisis cell can be expanded depending on the circumstances for instance by representatives of the energy sector or representatives of other relevant ministerial departments.
- The crisis cell can authorise an **operational cell** to implement, execute and supervise the directed measures and actions. An operational cell is chaired by a person appointed by the leader of the crisis cell.
- The task of the **cell for communication and information** is to inform the population and the media about the crisis situation and to provide regular updates when possible. Several crisis

messages have been prepared in advance to quickly inform the general population and give possible behavioural instructions to stay safe and informed.

Legally, temporary measures ordered by the government in an imminent or present crisis situation aiming to safeguard the electricity supply are covered by article 13 of the law on the organisation of the electricity market. It should be noted that such measures do not give rise to any form of financial or other type of compensation, and do not require the prior agreement of the electricity consumers concerned.

Specifically, measures may be activated by the crisis cell in order to minimise the overall impact on national economy and social life, such as

- the activation of the national demand disconnection procedure as depicted in the system defence plan (see section 3.1.4.2 below) by system operators
- the activation of the restoration plan (in case of a blackout situation) by system operators
- removal of physical impact (e.g. overthrown trees in overhead lines), emergency repair of transmission infrastructure, and installation of mobile generators by CGDIS and system operators

Meanwhile, system operations and other bodies do not necessarily have to wait for instructions from the Government in case of a crisis, as they often have dispositive power to activate a large number of measures themselves, as laid out in the various plans governing their roles and responsibilities. Indeed, necessary response times for operational measures are often extremely, such that related decisions need and can be taken by system operators without prior approval. A concrete example are load shedding plans that do not require the authorities' approval before activation (for details, see section 3.1.4.2 below).

### **Crisis management in case of a cyberattack**

In the specific case that the crisis is the result of a cyberattack, and depending on the role of respectively for energy therein, crisis management either follows or is complemented by the steps described in the ***Emergency response plan for an attack against or the outage of information systems***. Drawn up using the same logic as the ***Emergency response plan for an outage of energy supply***, the plan foresees the following bodies:

- The **crisis cell** is activated by the Prime Minister and Minister of State in case of an imminent or present crisis. The cell is responsible for directing, coordinating and monitoring all measures for managing the crisis with the aim to restore normal conditions. Members of the crisis cell are representatives of the relevant ministries, administrations and services depending on the nature and scope of the crisis. Depending on the circumstances, the crisis cell may be expanded by including representatives of further relevant ministerial departments and supplemented by representatives of Internet Service Providers and further organisations that are affected by the attack.
- The crisis cell can authorise an **operational cell** to implement, execute and supervise the directed measures and actions. It is chaired by a person appointed by the leader of the crisis cell.

- The role of the **cyber risk assessment cell** is to monitor the situation and to inform the crisis cell about its assessment.
- The task of the **cell for communication and information** is to inform the population and the media about the crisis situation.

In the case of an electricity crisis caused by the cyberattack, mitigating measures emanating from the Emergency response plan for an attack against or the outage of information systems may be activated. The crisis cell assesses the degree of urgency and the impact of the incident on Luxembourgish territory in order to determine the severity of the situation and to identify all systems impacted directly or indirectly (collateral damage). Based on the results of this assessment, the coordination and cooperation between the actors involved as well as the international cyber emergency response team (CERT) community can be organised. The role of the cyber risk assessment unit role is to monitor any critical national cyber-security incident or threat and to continuously keep the crisis cell informed. It consists of experts and offers a strengthened surveillance and vulnerability analysis within the national emergency response plan. It identifies potential targets, listed according to the type of attack, and ensures an upgrading and protection of threatened information systems. The unit can implement protective measures where targets have been confirmed and preventive measures where potential targets have been determined. It can also partially or totally isolate a target by disconnection if deemed necessary and appropriate.

If the event constitutes a crisis of significant magnitude and considerable impact, the crisis cell can request support by public administration experts in the field of information and communication system security through the activation of the national cyber reserve. For specific areas, the reserve can be supplemented by experts from the private sector or from international organisations of which Luxembourg is a member.

Further assistance can be requested via non-governmental CERTs.<sup>15</sup>

In addition to the governmental emergency response plan, the Network Code on Cybersecurity (NCCS) adopted on March 11, 2024, provides an additional level of resilience and crisis management. The NCCS focuses in particular on cross-border electricity flows and mandates the establishment of mechanisms for sharing information related to cyber threats, vulnerabilities, and incidents among relevant stakeholders. This includes collaboration with national Computer Security Incident Response Teams (CSIRTs) and coordination through networks like the Cyber Crisis Liaison Organisation Network (CyCLONE) to facilitate a unified response to large-scale cybersecurity incidents. In addition, the NCCS requires high and critical impact entities to establish cybersecurity crisis management plans and the organisation of cybersecurity exercises on an entity, national and regional level. The national regulatory authority Institut Luxembourgeois de Régulation (ILR) was designated as the Competent Authority for the national implementation of the NCCS. For the implementation of the network code, ILR is working closely with other public authorities such as the Ministry of the Economy and the national crisis centre.

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<sup>15</sup> The cyber emergency response community Luxembourg initiative “cert.lu” serves to enhance the collaboration between public and private CERTs in Luxembourg.

### **Crisis management in case of a nuclear accident**

For the crisis scenario of a nuclear accident, the preparatory measures according to the ***Emergency response plan in the event of a nuclear accident*** are applied.

- The Prime Minister activates the **crisis cell**. The crisis cell initiates, coordinates and monitors the execution of all the measures intended to deal with the crisis and its effects. In addition, the crisis cell works closely with its foreign counterparts.
- The main task of the **radiological evaluation cell** is to suggest appropriate emergency measures to the crisis cell, monitoring changes to the state of the damaged reactor, the scale and changes to radioactivity in the environment and its impact on the population. The aim is to provide the best possible protection for the population against all the dangers associated with ionising radiation. The members of this cell also work closely with their foreign counterparts. The radiological evaluation cell comprises experts from the Department for Radiation Protection at the National Health Directorate and members of CGDIS.
- The task of the **communication/information cell** is to support the crisis cell in its efforts to coordinate communication between the authorities and the population. It keeps the media and citizens informed of the changing situation as well as the prescribed preventive and protective measures.

As soon as the Luxembourg 112 emergency call centre is informed of a nuclear accident, it alerts the radiological evaluation cell, which immediately carries out an evaluation of the information available. If the accident is likely to pose a danger to the population, the High Commissioner for National Protection is informed.

After consulting with CGDIS and the Department for Radiation Protection at the National Health Directorate (Division de la radioprotection de la Direction de la santé), the High Commissioner for National Protection informs the Prime Minister and Minister of State who decides whether to activate the crisis cell.

The execution of this plan falls within the competency of the Prime Minister and Minister of State, the Minister for Home Affairs and the Minister for Health. All further ministries, agencies and departments of the State are bound to cooperate with the implementation of the plan using all the means available to them. Local authorities are considered key partners in this process.

For the crisis scenario of a nuclear accident, mitigation measures according to the ***Emergency response plan in the event of a nuclear accident*** are taken. These measures (taking shelter, taking potassium iodide tablets, evacuation) mainly serve to protect public health but may corrupt the ability to control the energy supply system. In case that power plants or control centres are within the region of contamination, the operation of the electricity system will be adapted to the emergency situation in order to maintain the electricity supply as far as possible. With respect to the Luxembourgish transmission grid, this is achieved by transferring the functionalities of the main control system to backup systems that can be operated in a decentralised way.

In case the event leads to a shutdown of major power plants in the region of Luxembourg and its surroundings or if grid operation is significantly disturbed, cross-border support from energy suppliers and system operators of less affected regions may be needed in order to maintain the electricity supply.



### **Crisis management in case of extreme weather and flooding**

The ***Government crisis management plan in the event of bad weather and flooding*** addresses a wide range of possible threats with varied impacts, providing essential tools for those responsible to react flexibly and appropriately. It consolidates various meteorological and hydrological phenomena into a single plan, replacing previous emergency intervention plans for weather and floods.

The plan identifies several phenomena that could escalate into a crisis, including:

- Wind
- Rain
- Snow or ice
- Storms
- Flash floods
- Heat
- Cold
- Flooding

It outlines the activities and measures that state entities and the government must implement to address the effects of these crises. Specifically, the plan defines:

- Crisis management bodies and their functioning
- The alert process for authorities and public information
- Specific emergency actions and the actors responsible for them

All ministries, administrations, and state services are required to fully cooperate to achieve the plan's objectives. They must establish and maintain internal procedures to implement the plan's provisions. At the local level, municipalities exercise their competencies according to their legal missions.

**MeteoLux** manages the activation of different alert levels based on the evolution of weather phenomena. They use weather forecast models, observations from weather stations in Luxembourg, as well as data from international organizations and partners. Collaboration and communication with neighboring countries' meteorological services are complementary and continuously deployed. MeteoLux is the authority responsible for issuing alerts for weather phenomena such as wind, rain, snow or icy precipitation, storms, heat, and cold. Regardless of whether a crisis cell is activated, MeteoLux assesses potential risks and dangers related to the forecasted weather situation and informs the CGDIS and the HCPN's permanent staff. When a crisis cell is activated, MeteoLux continues to evaluate the situation and regularly informs the crisis cell.

In addition to Meteolux, the **Flood Forecasting Service (Service de prévision des crues – SPC)** manages the activation of different management phases based on the water levels at various gauging stations and the weather situation. They use a flood forecasting model that relies on data from the hydrometeorological measurement network and weather forecasts.

In case of a heightened alert level, HCPN can activate the **Extreme weather-Flooding Evaluation Cell (CERI)**. Based on information reported by the CERI, the Prime Minister is responsible for the decision to declare a crisis and to activate the **crisis cell (CC)**.

Under the Government's authority, the CC makes strategic decisions to initiate and coordinate all measures to address the crisis and its effects. This does not exempt the relevant ministries,



administrations, and state services from taking immediate measures within their remit or establishing an internal crisis cell.

The CC is composed of representatives from the relevant ministries, administrations, and state services, depending on the nature and scope of the crisis. Due to the potential of extreme weather events affecting the electricity sector, the **Government Commissioner for Energy** is included in the crisis cell. The Prime Minister appoints a minister to chair the CC based on the nature of the events. Typically, the Minister of Internal Affairs presides over the CC under the plan.

#### Notification of the crisis

The competent authority sends a crisis notification to the European Commission and competent authorities of Member States within the same region in accordance with article 14 of the **Regulation (EU) 2019/941**, following the detection of an imminent blackout or if a blackout has already occurred.

#### 3.1.4.2 System operators

A large number of technical measures is activated automatically as they are embedded in real-time grid-operation procedures and therefore contribute to prevent an electricity crisis at very short timescales. In addition, the European legal framework defines further grid related procedures in particular in **Commission regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation** (hereafter 'System Operation Guideline'), which includes amongst others the following operational measures:

#### Load frequency control and system protection schemes

In situations where the above corrective measures in real-time have not been effective to safeguard security of supply, system operators are equipped with more exceptional measures and procedures for crisis management. Besides national law governing roles and responsibilities for system security, the **System Operation Guideline** as well as **Commission Regulation EU 2017/2196 of 24 November 2017 establishing a network code on electricity emergency and restoration** (hereafter '**Network Code E&R**') provide a European framework with harmonised rules for technical and organisational measures to prevent the spread or amplification of an incident in a national network and the spread of disturbances or blackout conditions to other networks.

**Load frequency control** serves to compensate imbalances between generation and consumptions and deviations from nominal frequency involved. With respect to the national crisis scenarios, there are various incidents that might cause relevant imbalances. These include attacks against critical assets, industrial accidents or the disconnection of consumers or generation units. The load-frequency control mechanism for the Creos transmission grid is embedded in the common Creos-Amprion load-frequency control area (which is operated by Amprion) of the load-frequency control block of Germany, Luxembourg and Denmark (West).

**System protection schemes** are part of the real-time grid operation. In the Luxembourgish system such protection procedures exist for the automatic disconnection of demand as a last resort in case of underfrequency configured by Creos in accordance with the requirements of ENTSO-E and are installed for preventing a voltage collapse by blocking the automatic step changing on the high voltage transformers. Furthermore, special protection schemes (SPS) are case specific measures for unexpected events that emerge and develop in such a short period of time that manual intervention is not possible. SPS are automatically activated when a predefined condition is reached. In the

Luxembourgish system a SPS is established for the condition that the connection to the Amprion grid is interrupted. In this case the Creos network will be automatically split to avoid a total blackout in Luxembourg.

#### Temporary violation of the (n-1) security

The system operator may also accept a **temporary violation of the (n-1) security** criterion provided that this allows to avoid the activation of measures with extensive impact on clients and market participants (disconnection of generators/consumers, restriction or suspension of the energy market) and to regain (n-1) security after short time. Such temporary non-compliance with the (n-1) security criterion is compatible with the article 35 of the System Operation Guideline.

#### Business Continuity Plan

In line with article 24 of the **System Operation Guideline**, TSO Creos has developed and adopted an internal **Business Continuity Plan** detailing its planned responses in a crisis situation. Critical business processes have been identified, and mitigation procedures are defined to mitigate the negative impacts by means of measures in the field of IT, telecommunication, critical infrastructure, etc. The plan is an important element to avoid business interruption or at least reduce downtimes to a minimum in case of an emergency. The plan is reviewed and tested regularly to confirm or adjust critical processes, and to train and verify the technical solutions and organisational recovery procedures.

#### Switching of part of the load to the Elia grid

In case the Creos network loses connection with the Amprion grid, it will be split automatically to allow, within the limits of available capacity, the power supply of the southern part of Luxembourg, including the City of Luxembourg, via the Elia grid in Belgium. The rest of the country will be in a state of blackout (cf. section 1.2 of the system restoration plan).

#### System Defence Plan

**Demand disconnection** is a tool that can be used as a last resort by the system operators of to prevent the emergence of major incidents and to limit their consequences when they occur. The **System Defence Plan**, collaboratively drawn up by Luxembourg's electricity system operators, defines the circumstances and conditions under which demand disconnection may be used by electricity system operators, the responsibilities and decision-making procedures associated with the practice of demand disconnection, its operational modalities, as well as the priority rules for demand disconnection of customers with the least damage. It is designed for the current structure of Luxembourg's electricity grids, but also to be easily adaptable to potential changes, in particular possible developments in interconnections with neighbouring grids or in the deployment of control-command systems that facilitate the implementation of demand disconnection.

Demand disconnection is used to ensure operational security of the transmission grid (based on the safety analysis, and in addition to the available corrective measures) or in case the grid is in an emergency state and no corrective measures are available to restore the normal state. An emergency state of the grid may occur in case of significant frequency deviations or malfunctions of tools, equipment, and installations.

As there are no large power plants connected to the Creos transmission grid, and the installed capacity of renewable energy sources like wind, photovoltaics and biomass is still rather small<sup>16</sup>, the potential for shedding generation is highly limited and therefore not particularly relevant in the context of possible measures for national crisis scenarios.

The system defence plan introduces the circumstances to initiate manual load shedding and coordination processes between the system operators, the operational procedures, priority rules and disconnectable consumer groups in hierarchical order. The main provisions are briefly summarised in the following paragraphs.

The activation of demand disconnection can be caused by an electricity shortage observed or anticipated by the system operator, in particular a significant imbalance between electricity supply and demand, the limitation of import capacities below an adequate level to ensure supply in Luxembourg or grid failures resulting in extensive overloading. The measure aims at preventing a cascade of overloads and a collapse of voltage or frequency, which would likely result in a total collapse of the grids in Luxembourg.

The disconnection follows a predefined priority ranking regarding the urgency of electricity supply. This hierarchy is set up in order to meet the country's essential needs and to limit the consequences of demand disconnection as much as possible.

The priority list of electricity consumers comprises the following four levels of priority:

- **N3: High voltage consumers  $\geq 65$  kV**
  - N3.2 High voltage consumers  $\geq 65$  kV except SEVESO and critical infrastructures, with 5 batches in monthly rotation and with flexible allocation by mutual agreement
  - N3.1 High voltage consumers  $\geq 65$  kV classified according to the European SEVESO directive
- **N2: Low and medium voltage consumers  $< 65$  kV**
  - 65/20 kV transformers without critical infrastructures connected, with rotational disconnection
- **N1: Critical infrastructures** as defined in the law of July 23 established by the High Commission for National Protection

Consumers with the lowest priority level (i.e. N3) are disconnected first, while consumers belonging to the highest priority level (i.e. N1) are disconnected last. The priority list was established taking into consideration the economic efficiency and technical feasibility.

The lowest priority level comprises consumers who are directly connected to the 65 kV grid (or higher). The ranking within this level is further refined by giving industrial sites classified according to the European SEVESO directive priority over the remaining industrial sites. The industrial sites are distributed into separate batches of a known total peak demand, which are sorted by monthly rotating schedules to determine which batches are disconnected first in case of an activation of the manual disconnection procedure. The schedule also allows for flexible allocation by mutual agreement, i.e. an

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<sup>16</sup> Automatic disconnection capabilities for specific situations are usually integrated in those units.

industrial site can trade places with another to avoid being disconnected to avoid the disruption of a critical production process for example.

The priority level N2 covers low and medium voltage consumers connected to voltage levels below 65 kV. These consumers are disconnected by switching 65/20 kV transformers which do not serve any higher priority consumers downstream. To the extent possible, low voltage consumers are disconnected on a rotational basis to ensure no consumer is without electricity for longer periods of time. Similar to the N3 priority level, the low voltage costumers are thus grouped into batches.

Lastly, the highest priority level (i.e. N1) includes all critical infrastructures. As defined in the law of July 23 established by the High Commission for National Protection, critical infrastructure means any point, system or part thereof, which is essential to the safeguarding of vital interests or essential needs of all or part of the country or of the population or which is likely to be subject to a particular threat.<sup>17</sup> In a detailed analysis of these critical infrastructures, it was found that electricity supply is essential for the proper functioning of these entities, thus explaining the priority level.

In case of an anticipated enduring crisis situation, the disconnection scheme may apply a rotational procedure consisting in alternately disconnecting different groups of consumers within the same level for a limited period of time.

Due to the country's strong dependence on imports from neighbouring countries any action to avoid imbalance between generation and demand in Luxembourg, and in particular demand disconnection, must be established in accordance and alignment with the measures taken by the German TSO Amprion, and if necessary, by the Belgian TSO Elia as well as the French TSO RTE.

#### Cascading Measures for the System Safety of Power Grids

See Section 3.2.2.3 Cooperation between system operators.

#### Market suspension and restoration

In accordance with the **Network Code E&R**, Creos has drawn up **Rules for Market Suspension and Restoration**. As Luxembourg is in a common electricity with Germany, it does not have separate rules for the suspension and restoration of market activities, but follows the rules established for the common DE/LU market, including non-discriminatory principles of imbalance settlement for Luxembourg grid users in line with the imbalance settlement rules applied in the context of market suspension in Germany.

As a general rule, market activities can only be suspended if other safeguard measures are no longer available. The market suspension rules are therefore limited to emergency situations and subject to strict conditions as proposed by German TSOs and approved by the German Regulator Bundesnetzagentur<sup>18</sup>.

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<sup>17</sup> In national law, critical infrastructures are defined as follows: « tout point, système ou partie de celui-ci qui est indispensable à la sauvegarde des intérêts vitaux ou des besoins essentiels de tout ou partie du pays ou de la population ou qui est susceptible de faire l'objet d'une menace particulière. »

<sup>18</sup> *Bestimmungen für die Aussetzung und Wiederaufnahme von Marktaktivitäten und die Bestimmungen für die Abrechnung im Falle einer Aussetzung von Marktaktivitäten gemäß Artikel 36 Abs. 1 und Artikel 39 Abs. 1 i.V.m. Artikel 4 Abs. 2 e und f der Verordnung (EU) 2017/2196 der Kommission vom 24. November 2017 zur Festlegung eines Netzkodex über den Notzustand und den Netzwiederaufbau des Übertragungsnetzes (24. April 2020), § 4.1 - Voraussetzungen für die Aussetzung von Marktaktivitäten*

It should be noted that:

- the activities of the DE/LU common market will not be suspended by Creos but by the German TSOs, and that
- an interruption of supply in the Creos system is not a sufficient precondition to justify a suspension of the DE/LU common market activities by the German TSOs.

After a blackout, the TSOs are responsible for ensuring that the network is restored and that market activities are re-established as quickly as possible. A restoration of market activities can only take place if the incidents at the origin of the suspension are resolved and once the concerned market players have been informed by the TSOs.

The rules furthermore stipulate that Creos sends all relevant notifications and information concerning the suspension and re-establishment of the DE/LU common market activities to the relevant Luxembourg entities as soon as possible and after consultation with the German TSOs.

### System Restoration Plan

In case that the remedial measures have not been successful and the system falls into a partial or total blackout condition, a structured restoration of energy supply according to the **System Restoration Plan** is initiated.

Since there are currently no large power plants connected to the Creos transmission grid, Creos is not capable to restore the Luxembourgish energy supply on its own. However, the Vianden pumped storage plant (located in Luxembourg but connected directly to the German Amprion grid) plays an important role for grid restoration in the region, including Luxembourg.

If the restoration plan is triggered, regional dispatching (e.g., medium voltage grids) is subordinated to the Creos control centre, which is also responsible for the coordination with the Amprion control centre, the Elia national and regional control centres, and the dispatching of the Sotel industrial grid. The lines of communication are secured and will also work in the event of a blackout (cf. section 1.2 of the aforementioned plan).

Creos' restoration procedures include decision-making schemes to guide operators through the different phases of recovery. These schemes avoid neglecting important elements, allow for working in a structured manner and ensure that all the information necessary to be able to choose the most appropriate strategy is evaluated. The documentation of the process will form the basis of the ex-post analysis of the crisis, whose results will provide valuable elements for a better understanding of the crisis and for improving procedures and the restoration plan (cf. section 3.1 of the aforementioned plan).

In the event of a solar storm which can be forecasted by Space Agencies a few days in advance, it may be appropriate to initiate a voluntary (partial) blackout in order to protect the grid and power generation centres from the damaging consequences. As a voluntary blackout is a coordinated process, the restoration procedure after the event may be simpler to manage compared to an uncontrolled state of emergency. Nevertheless, it would follow the same procedures laid out in the system restoration plan.

### 3.1.4.3 Final customers

#### Business continuity plans

Business continuity plans enhance the capability of organizations to continue their delivery of products or services at pre-defined acceptable levels following a disruptive incident. The goal is to enable ongoing operations before and during a crisis situation, and very often comprises the risk (respectively scenario) of interrupted power supply.

Business continuity plans are particularly relevant for entities which are critical for the functioning of society and which are consequently declared as critical infrastructures by the HCPN. National law<sup>19</sup> requires owners or operators of those infrastructures to develop **Business Continuity Plans** which shall include at least the following:

- characteristics of the critical infrastructure;
- risk identification, analysis and assessment ;
- risk reduction measures and preventive strategies;
- business continuity measures.

As part of addressing the risk of possible power supply interruptions, entities may for instance install backup generators and/or uninterruptible power supplies (UPS), according to their respective business needs and risk aversion.

It should be noted that precautionary measures at the level of final customers is not strictly linked to the risk and occurrence of crisis situations at national level. Indeed, a very local interruption of power supply, e.g. during construction works, may equally cause such measures to be triggered.

### 3.1.5 Communication

In all phases of the crisis management, communication and the flow of information plays a decisive role. The internal communication serves to keep all relevant bodies informed and coordinated, and provides the basis for deciding and approving on the most sensible measures. External communication, i.e. specifically the transparent information towards the public, serves to strengthen the trust in the respective strategy of crisis management and to avoid irrational behaviour.

#### 3.1.5.1 Procedures and measures by the government and public authorities concerning information flows

On a government level, the procedures related to information flows are defined in the respective emergency response plans.

According to section 5 of the **Emergency response plan for an outage of energy supply**, the main procedures of internal communication for any kind of electricity crisis are as follows:

- The system operator alerts the head of cell for the evaluation of the risk for an outage of energy supply as soon as the system operator becomes aware of a major incident or attack.
- The High Commissioner for National Protection is alerted if the incident is likely to have a significant impact.

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<sup>19</sup> *Loi du 23 juillet 2016 portant création d'un Haut-Commissariat à la Protection nationale*, article 8 ; *Règlement grand-ducal du 21 février 2018 fixant la structure des plans de sécurité et de continuité de l'activité des infrastructures critiques*.

- The Prime Minister and Minister of State is alerted.

The information of the public is provided by the cell for communication and information. Based on the communication strategy the public is informed of

- the incident or attack and its impacts,
- the emergency plan in the event of an attack or technical fault in energy supply system,
- the establishment of the crisis cell including its composition and missions,
- the measures taken by the relevant authorities,
- the behaviours to be adopted by the population, and
- the stages of restoration of supply.

This information is spread through communication channels defined in the crisis communication strategy such as radio, TV, print media, website (in particular [www.infocrise.lu](http://www.infocrise.lu), hotlines, social networks, etc., provided that these channels are still available.

According to the ***Emergency response plan for an attack against or the outage of information systems***, the internal communication procedures are triggered as soon as any national or international actor reports a major cyber incident to the relevant Luxembourg authorities (cf. section 3 of the aforementioned plan).

- The cyber risk assessment cell is informed about the incident or attack.
- The High Commissioner for National Protection is alerted if the incident is likely to have a significant impact.
- The Prime Minister and Minister of State is alerted.

The public is informed of developments by the government (cell for communication and information) through the communication tools as described for the response plan for an outage of energy supply (cf. section 6 of the aforementioned plan).

According to section 3.1 of the ***Emergency response plan in the event of a nuclear accident***, the internal information procedure comprises the following three elements:

- The radiological evaluation cell is alerted as soon as the information of the incident is available.
- The High Commissioner for National Protection is alerted if the accident is likely to pose a danger to the population.
- The Prime Minister and Minister of State is alerted.

The crisis cell informs the public of all protective measures, recommendations and bans at the necessary time via the press, social media and the website [www.infocrise.lu](http://www.infocrise.lu) (cf. section 5 of the aforementioned plan). Furthermore, it directs CGDIS to activate specific warning signals through the national siren network, as described in section 2.5 of the aforementioned plan).

#### ***3.1.5.2 Procedures and measures by system operators concerning information flows***

In case that the system operator has activated measures according to the ***System Defence Plan***, the system operator in charge of the coordination informs the Government Commissioner of Energy and



the Institut Luxembourgeois de Régulation (ILR), as well as the High Commissioner for National Protection in writing of actions and measures.

In case of a prolonged situation, the affected system operators inform their customers of the decisions made, and in particular of the expected duration of the crisis situation.

In case of national disconnection, the TSO informs the public through appropriate communication channels.

## 3.2 Regional and bilateral cooperation

Luxembourg is involved in several arrangements aiming at regional and bilateral cooperation on both a government as well as a system operator level. Some of these arrangements are of binding nature and define procedures for mutual support in specific crisis and emergency situations, while others are activities to contribute actively to achieve further progress related to risk preparedness in the energy sector and other fields of international interests.

### 3.2.1 Overview of regional and bilateral cooperation

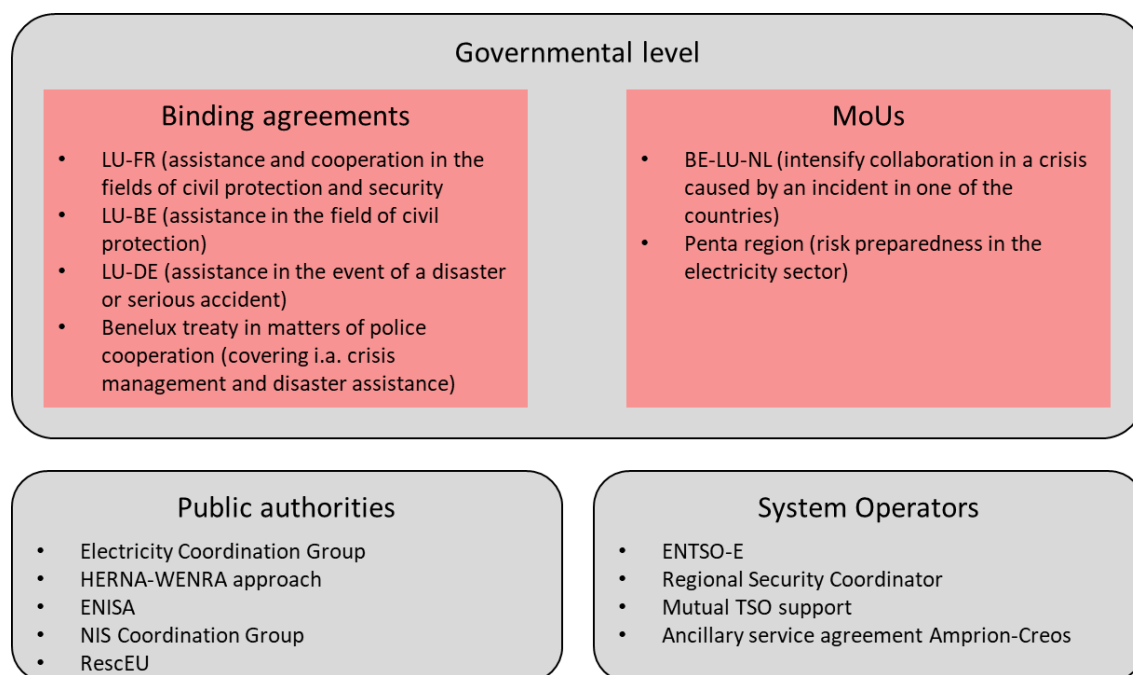


Figure 5: Arrangements related to bilateral and regional cooperation

### 3.2.2 Mechanisms for regional and bilateral cooperation

#### 3.2.2.1 Cooperation on a governmental level

Luxembourg has concluded several binding intergovernmental agreements in the context of managing crisis situations with potential cross-border consequences. These agreements comprise:

- The **Agreement between Luxembourg and France on assistance and cooperation in the field of civil protection and security** (act of April 2016) for the implementation of voluntary and mutual assistance in the event of a disaster or serious accident requested either through diplomatic channels or by the respective competent authority.



- The ***Agreement between Luxembourg and Belgium on mutual assistance in the field of civil protection*** (act of August 2016) in the event of a disaster or serious accident, especially incidents of chemical and nuclear nature.
- The ***Agreement between Luxembourg and Germany on mutual assistance in the event of a disaster or serious accident*** (act of December 1981).
- The ***Treaty between Belgium, Luxembourg and the Netherlands in matters of police cooperation*** (July 2018).

The assistance foreseen in these agreements generally consists in the following aspects:

- sending rescue teams,
- providing equipment,
- transmitting information.

The agreements typically foresee cooperation covering:

- measures to predict and prevent major natural and technological hazards including but not limited to the hazards identified in section 1.2.,
- protecting and safeguarding people, property and the environment threatened by a major natural or technological disaster,
- training for civil protection and security actors,
- mutual assistance in the event of disasters or serious accidents,
- mutual assistance between emergency services on both sides of the border
- methodologies for the establishment of contingency plans,
- the study of common interest problems in forecasting, prevention, assessment and management of emergencies,
- exchanges of experts and specialists, and
- exchanges of information and documentation on civil protection and security.

Different working groups for crisis management and disaster assistance (e.g. “SENN-CRISE”) enable the cooperation within the **Benelux** union and with Germany. The main pillars are the collaboration of national crisis cells, improvement of communication against the background of specific crisis scenarios and common exercises to ensure a smooth communication flow during a crisis.

These binding agreements are complemented by the following MoUs:

- The ***Memorandum of Understanding between Belgium, Luxembourg and The Netherlands***<sup>20</sup> from June 2006 to intensify their collaboration in a crisis caused by an incident in the territory of one of the countries. The cooperation covers the coordination of national policies as well as planning and execution of countermeasures. This coordination is established inter alia by risk identification, planning of civil protection measures, crisis management, mutual assistance on an ad-hoc basis, exchange of information, and communication with the public and corporate exercises.
- Pursuant to the requirements on solidarity and regional cooperation, the Pentalateral Energy Forum drafted and signed a ***Memorandum of Understanding on risk preparedness in the***

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<sup>20</sup> Original title *Le Mémorandum d'Accord concernant la coopération dans le domaine de la gestion des crises pouvant avoir des conséquences transfrontalières entre le Royaume de Belgique, le Royaume des Pays-Bas et le grand-duché de Luxembourg*

**electricity sector** in December 2021, which can be found in annex A of this plan. It provides a common understanding and clear mandate to continue the collaboration concerning the identification of possible common measures.

The common measures that will be assessed in further detail within the Penta Context will build upon existing inter-TSO agreements, as well as other relevant solidarity mechanisms. Examples of such existing mechanisms are the network code on electricity emergency and restoration or the guideline on electricity transmission system operation. More specifically, possible common measures that will be analysed in more detail are: cross-border usage of reserve capacities and flexible loads, exchange about demand disconnection plans, surveillance of the short-term security of electricity supply, coordinate information regarding saving appeals to the public, support with electric equipment, knowledge and expertise, and usage of mobile generators. Within the context of Support Group II of the Pentilateral Energy Forum dealing with security of supply, a preliminary exchange on these measures already took place. Based on the mandate and intentions expressed in the MoU, they will be further analysed from a regional point of view with respect to their technical, legal and economic characteristics.

### *3.2.2.2 Cooperation between public authorities*

In the framework of international collaboration related to security of supply on European level, the **Electricity Coordination Group** is a forum for the exchange of information and coordination of electricity policy measures having a cross-border impact. It also shares experiences, best practices and expertise on security of supply in electricity, including risk-preparedness, generation adequacy and cross-border grid stability, and assists the European Commission in designing its policy initiatives. The group's members represent national government authorities, in particular ministries responsible for energy; national energy regulatory authorities for energy; the Agency for the Cooperation of Energy Regulators (ACER), and the European Network of Transmission System Operators for Electricity (ENTSO-E).

For the particular risk of nuclear incidents, Luxembourg is also involved in the Europe-wide **HERCA-WENRA approach**, which comprises the necessary mechanisms for countries to exchange adequate information and to achieve practical and operational solutions on a voluntary basis during a nuclear accident. This approach aims to establish a uniform way of dealing with any serious radiological emergency situation, regardless of national borders, hence allowing for coherent and coordinated protective actions.

With regards to cyber related risks, cross-border cooperation is guaranteed and cross-border assistance is possible both at the **CERT** level and within the framework of international organisations of which the Grand Duchy of Luxembourg is a member (European Union, Benelux, NATO, UN, OSCE). In particular, the **European Union Agency for Cybersecurity (ENISA)** pays attention to a common strategy to strengthen Europe's preparedness and response capabilities to cyber incidents and to improve cyber security.

Furthermore, the **NIS Cooperation Group**, which regroups representatives of the EU Member States, the European Commission and ENISA, was established by the NIS Directive to foster cooperation in view of achieving a high common level of security for network and information systems in the European Union. It supports and facilitates the strategic cooperation and the exchange of information among EU Member States. On the operational side, the NIS Cooperation Group is supported by the work of the network of Computer Security Incident Response Teams (CSIRTs network), dedicated to sharing information about risks and ongoing threats and cooperating on specific cybersecurity

incidents. The CSIRTs network was established under article 12 of the NIS Directive, which also defines its role. The NIS Cooperation Group provides strategic guidance for the activities of the CSIRTs network. The NIS Cooperation Group is also working closely with the European Cooperation Network on Elections to counter threats to electoral processes under a new joint operational mechanism set-up as a part of the European Democracy Action plan. As the national competent authority for Luxembourg for implementing the NIS Directive, the national regulatory authority ILR represents Luxembourg in the NIS cooperation group.

In regard to the **NIS Directive**, it is also important to note that Directive 2022/2555, also known as **NIS2**, replaced its predecessor, Directive 2016/1148 or NIS1, to respond to the increased exposure of Europe to cyber threats. NIS2 raises the EU common level of ambition on cyber-security, through a wider scope, clearer rules and stronger supervision tools. It requires Member States to enhance their cybersecurity capabilities, while introducing risk management measures and reporting requirements to entities from more sectors and setting up rules for cooperation, information sharing, supervision, and enforcement of cybersecurity measures.

In addition to the aforementioned cyber-related frameworks, the recently adopted **Network Code on Cybersecurity** (NCCS, see also section 3.1.4.1) introduces enhanced cross-border cooperation, specifically focusing on processes that impact cross-border electricity flows. Unlike NIS2, the NCCS mainly addresses cyberattacks that result in criticality levels ranging from "high" to "critical," as defined by the cyber-attack classification scale methodology, which have a significant effect on cross-border electricity flows. Given the critical nature of the events covered by the NCCS, the information sharing and crisis management procedures must occur at an accelerated pace (no later than 4 hours after the incident is identified) compared to the timelines outlined in NIS2. Since its adoption in 2024, the NCCS is currently in the implementation phase, where various processes, standards, and methodologies are being developed at the European level by ENTSO-E and the DSO Entity, in close collaboration with national Competent Authorities (ILR for Luxembourg).

**RescEU** is an initiative under the European Union Civil Protection Mechanism designed to enhance disaster response capabilities across Europe. It serves as a strategic reserve of essential resources, fully funded by the EU, to manage emerging risks and protect citizens from various disasters. RescEU includes a reserve of emergency energy supply assets aimed at providing backup power during different emergency scenarios. This reserve comprises power generators and other energy-related equipment to ensure a reliable supply of electricity in crisis situations and is made available for response operations within the framework of the Union Mechanism. Following a request for assistance via the Emergency Response Coordination Centre (ERCC), the Commission, in close coordination with the requesting Member State and the Member State owning, renting, or leasing the RescEU capacity, decides on the deployment of this capacity. The capacities must be ready for deployment within the timeframes set by the quality requirements for each type of RescEU capacity, ensuring an effective and rapid response to disasters.

### *3.2.2.3 Cooperation between system operators*

**ENTSO-E**, the European Network of Transmission System Operators for Electricity, is the association for the cooperation of the European TSOs. Member TSOs are responsible for the secure and coordinated operation of Europe's electricity system. ENTSO-E's key responsibilities include the following:

- Development and implementation of standards, network codes, platforms and tools to ensure secure system and market operation as well as integration of renewable energy
- Assessment of the adequacy of the system in different timeframes
- Coordination of the planning and development of infrastructures at the European level (Ten-Year Network Development Plans)
- Coordination of research, development and innovation activities of TSOs
- Development of platforms to enable the transparent sharing of data with market participants.

Regional mechanisms to ensure an appropriate reaction at regional level are provided by the **Regional Coordination Centre (RCC)**. In accordance with article 35 of *Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity*, the existing RSCs will be replaced by Regional Coordination Centres (RCCs) as of 1 July 2022.

Creos is a customer of the RCC TSCNet Services<sup>21</sup>.

RCCs are entrusted with a set of mandatory services for their customers according to EU legislation:

- **Establishing a common grid model:** the establishment of a common grid model (CGM) is the basis for every single evaluation of transmission system security. The European CGM is tailored to the requirements of the most important services of an RCC and consists of detailed input and forecast data on generation, consumption, and network connectivity for all TSOs. The data is provided by the TSOs in the form of their individual grid models (IGMs) and other specific information. The RCC must check the quality of the IGMs and integrate them into the CGM in accordance with predefined rules.
- **Coordinated security analysis:** the aim of the coordinated security analysis is to identify possible security restrictions after the market closure based on the so-called (n-1) security principle in the framework of the day-ahead congestion forecast (DACF) and intraday congestion forecast (IDCF) processes. If security restrictions are detected, countermeasures can be identified and validated with the affected TSOs. For example, switching configurations can be changed based on results of an outage planning coordination process, tap positions of phase-shifting transformers can be changed or redispatch actions can be done, even if they cover complex security restrictions that require corrective measures in the networks of more than two TSOs at the same time (Multilateral Remedial Actions). The decision-making process between TSOs is organised via teleconferences.
- **Coordinated capacity calculation:** in its function of coordinated capacity calculator, the RCC calculates the cross-border transmission capacities for each relevant Capacity Calculation Region (CCRs) based on the methods approved by the national regulatory authorities and a tailor-made common network model.
- **Outage planning coordination:** the process collects all planned shutdowns of transmission and relevant generation elements and evaluates whether their simultaneous overlay meets the requirements for system security. If necessary, the RCC identifies and coordinates remedial actions with the TSOs and other RCCs in order to optimise the outage plans and to

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<sup>21</sup> Further shareholders and customers of TSCNet Services can be found on TSCNET's website [www.tscnet.eu](http://www.tscnet.eu).

ensure that the planned measures are implemented as effectively as possible. The final outage plan is incorporated into the coordinated security analysis and capacity calculation processes.

- **Short and medium-term adequacy forecasts:** a secure supply requires the availability of a minimum of installed generation capacity in order to reliably provide the necessary supply capacity. TSOs need an early assessment of whether market liquidity is limited or whether the regional distribution of generation capacity and consumption leads to congestion in order to prepare for such an exceptional situation. The RCC provides detailed and continuously updated short and medium-term adequacy forecasts based on information on the availability, consumption and expected state of transmission corridors with forecast horizons between weeks and a few days in advance. The results are discussed in a weekly operational planning teleconference.
- **Consistency check of TSOs' system defence and restoration plans:** application of common grid operation rules shall prevent the power grid from reaching an emergency state or from suffering a power failure. TSOs are obliged to take care of these unlikely situations and to draw up system defence and recovery plans in order to maintain and restore the functioning of the transmission grid. The RCC reviews the TSOs' restoration plans for consistency and provides a technical report for all TSOs to be forwarded to the national regulatory authorities and ENTSO-E to monitor the implementation.

In addition to European cooperation, mutual TSO support is in place on a bilateral and regional basis, based on the following technical measures in case that national measures are not sufficient to fully mitigate the respective crisis:

- If critical assets of the electricity system fail, e.g. due to attacks or extreme weather, parts of the transmission grid of Luxembourg and connections with Germany, Belgium, and France can be reconfigured to preserve system stability (cf. **System Defence Plan** and explanations provided in section 3.1.4.2). Through the possibility to use foreign grid infrastructure more extensively, this measure allows for a more flexible load flow control and shall prevent severe overloads in the region. This measure would also be applied as coordinated preventive action in case that the results of the network security analyses performed by the RCC point to the necessity of suitable regional measures.

The mechanism of mutual TSO support in emergency situations is part of the **Network Code E&R**.

- As Luxembourg and Germany form a common electricity market, **Rules for Market Suspension and Restoration** include closely coordinated processes between all TSOs in the two countries (cf explanations in section 3.1.4.2).
- In the case that preventive and corrective measures have not been successful and the system falls into a blackout condition, a structured restoration of energy supply is initiated. This process is in the first instance based on the national **Grid Restoration Plan**. As laid down in the **Network Code E&R**, these restoration plans shall be harmonised to ensure their effectivity also on regional level and to consider mutual support or even to handle cases where a national system is in principle not capable to recover energy supply on its own (cf. section 3.1.4.2).

Creos and Amprion have an ancillary service agreement in the context of load-frequency control and system restoration. As described in sections 3.1 and 3.2 of the **System Defence Plan** and in section 1

of the **System Restoration Plan**, Creos appointed Amprion as LFC area operator for the common load and frequency control area of Amprion and Creos in accordance with article 120 of the **System Operation Guideline**. Furthermore, section 3 of the **System Restoration Plan** sets out that the agreement covers the procurement of ancillary services by Amprion including black start and support in a blackout situation in Luxembourg.

#### Cascading Measures for the System Safety of Power Grids

Beyond the above-mentioned agreements, Creos signed an additional agreement with Amprion in 2024 to participate in the collaboration of network operators during critical grid states and to enforce the VDE Application Rule VDE-AR-N 4140. During a critical grid state, network operators can request supportive measures from downstream network operators within the scope of a “cascade”. The safe and reliable functioning of this cascade is a fundamental prerequisite for maintaining a reliable system operation. The VDE Application Rule describes the collaboration of network operators if system safety is at risk or disrupted. The goal of the Application Rule is to optimize the operational and informational cascade which must be triggered in critical grid situations across all network levels. With the signing of the agreement, Creos participates, as a last resort measure, in a coordinated load shedding if requested by Amprion.

## 4. Crisis coordinator

The execution of the **Emergency response plan for an outage of energy supply** is the responsibility of the **Prime Minister and Minister of State** and of the **Minister responsible for Energy**. The crisis cell is activated by the **Prime Minister and Minister of State**. The **High Commission for National Protection** ensures coordination at the operational level related to the prevention, anticipation and management of crises.

#### Prime Minister and Minister of State

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#### Minister responsible for Energy

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## High Commission for National Protection

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## 5. Stakeholder consultations

The Ministry of the Economy closely collaborated with the High Commission for National Protection HCPN and TSO Creos during the complete process of preparing the Luxembourg risk preparedness plan for the electricity sector.

**For the identification of national crisis scenarios**, the Ministry consulted the transmission and distribution system operators, relevant energy suppliers, the High Commission for National Protection HCPN as well as the national regulatory authority ILR. **the complete draft plan was consulted in March 2025 with the most relevant stakeholders**, i.e., the High Commission for National Protection HCPN, the national regulatory authority ILR, the transmission and distribution grid operators, all suppliers active in the Luxembourg electricity market, relevant producers, the Union of Consumers (Union Luxembourgeoise des consommateurs nouvelle ASBL, ULC) as well as the Federation of Luxembourgish Industrials (Fédération des Industriels Luxembourgeois, FEDIL).

On a **regional level**, the **Pentalateral Energy Forum** organized a regional assessment of the draft national Risk Preparedness Plans amongst its Member States over the course of 2025. The focus of this assessment was on cross-checking the consistency of the procedures and measures at national, bilateral and regional level.

## 6. Emergency tests

Crisis prevention and management on bilateral or regional level require seamless coordination and communication under the responsibility of the crisis coordination entity. On the level of system operators, emergency tests are executed regularly, as outlined in the **Creos Test Plan**<sup>22</sup> according to article 43 of **Regulation EU 2017/2196**. The requirements for compliance testing of capabilities are defined in the section “Compliance and review” where each TSO shall periodically assess the proper functioning of all equipment and capabilities considered in the system defence plan and the restoration plan involving all relevant distribution system operators and defence/restoration service providers.

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<sup>22</sup> Original title *Plan d'essais de Creos Luxembourg SA, en sa qualité de gestionnaire de réseau de transport, conformément à l'article 43, paragraphe 2 du règlement (UE) 2017/2196 de la commission du 24 novembre 2017 établissant un code de réseau sur l'état d'urgence et la reconstitution du réseau électrique*



The **Creos Test Plan** comprises the following compliance tests:

- Under-frequency disconnection relays are tested during the commissioning phase to verify the compliance of newly installed equipment. The test is repeated every 5 years.
- Production facilities (incl. batteries) are tested whether they are able to reduce their active power infeed if the frequency is above 50.2 Hz following a static given by Creos. The facilities must also be able to inject the maximum active power if the frequency drops below 49.8 Hz. This test is to be carried out during commissioning or after any intervention on equipment that has an impact on this ability to adapt the active power according to the frequency of the network, respectively.
- Blocking the automatic tap changing of power transformers is a measure to prevent a collapse of the network voltage and thus avoid a blackout. The compliance test of this functionality is carried out annually.
- Annual testing of generators and batteries to ensure continuity of control of substations being a relevant element in a potential grid reconstruction procedure.
- Testing of critical IT and telecommunications systems and installations related to availability and operation is performed at least every 3 years.
- The backup dispatching transfer procedure is tested annually.
- Simulator tests of the reconstruction plan as well as dispatcher training in the application of the procedures established by the reconstruction plan at least every 5 years.

Restoration of the Luxembourg transmission grid cannot be achieved without support provided by the neighbouring TSOs Amprion (Germany) or Elia (Belgium), respectively. For this reason, **bilateral tests and trainings** related to restoration procedures are periodically performed.

Further obligations to pursue **inter-TSO trainings** related to aspects of real-time operation to consolidate and improve communication and coordination are defined in the SO GL.

Furthermore, on a national level, a meeting was held in November 2022 between public authorities and the transmission system operator to dry run through the concrete scenario of a (possibly persisting) blackout and to identify potential shortcomings in the current preparation. Fuel supply and communication were identified as particular challenges during a blackout which lasts several days. Further meetings have been agreed upon to further improve the crisis management on a national level.

In June 2024, **ENISA organized a cyberattack exercise targeting the energy sector**, particularly the gas and electricity sectors. In Luxembourg, several entities participated in the exercise, including the HCPN and the transmission system operator Creos. Although the exercise was primarily focused on cybersecurity, Creos took the opportunity to enrich the scenario by testing its own internal crisis management procedures, as well as information-sharing at the national level. The exercise enhanced the understanding of information flows between the transmission system operator, the crisis center, and the competent authority. Furthermore, it enabled Creos to identify new areas for improvement to strengthen its internal crisis management procedures.

On a **regional level**, Penta-members carried out a first joint exercise in 2018 based on the MoU on Emergency Planning and Crisis Management concluded in 2017.



The successful exercise enabled the sharing of different national power crisis management mechanisms and established contact between crisis management bodies in the Penta region for the first time. The report after the joint exercise expressed the following:

1. “The exercise goals were met:
  - The participants got to know each other better, even in a national setting, and strengthened the Penta network,
  - Awareness was raised on national and cross-border issues arising from a Europe-wide scarcity situation,
  - Some best practices were identified and explored,
  - This exercise was a first step in jointly working towards an even better collaboration within the Penta community.
2. Penta sets a good example, but needs to keep on running:
  - Penta is a front runner amongst multilateral forums in the area of crisis management and leads the effort on cross border harmonization
  - Penta needs to build a road map for future improvements in effective crisis prevention and management based on the lessons learned and,
  - The effort needs to be expanded to the EU-level
3. We have to be aware that, in order to maintain grid stability, the technical solution always prevails over political solutions.
4. At TSO level, there are mechanisms and tools in place to coordinate, to operate and to communicate on a daily basis with each other, but in case of electricity crisis prevention and management a formalization of this platform should be encouraged.”

Given the success of the first joint exercise and the identified action points, Penta members acknowledge the importance of continuing to regularly organize joint exercises. Based on the MoU signed in December 2021 and pursuant to article 12 of the Risk Preparedness Regulation, these will be held biannually starting in 2022. The exercises will mainly aim to assess the coordination, communication and mutual assistance mechanisms. The specifics of the upcoming joint exercises were drafted and aligned within Support Group II during the finalization of the initial versions of their Risk Preparedness Plans submitted beginning of 2022.

Therefore, on May 24, representatives of all Penta countries participated in the ‘Black-out 22 exercise’, a major electricity crisis exercise, to reinforce communications flows between the neighboring countries.

This simulation exercise was set up by France as a national crisis exercise. It involved all French ministries under the coordination of the General Secretariat for national defense and security (Prime Minister’s directorate). For the first time in the electricity sector, such exercise was enlarged with other members of the Penta Forum.

The main objective of the regional exercise was to test the effectiveness of the mechanisms to share information and to cooperate for preventing an electricity crisis.

The simulation took place in Paris on May 24. Experts from Energy authorities, Transmission System Operators or crisis centers from these seven countries participated. The simulation featured shortages

in energy supply due to a severe and prolonged cold spell in Western-Europe, which led to the activation of a controlled load-shedding plan.

Building up on the experience of the previous exercises, additional exercises were held in 2023 under the Dutch Penta presidency and in 2024 under the Belgian Penta presidency.

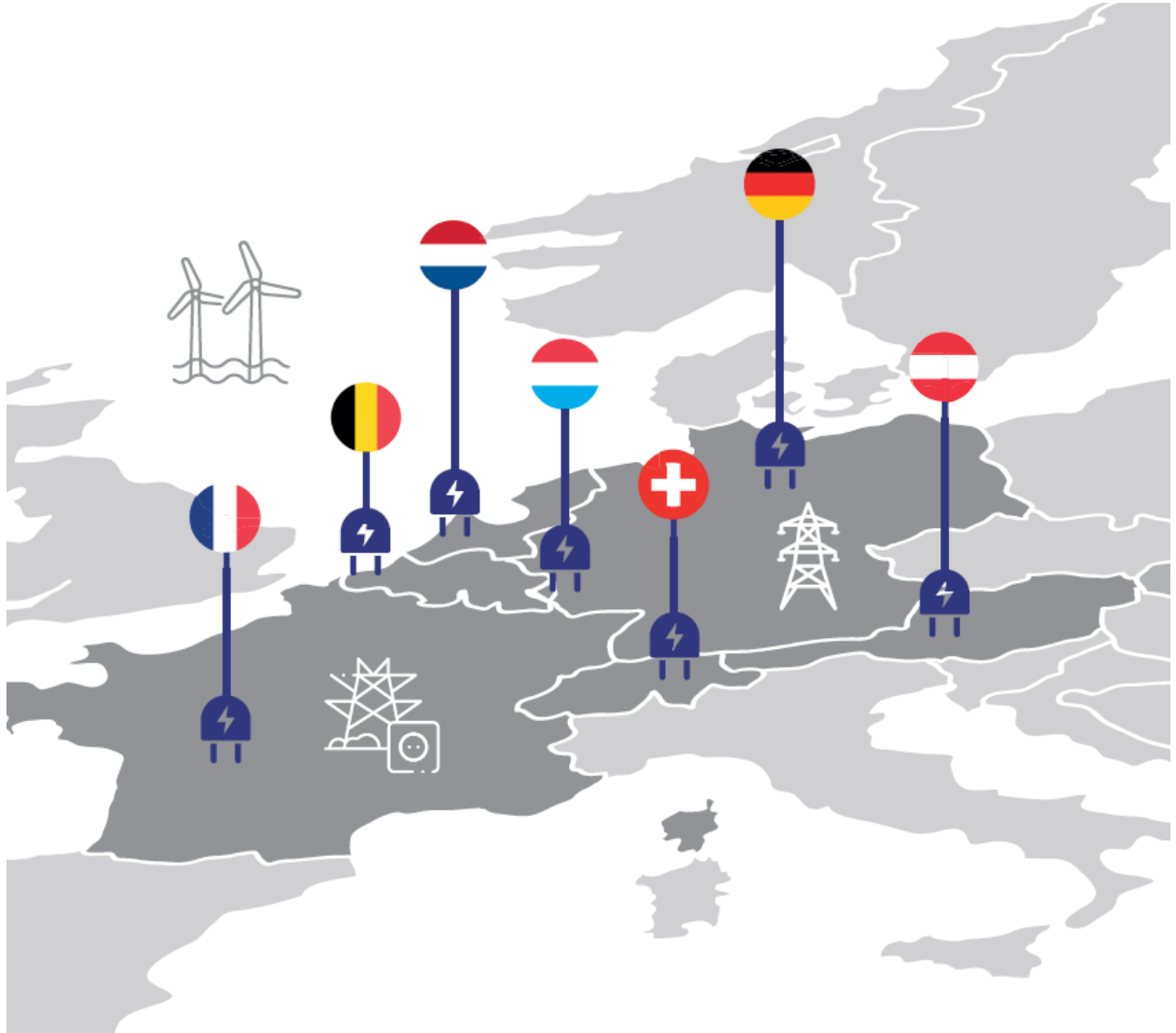
PENTEX 2023, hosted in The Hague, was the first Penta electricity crisis exercise providing an opportunity to train on the use of the commonly agreed-upon Communication Protocol and explore potential regional measures in line with the developed Catalogue of Measures. The scenario for the exercise involved a successful cyberattack on multiple power plants, with the threat of more plants potentially being affected. The exercise therefore provided a good base to test communication and decision-making when facing a looming crisis.

PENTEX 2024 BXL was organized under the Belgian Presidency and introduced new concepts to the exercise formula. For the first time, the exercise included both the electricity and gas sectors, reflecting the need to address not only an electricity crisis but also a potential gas crisis and its cross-sector impacts. Additionally, Penta countries were asked to participate in a setup that mirrored their roles within national crisis cells, incorporating representatives from national crisis centers. The scenario for this exercise expanded on the previous year's situation, continuing the theme of uncertainty and unrest surrounding energy security. To escalate the situation and trigger national and regional crisis management procedures, multiple physical attacks on critical infrastructure occurred in most Penta countries. These attacks led to N-1 violations and electricity shortages. Through the exercise countries were able to test national and regional information flows and practice the process for identifying measures.

As a natural continuation of the previous exercises, dedicated dilemma sessions were organised in 2025 under the Luxembourgish Penta Presidency. The PENTEX Dilemma Sessions '25 aimed to test and refine regional crisis management and solidarity mechanisms for electricity crises. The main focus of the workshop was to operationalise the Catalogue of Measures, which includes regional actions such as demand reduction, equipment sharing, and cross-border use of reserves. The exercise sought to identify activation procedures, technical conditions, and potential financial arrangements required to enable regional solidarity in times of crisis. The sessions particularly focused on short-term coordinated demand reduction to maintain regional adequacy and on equipment sharing to strengthen grid resilience. The discussions revealed several legal, technical, and political challenges to joint action, especially regarding cost-sharing. Potential solutions included the development of distribution keys to allocate the level of support among countries and the use of cost-benefit analyses (CBAs) to identify the most effective technical and financial approaches to solidarity. Despite these challenges, the workshop demonstrated a strong commitment among Penta countries to offer mutual support and to further develop practical, trust-based, and streamlined solidarity mechanisms.

Overall, Penta countries agreed to further discuss results and use lessons learned to further improve their communication protocols, enhance resilience against a major electricity crisis and increase cross-border cooperation and assistance, also outlined in section 7 here below.

## 7. Risk preparedness in the Pentalateral Energy Forum (Version November 2025)



### **Risk Preparedness in the Pentalateral Energy Forum**

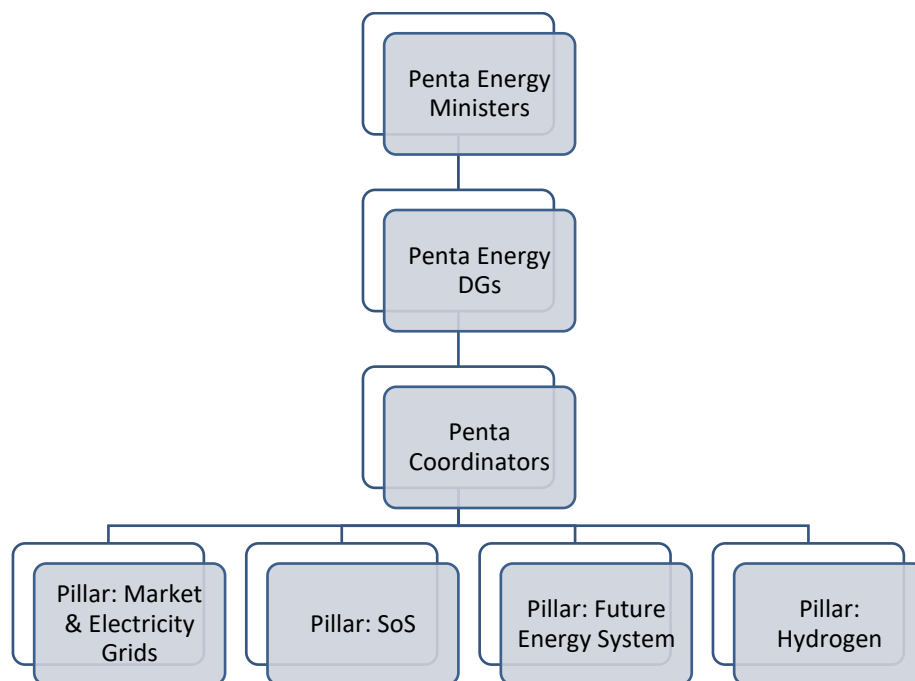
*Common Risk Preparedness Chapter*

November 2025

## 7.1 Introduction & Context

Since 2005, the Pentalateral Energy Forum (Penta) is the framework for regional cooperation in Central Western Europe, consisting of Austria, Belgium, France, Germany, Luxembourg, The Netherlands and Switzerland. This cooperation was formalized through the Memorandum of Understanding (MoU) of the Pentalateral Energy Forum, signed on 6 June 2007 in Luxembourg<sup>23</sup>. Jointly, the Penta countries cover more than one third of the EU population, and more than 40% of EU electricity generation. For over 20 years, the seven Penta countries have been working on initiatives towards improved electricity market integration, electricity security of supply, and accelerating the energy transition.

The forum is structured around various thematic pillars, of which one pillar focuses on security of supply and risk-preparedness in the electricity sector. The forum remains flexible to organize ad hoc meetings if and when themes occur that merit a dedicated workstream (e.g. implementation of the emergency gas regulations).



*Figure 6: Penta working structure*

The Ministers for Energy of the Region regularly meet to discuss these pillars, energy policy matters and to provide political guidance on further regional cooperation. They define annual and long-term priorities while the progress is monitored regularly by the Penta Energy DGs. Penta Coordinators translate these priorities into projects for the different pillars and seek the involvement of network operators, regulators, market players and where possible the European Commission as well as other stakeholders. For example, the regional implementation of the Risk Preparedness Regulation is a project under the Pillar “Security of Supply”. Since the start, the Benelux General Secretariat has ensured day-to-day continuity.

<sup>23</sup> Memorandum of Understanding of the Pentalateral Energy Forum on Market Coupling and Security of supply in Central Western Europe [https://www.benelux.int/files/3214/2554/2929/Memorandum\\_of\\_understanding\\_Pentalateral\\_2007\\_-\\_EN.pdf](https://www.benelux.int/files/3214/2554/2929/Memorandum_of_understanding_Pentalateral_2007_-_EN.pdf)

In the MoU on Emergency Planning and Crisis Management in the Power Sector, signed on 26 June 2017<sup>24</sup> in Luxembourg, the Penta countries agreed to strive for joint coordination of national and regional measures in case of a simultaneous emergency situation, for the region covering Austria, Belgium, France, Germany, Luxembourg, the Netherlands and Switzerland.

Following the entry into force of the Regulation (EU) 2019/941 of the European Parliament and of the Council of 5 June 2019 on risk-preparedness in the electricity sector and repealing Directive 2005/89/EC (Risk Preparedness Regulation), a first Penta common risk preparedness chapter was drafted, and a new MoU on Risk Preparedness in the Electricity Sector was signed. Both documents aim to provide an answer to the requirements on regional and bilateral measures pursuant to articles 12 and 15 of the Risk Preparedness Regulation. The first Penta common risk preparedness chapter was notified to the European Commission in January 2022 and was incorporated into the national risk preparedness plans of the Penta members. The MoU on Risk Preparedness was signed by the Penta Energy Ministers on 1 December 2021<sup>25</sup> in Brussels. These documents form the basis for the action points identified and addressed by the Penta Risk Group, the working group focussing on the regional implementation of the Risk Preparedness Regulation.

In April 2023 the Penta Risk Group notified an updated Penta common risk preparedness chapter to the European Commission. This updated version addressed the recommendations from the European Commission and included important lessons learnt from a drastically changed geopolitical energy context. Since February 2022, the Penta forum proved its added value once more by jointly dealing with the energy supply consequences caused by the Russian invasion of Ukraine. Several ad hoc meetings were organized to exchange best practices on implementing the EU action packages, and to share information on the preparedness measures in place.

Since 2022, electricity security has been a major priority on the international energy policy agenda. Within this context, Penta has been working on strengthening and operationalising the regional electricity risk preparedness tools, without losing sight of the bigger energy security picture. This focus is reflected in this present third update of the Penta Common Risk Preparedness Chapter.

## 7.2 Regional Electricity Crisis Scenarios

### 7.2.1 ENTSO-E's regional electricity crisis scenarios

As highlighted in the Risk Preparedness Regulation, regional electricity crisis scenarios play a key role in identifying opportunities for cross-border cooperation and support. With the update of ENTSO-E's methodology for identifying the most relevant regional electricity crisis scenarios<sup>26</sup>, and in line with article 6 of the Risk Preparedness Regulation, the Penta Region was formally

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<sup>24</sup> Memorandum of Understanding of the Pentalateral Energy Forum on emergency planning and crisis management in the power sector, 26 June 2017  
[https://www.benelux.int/files/7515/1749/6862/Penta\\_MoU\\_emergency\\_planning\\_and\\_crisis\\_management\\_in\\_power\\_sector\\_signed.pdf](https://www.benelux.int/files/7515/1749/6862/Penta_MoU_emergency_planning_and_crisis_management_in_power_sector_signed.pdf)

<sup>25</sup> Memorandum of Understanding of the Pentalateral Energy Forum on risk preparedness in the electricity sector  
[https://benelux.int/files/7216/3845/2580/PENTA\\_MoU\\_def.pdf](https://benelux.int/files/7216/3845/2580/PENTA_MoU_def.pdf)

<sup>26</sup> Annex I to ACER Decision 02/2024 Regional Electricity Crisis Scenarios Methodology Amendment

recognized as a subgroup. This recognition gave Penta the opportunity to contribute to ENTSO-E's list of candidate regional scenarios. This allowed the region to assess the relevance of each scenario and to give input on which scenarios should be removed, maintained, updated or combined with other scenarios. The Penta Risk Group also requested ENTSO-E to reduce the number of crisis scenarios and to focus on the most critical ones. Because of its status as a subgroup, a dedicated overview of the most relevant scenarios for the Penta Region was included in the ENTSO-E report. This meant a shift from the 2020 report, where the focus was mainly on Pan-European scenarios.

In the 2024 ENTSO-E cycle for identifying regional electricity crisis scenarios, the number of regional scenarios was reduced from 31 to 23. The reduction of scenarios was done by increasing the focus on scenarios with a significant regional impact and by merging closely related scenarios. For example, the new "severe winter" scenario now combines the previous "cold spell" and "winter incident" scenarios.

The updated ENTSO-E list also introduces a new way of grouping scenarios, topical groupings based on initiating or contributing hazards and factors. Table 1 below shows the Penta-rating of ENTSO-E's regional electricity crisis scenarios and their respective topical grouping.

In comparison to the 2020 ENTSO-E cycle, several changes stand out. These are partly due to newly introduced crisis scenarios with more detailed descriptions, and partly a result of recent geopolitical developments. Notably, scenario "physical attack on critical assets" is now considered the most relevant for the Penta Region, where it was ranked fourth in 2020. "Severe winter" is now the second most relevant scenario for the Region. The top 5 scenarios for Penta are completed by:

- "Cyberattack" (previously ranked first);
- "Unauthorised action by personnel (merged scenario of "threat to key employees" and "insider attack"); and
- "Heavy flooding.

ID	Regional electricity crisis scenario	Penta-Rating	Topical grouping
M.AA	Physical attack on critical assets	28.4	▲
W.SW	Severe winter	28	●
M.CA	Loss of ICT systems to cyber-attack	28	▲
M.UA	Unauthorised action by personnel	20	■ ▲
W.FL	Heavy flooding	19.8	●
W.ST	Severe storm	18	●
M.AC	Physical attack on control centres	18	▲
W.SS	Severe summer	16.4	●
W.FE	Unusually big demand / RES forecast errors	16.4	● ■ ■ ▲
S.FF	Fossil fuel shortage	13.2	● ▼ ■ ▲
H.IM	Unforeseen interaction of energy markets	12	● ■ ■ ▲
W.IL	Heavy ice loading	10.8	●
W.DF	Dunkelflaute	9.6	● ■
T.IA	Large nuclear/industrial accident	8	● ■ ■ ▲
M.AS	Targeted political malicious actions by adversarial states	7.2	▲
M.AE	Attack on entities not connected directly to the grid	6.4	▲
H.PA	Pandemic	6.4	● ▼ ■
T.SD	Serial technical defects	5.6	▼ ■ ■
H.IA	Industrial action, strikes, riots	5.6	▼ ■ ▲
S.NF	Nuclear fuel shortage	5.2	▼ ■ ▲
N.SW	Space weather	4.2	● ▼
N.EQ	Earthquake	2.4	● ▼
N.VE	Volcanic eruption	0	● ▼

● Weather ▼ Supply chain ■ Technical ■ Human ▲ Malicious actions

Table 2: Penta-rating of ENTSO-E's 23 crisis scenarios

Based on the table, the Penta members agreed that the top five scenarios should receive particular attention when assessing their impact, investigating preventive measures and elaborating on possible regional crisis response measures.

### 7.2.2 Penta methodology to assessing regional electricity crisis scenarios

Significant cross-border dependencies arise from the fact that Penta is characterized by high levels of integration and interconnectivity<sup>27</sup>, as well as coordination and cooperation among Ministries, TSOs, regulators and market participants. This leads to significant benefits, but also interdependencies when it comes to electricity crises. This level of integration and interconnectivity however, allows the region to manage risks more effectively by jointly identifying appropriate measures.

As mentioned before, the initial ENTSO-E list of regional scenarios had a Pan-European focus. To make the scenarios more useful for identifying regional measures, Penta experts decided to complement their own scenario ranking with a more generic description of the crisis scenarios,

<sup>27</sup> As for market integration, note that Penta has been at the forefront of running a Flow-Based-Market Coupling regime. High levels of interconnectivity are demonstrated in the report of the Commission Expert Group on electricity interconnection targets "Towards a sustainable and integrated Europe".

by identifying topical groupings specifically relevant for the region. The assessment showed that it is more useful to work with more generally defined scenario categories to identify concrete measures and arrangements. For instance, whether a key transmission line fails due to a storm or a severe winter incident, both considered extreme weather conditions, does not necessarily change the type of response needed.

In 2025, Penta experts built on this approach by focusing more on the impact of a crisis and the related measures. Similar to the previous reflection, for crisis management purposes it is irrelevant whether a transmission line becomes unavailable due to a storm or a physical attack. In this example, the resulting impact would most likely lead to grid congestion. By categorizing scenarios based on their consequences, experts gain valuable insights into how initiating factors can affect the electricity system in different ways. The new categorisation therefore allows experts to quickly assess the overall impact of a crisis situation considering key elements such as the event's nature, location and severity.

Concretely, four distinct categories were identified by the Penta Risk Group, each reflecting the consequences of an event in the regional electricity crisis scenarios and aligning with the regional measures outlined in the Catalogue of Measures:

#### **I. Loss of grid control**

The loss of grid control category covers scenarios where the main control systems available to TSOs, large DSOs or critical power plants are affected and significantly impact the safe operation of the grid. Potential triggers include:

- a) Control unavailability due to the corruption or destruction of the control systems
- b) Malicious controls caused by internal or external unauthorized actions
- c) External events which cause key assets to be unavailable or inaccessible.

#### **II. Grid congestion**

Unexpected grid congestion occurs when the electricity grid suffers reduced transmission capacity to deliver electricity from where it's generated to where it's needed due to an unforeseen event. The main triggers leading to unexpected grid congestion can include:

- a) Unforeseen electricity flows caused by forecasting errors or unforeseen energy market interactions
- b) The unavailability of critical infrastructure due to damages or due to having become inaccessible

#### **III. Supply adequacy**

Supply adequacy is not assured when supply cannot meet demand anymore or when supply exceeds demand.

The main triggers can include:

- a) Weather-related causes
- b) The unavailability of critical infrastructure such as cross-border interconnectors and power plants due to damage
- c) Unforeseen electricity flows caused by forecasting errors or unforeseen energy market interactions



#### **IV. Long-term system degradation**

Long-term system degradation is understood to be a consequence due to:

- a) Large scale (and potentially continuous) damage to critical infrastructure
- b) Supply chain issues (equipment or personnel) affecting the normal system operation and maintenance

Dividing the scenarios into these four categories helps create a clearer link between regional measures and the consequences of each scenario. It also provides a complementary perspective on regional crisis scenarios, alongside the analyses carried out by ENTSO-E.

It should be noted that some scenarios may appear in multiple categories since the location, nature and severity of the scenario affects the consequences. For example, the scenario “physical attack on critical assets” appears in three categories (grid congestion, supply adequacy and long-term system degradation). In this case, the nature of the physical attack is decisive to determine the consequences for the energy sector. An attack on transmission infrastructure within the Penta region would most likely lead to internal congestion. Attacks on interconnectors to the Penta region or attacks on generation assets on the other hand would most likely lead to adequacy issues resulting from reduced cross-border flows or decreased production capacity, respectively. In case of continuous and large-scale physical attacks (i.e. a war-like scenario), a long-term system degradation would most likely be the result.

In addition to swiftly understanding and evaluating the impact of a crisis event, timely identification of potential regional measures is essential for an effective crisis response. The expert-developed Catalogue of Measures supports the selection of actions that are tailored to each situation.

The measures are grouped into the different scenario categories. While all measures in the Catalogue of Measures could, in principle, be relevant to any crisis scenario, their actual applicability depends on the nature and context of the specific event. The goal is to better evaluate the relevance of regional measures in different crises and identify those most likely to resolve it.

Some measures appear in more than one category, reflecting their relevance across different domains. Information and knowledge sharing are considered actions that are applicable under all circumstances and form the cornerstone of any regional crisis response. Similarly, grid congestion and resource adequacy may be addressed through a reduction of demand<sup>28</sup> or, where feasible, the activation of non-contracted power plants or reserves in the region. In situations of energy surplus, curtailing generators may be necessary to restore the balance between supply and demand. A comprehensive understanding of the crisis is essential to determine the most appropriate and cost-efficient measures, while minimizing the impact on the general public.

It is important to note that in the case of grid control loss and long-term system degradation, the most effective crisis response measures may largely fall outside the scope of the energy sector. To effectively prepare for such situations, preventive measures are key to increase the

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<sup>28</sup> Demand reduction is understood to be a collection of measures which aim to reduce electricity consumption. These measures include voluntary measures such as energy savings campaigns, market-based measures and the targeted obligatory reduction of demand (potentially by load-shedding).

resilience of the electricity system. For the cybersecurity field, legislations such as the Directive (EU) 2022/2555 of the European Parliament and of the Council of 14 December 2022 on measures for a high common level of cybersecurity across the Union (NIS2 Directive) and the Commission Delegated Regulation (EU) 2024/1366 of 11 March 2024 supplementing Regulation (EU) 2019/943 of the European Parliament and of the Council by establishing a network code on sector-specific rules for cybersecurity aspects of cross-border electricity flows (Network Code on Cybersecurity) are key instruments in strengthening the protection of critical energy infrastructure. Additionally, the Directive (EU) 2022/2557 of the European Parliament and of the Council of 14 December 2022 on the resilience of critical entities and repealing Council Directive 2008/114/EC (CER Directive) introduces further criteria for critical infrastructures to assess potential risks and increase their resilience against unforeseen and extreme events.

Loss of grid control		Grid congestion		Supply adequacy		Long-term system degradation	
Loss of ICT systems to cyber-attack	28	Physical attack on critical assets (Targeted attacks within Penta region)	28.4	Physical attack on critical assets (attack on interconnectors to Penta region or power plants)	28.4	Physical attack on critical assets (large scale attacks)	28.4
Unauthorised action by personnel	20	Heavy flooding (localised flooding damages critical infrastructure)	19.8	Severe winter	28	Heavy flooding (large scale flooding)	19.8
Physical attack on control centres	18	Severe storm (localised damage to critical infrastructure)	18	Severe storm (shutdown of wind turbines)	18	Severe storm (large scale storm)	18
Large nuclear/industrial accident	8	Severe summer (overheating cables and forest fires)	16.4	Severe summer	18	Pandemic	6.4
Space weather	4.2	Unusually big demand / RES forecast errors	16.4	Unusually big demand / RES forecast errors	16.4	Serial technical defects	5.6
		Unforeseen interaction of energy markets	12	Fossil fuel shortage	13.2	Industrial action, strikes, riots	5.6
		Heavy ice loading (localised damage to critical infrastructure)	10.8	Unforeseen interaction of energy markets	12	Earthquake	2.4
				Dunkelflaute	9.6		
				Nuclear fuel shortage	5.2		
<b>Catalogue of Measures</b>							
The Catalogue of Measures provides a non-exhaustive overview of identified regional actions. In a given crisis, additional measures may be required to reduce its impact, including those from sectors outside the energy domain. Which of the following measures are applied, and by which countries, in the event of an electricity crisis depends on the specific situation at hand, the concrete way the crisis unfolds as well as the national legal framework in each PENTA-country.							
Relevant measures in all cases: Information, knowledge & expertise sharing							
<ul style="list-style-type: none"><li>• (Joint) elaboration on cross-border aspects of potential measures of demand reduction to reduce system stress</li><li>• Support with electrical equipment via stocks if equipment was damaged</li></ul>		<ul style="list-style-type: none"><li>• (Joint) elaboration on cross-border aspects of potential measures of demand reduction to reduce congestion</li><li>• Depending on location and grid topology, redispatch (activation of available power plants or reserves) to deviate electricity flows and alleviate congestion</li><li>• Support with electrical equipment via stocks to repair infrastructure</li></ul>		<ul style="list-style-type: none"><li>• (Joint) elaboration on cross-border aspects of potential measures of demand reduction to restore adequacy</li><li>• Activation of available power plants or reserves to restore adequacy</li><li>• If cross-border infrastructure is impacted, support with electrical equipment via stocks to repair cross-border infrastructure</li></ul>		<ul style="list-style-type: none"><li>• (Joint) elaboration on cross-border aspects of potential measures of demand reduction to reduce system stress</li><li>• Support with electrical equipment</li></ul>	

Table 3: Grouping of scenarios in function of electricity crisis scenario consequences

During different meetings of the Penta Risk Group in 2025, possible national and cross-border consequences of the scenarios and topical groupings identified as most important, were thoroughly discussed. The discussions and estimations of these possible consequences lie at the root of the work that has been done since the signing of the Risk Preparedness MoU in December 2021. The concrete outcomes are more thoroughly described in chapters four and six.

### 7.3 Competent authorities in the region

The table below provides an overview of the competent authorities for the Penta Region.

Country	Competent authority	Contact details
Belgium	Federal Minister of Energy	<a href="https://www.belgium.be/en">https://www.belgium.be/en</a> Email: be-riskpreparedness@economie.fgov.be
Germany	Federal Ministry for Economic Affairs and Energy	<a href="https://www.bmwk.de/Navigation/EN/Home/home.html">https://www.bmwk.de/Navigation/EN/Home/home.html</a> Email: buero-VIIIB2@bmwe.bund.de; riskpreparedness@bmwe.bund.de
France	Directorate General for Energy and Climate	<a href="https://www.ecologie.gouv.fr/">https://www.ecologie.gouv.fr/</a> Email: ccr.pole-dgec@developpement-durable.gouv.fr
Luxembourg	Minister responsible for Energy	<a href="https://meco.gouvernement.lu/fr.html/">https://meco.gouvernement.lu/fr.html/</a> E-Mail: secretariat.energie@eco.etat.lu
Netherlands	Ministry of Climate Policy and Green Growth	<a href="https://www.rijksoverheid.nl/ministeries/ministerie-van-klimaat-en-groene-groei-d.nl">https://www.rijksoverheid.nl/ministeries/ministerie-van-klimaat-en-groene-groei-d.nl</a> Email: secretariaatenergiemarkt@minezk.nl
Austria	Federal Ministry of Economy, Energy and Tourism	<a href="https://www.bmwet.gv.at/">https://www.bmwet.gv.at/</a> Email: mailto:stabst-krima-el@bmk.gv.at energielenkung@wirtschaftsministerium.at
Switzerland	Swiss Federal Office of Energy	<a href="https://www.bfe.admin.ch/">https://www.bfe.admin.ch/</a> Email: contact@bfe.admin.ch

*Table 4: Competent authorities in the Penta region*

Besides this overview, a first step in establishing a common communication protocol for the Penta region, was to better understand who to contact at what point in time. The Penta Risk Group reached an agreement on two main contact lists: one for the formal communication level and one for informal communication. The guiding principles on the usage of these contact lists are described in more detail in chapter four. Both lists are confidential and are therefore not added to this common chapter.

### 7.4 Regional Procedures & Measures

#### 7.4.1 Communication Protocol

One of the most important regional preparedness measures is a common communication protocol. The Penta communication protocol has been tested and further developed in recent years through a series of regional exercises and workshops. Two important elements of this protocol are the contact lists, as noted in the previous chapters, and the Penta Crisis Management Toolkit. Both are available for the Penta Risk Group members through a shared online platform.

### Notification procedure

Based on the regional exercises and lessons learnt from previous crises, the Penta Risk Group has agreed on a common procedure for mutual notification in the event of an early warning or an electricity crisis.

In line with Article 14 of the Risk Preparedness Regulation, Member States are required to inform the European Commission when declaring an early warning or an electricity crisis. Accordingly, if any of the Penta countries declares such a situation, they will simultaneously notify both the European Commission and all other Penta countries.

A first notification by one or several Penta countries will automatically lead to an ad hoc Penta Risk Group call, unless the notifying Penta member country requests otherwise. In the event of an electricity crisis, the Penta Risk Group will assume the role of the central platform for coordination and information exchange among the Penta countries, with the possibility to extend to an informal regional crisis cell if deemed useful. The online platform where the necessary documents are available, also offers the option for the Penta Risk Group members to informally share information via a chat function. Information sharing, including on the online platform, shall comply with each country's national rules on data protection, confidentiality and classified information.

The method of contacting or notifying the other Penta countries in the event of an early warning and/or electricity crisis will depend on the nature and urgency of the crisis, distinguishing between two main scenarios:

#### **A. Imminent threat:**

- In the event of an imminent threat, the Penta country that is, or will be affected, shall immediately contact the other Penta countries by telephone—using the details provided in the informal contact list—both during and outside office hours. This initial contact will be followed up by a written confirmation via e-mail.
- The other Penta countries are required to acknowledge receipt of the notification by email and confirm their availability for an ad hoc Penta Risk Group meeting.

#### **B. No imminent threat:**

- In the case of a non-imminent threat, the Penta country that is, or may be, affected shall promptly notify the other Penta countries by email, using the contact details provided in the informal contact list, regardless of office hours.
- The other Penta countries are required to acknowledge receipt of the notification by email and confirm their availability for an ad hoc Penta Risk Group meeting.

The practical arrangements for these meetings, such as the chair of the meeting, secretariat support, and other organizational details, will be discussed at the start of the first ad hoc Penta Risk Group meeting. These arrangements will remain in effect until the end of the crisis, unless the Penta Risk Group decides to adjust them due to changed circumstances.

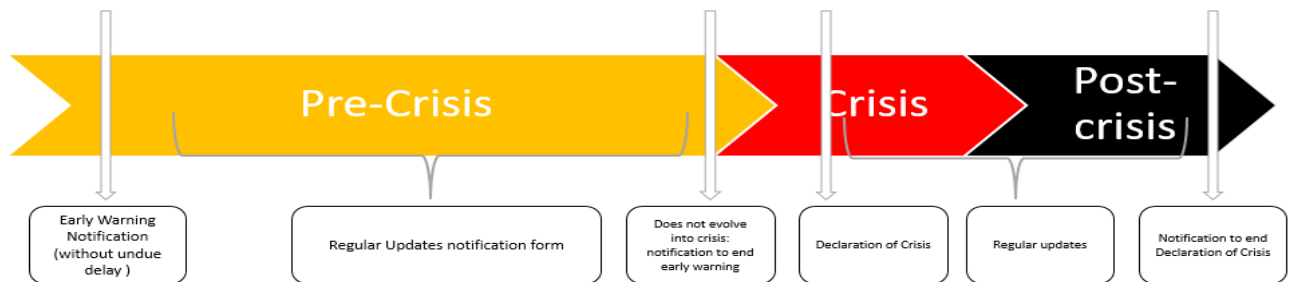
Penta will use the notification template (part of the Penta Crisis Management Toolkit) to formally communicate on:

1. Declaration of an early warning
2. Declaration of a crisis
3. Update on an early warning or a crisis

4. Request for assistance
5. End early warning
6. End crisis

The template will be filled out in English. Information will be shared as soon as possible. However, it is commonly understood that, specifically in the early stages, not all information requested might be available.

Following the first notification, an update will be sent at least once every week (even if no new information is available), unless circumstances warrant a different frequency.



*Figure 7: Notification procedure*

This coordinated approach aims to ensure timely information sharing, enhance regional situational awareness, thereby facilitating consistency and complementarity between national crisis responses to potential or ongoing electricity crises. It also supports solidarity and consistency in the implementation of national and regional measures, minimizing cross-border impacts and strengthening overall energy security in the Penta region.

#### Penta Crisis Management Toolkit

Based on the regional exercises and lessons learnt a comprehensive toolkit was developed, containing all key documents and templates necessary to effectively manage a crisis at the Penta regional level. The toolkit serves as a practical and operational resource to help the Penta Risk Group in implementing the agreed procedures in the event of an early warning or electricity crisis. As mentioned before, it is made available for all Penta Risk Group members through an online platform.

This toolkit includes among other things the notification template, situation report (sitrep) template, agenda template, updated contact lists for all relevant stakeholders and the latest Risk Preparedness Plans of the Penta members. These documents are designed to ensure a harmonized and efficient exchange of information, enable swift coordination between the Penta countries, and support transparent decision-making during all stages of a crisis. Due to the operational and confidential nature of this toolkit this is not included in the common chapter.

#### Contact lists

The contact lists form an integral part of the Penta Crisis Management Toolkit. As both lists contain confidential information, they will not be included in the Risk Preparedness Plans.

#### **I. Formal Contact List:**

- The formal contact list will be updated at least once a year before the start of winter.
- This contact list will be used for formal communication including:
  - Notification of an early warning or crisis;
  - Formal updates of the situation;
  - Request for assistance;
  - And formally ending an early warning or crisis situation.
- The contact details on this formal list are also shared with the European Commission and the members of the Electricity Coordination Group (ECG), with the addition of the main Swiss contacts.

#### **II. Informal Contact List:**

- The informal contact list will also be updated at least once a year before the start of winter.
- This contact list is used for informal information sharing as well as to organize an ad hoc Penta Risk group meeting
- The list contains the details of the national contact persons involved in electricity and/or energy crisis management. This will allow for swift and informal information sharing ahead of or during a crisis. It is clearly indicated which contacts can be reached in case of an emergency (24/7)

### **7.4.2 Catalogue of regional measures**

The Risk Preparedness MoU signed in December 2021 identified a number of possible regional measures to be further analysed. Building on this, and in order to address the requirements of articles 12 and 15 of the Risk Preparedness Regulation, a catalogue of regional measures was identified (see annex II). This catalogue builds upon the already existing inter-TSO agreements. Upon a request for assistance by one or more of the Penta countries, this catalogue can be shared and assessed with the competent authorities in order to identify the most suitable solidarity measures to deal with the specific circumstances. The Penta countries commit to further elaborate on the triggers, the possible consequences, the technical and the financial implications as well as the national legal framework needed of the different measures that have been identified in the catalogue. Elaborating on the existing catalogue of regional measures was a key objective of the Pentex Dilemma sessions organized in Luxembourg in September 2025.

### **7.5 Consultations**

An essential factor in setting-up an effective and efficient crisis management framework is ensuring its overall consistency. Therefore, the interaction between the regional procedures and measures identified in the previous chapters and the policies set out at national level was assessed at different points in time. The Penta Risk Group continues to strive for a better understanding of the interaction between the regional and national level through workshops and exercises.

During the first risk preparedness cycle, the Penta Forum conducted a regional assessment of the draft national risk preparedness plans amongst its Member States. The focus of this assessment was on cross-checking the consistency of the procedures and measures at national,

bilateral and regional level. To achieve this, competent authorities shared the English version of their draft risk preparedness plans within Support Group II in May 2021. In June 2021 a dedicated meeting of Support Group II was organized to exchange initial concerns and make clarifications. To align this initiative with the activities at a European level, the European Commission was invited to the meeting, and a Penta representative was available shortly after to give a presentation of the main results during a dedicated meeting of the Electricity Coordination Group.

The outcomes of these meetings were included in the progress report on the implementation of the regional aspects of the Risk Preparedness Regulation, which was presented to Penta Directors-General at the end of June 2021. Afterwards, Penta countries had until mid-July to file written comments to the draft national risk preparedness plans. Member States took these comments into account when finalizing their risk preparedness plans by 5 January 2022.

By December 2022, this common chapter was updated, taking into account lessons learnt and recommendations from the European Commissions. The revisions to the common chapter were thoroughly discussed and finalized in consultation with the experts of the Penta Risk Group. The finalized document was subsequently submitted during the Penta Ministerial meeting held at the end of 2022.

Since 2022, the focus has increasingly shifted towards the operationalization of regional crisis management. The Penta Risk Group has drawn valuable lessons from the various exercises and workshops conducted in recent years, which resulted in this updated version of the Penta Common Chapter. This revised version was once again reviewed and finalized by the group's experts, and subsequently approved by Penta DGs in early November 2025.

## 7.6 Emergency Tests

Penta countries carried out a first joint exercise **“Pentex” in 2018** based on the MoU on Emergency Planning and Crisis Management concluded in 2017. The successful exercise enabled the sharing of different national power crisis management mechanisms and established contacts between different crisis management bodies in the Penta region.

Given the success of the first joint exercise and the identified action points, the Penta members acknowledge the importance of continuing to organise joint exercises on a regular basis. In 2022, the Penta countries therefore organised two exercises focussing mostly on the assessment of regional coordination, communication, and assistance mechanisms.

**The ‘Black-out 22’** exercise, took place on 24 May 2022 in Paris as part of a French national crisis exercise. The regional layer that was added to the national exercise gave the Penta Risk Group members, representatives of the national TSOs and representatives of the regulatory authorities, the possibility to learn more about each other's roles in crisis management, the national crisis structures, and the national crisis procedures and measures. During the afternoon session, participants examined the potential cross-border impacts of such incidents and discussed the frameworks for communication and coordination in similar future scenarios. Based on these discussions, the Penta countries identified a set of action points that were tested in a second smaller exercise.

The follow-up exercise was held in Brussels on 13 July 2022 in the form of a risk preparedness workshop. To further deepen the knowledge of each other's national crisis structures and procedures, both national and cross-border consequences of extreme weather conditions were



discussed. The remaining gaps in regional coordination and regional cooperation were then re-identified and by the end an agreement was reached on the establishment of a common communication protocol and a catalogue of regional measures.

Building on the experiences of the previous exercises, further exercises were held in 2023 under the Dutch Penta presidency and in 2024 under the Belgian Penta presidency.

**PENTEX 2023 The Hague**, was the first Penta electricity crisis exercise providing an opportunity to train on the commonly agreed-upon Communication Protocol and explore potential regional measures, in line with the developed Catalogue of Measures. The scenario for the exercise involved a successful cyberattack on multiple power plants, with the threat of more plants potentially being affected. As the scenario primarily presented a looming crisis rather than an immediate full-scale emergency, several critical points were highlighted:

- The necessity of establishing a shared understanding of an electricity crisis, including thresholds and triggers for transitioning from national to regional crises.
- The identification of potential regional measures that could be implemented proactively.
- The role of the Penta Risk Group as a regional crisis cell and the need to further strengthen and formalize communication between Penta countries.

Building on these lessons, **PENTEX 2024 BXL** was organized under the Belgian Penta Presidency, introducing new concepts to the exercise formula. For the first time, the exercise included both the electricity and gas sectors, reflecting the need to address not only an electricity crisis but also a potential gas crisis and its cross-sector impacts. Additionally, Penta countries were asked to participate in a setup that mirrored their roles within national crisis cells, incorporating representatives from national crisis centres.

The scenario for this exercise expanded on the previous year's situation, continuing the theme of uncertainty and unrest surrounding energy security. To escalate the situation and trigger national and regional crisis management procedures, multiple physical attacks on critical infrastructure occurred in most Penta countries according to the exercise scenario. These attacks led to N-1 violations and electricity shortages. The exercise concluded with a scenario where several countries required critical equipment, and the availability of that equipment was subject to varying levels of difficulty. In one case, a TSO-TSO agreement between two countries was reached. In another, a bilateral solution was found, though the financial agreements were still pending. The most complex case involved sourcing a critical piece of equipment from a country that was already using it for its own repairs. This challenging scenario underscored the need for continued development of regional measures and an understanding of the limits of solidarity between countries.

In addition to the crisis scenario, several new concepts were introduced, such as a pre-designated chair for Penta Risk Group meetings, a dedicated secretary, and situation reports. These elements enhanced communication and brought more structure to the information-sharing process between countries.

Overall, the exercise was deemed highly successful by participants, with clear takeaways and action points for future improvement:

**Catalogue of Measures:**

- The catalogue must be further refined through a legal analysis to identify potential limitations in providing solidarity.
- It was noted that pre-determining technical and financial agreements to some extent could be beneficial, in line with the legal analysis.
- A more detailed analysis of the equipment that can be shared, as well as the availability of such equipment (e.g. TSO stocks), is necessary.

**Communication Protocol:**

- A more structured approach is needed to ensure rapid and efficient information exchange among countries.

**Crisis Management Structures:**

- As in previous exercises, it became evident that countries have varying crisis management structures. It was agreed to continue working on a common vocabulary, where feasible, and share national procedures to improve coordination.

As a natural continuation of the previous exercises, dedicated dilemma sessions were organised in 2025 under the Luxembourgish Penta Presidency. The **PENTEX Dilemma Sessions '25** aimed to test and refine regional crisis management and solidarity mechanisms for electricity crises.

The main focus of the workshop was to operationalise the Catalogue of Measures, which includes regional actions such as demand reduction, equipment sharing, and cross-border use of reserves. The exercise sought to identify activation procedures, technical conditions, and potential financial arrangements required to enable regional solidarity in times of crisis.

The sessions particularly focused on short-term coordinated demand reduction to maintain regional adequacy and on equipment sharing to strengthen grid resilience. The discussions revealed several legal, technical, and political challenges to joint action, especially regarding cost-sharing. Potential solutions included the development of distribution keys to allocate the level of support among countries and the use of cost-benefit analyses (CBAs) to identify the most effective technical and financial approaches to solidarity.

Despite these challenges, the workshop demonstrated a strong commitment among Penta countries to offer mutual support and to further develop practical, trust-based, and streamlined solidarity mechanisms.

Overall, Penta countries agreed to continue discussions, build on the lessons learned, and use the outcomes of the past exercises to enhance communication protocols, strengthen resilience against major electricity crises, and improve cross-border cooperation and assistance.

## **Annex I : Memorandum of Understanding on Risk Preparedness in the Electricity Sector**

### **MEMORANDUM OF UNDERSTANDING OF THE PENTALATERAL ENERGY FORUM ON RISK PREPAREDNESS IN THE ELECTRICITY SECTOR**

The Ministers for Energy of the Pentalateral Energy Forum, consisting of Austria, Belgium, France, Germany, Luxembourg, the Netherlands and Switzerland, hereinafter referred to as the “signatories”, wish to confirm their intention to maintain and strengthen their existing cooperation on risk preparedness in the electricity sector.

The signatories have regard to Article 15 of Regulation (EU) 2019/941 of the European Parliament and of the Council on risk preparedness in the electricity sector and repealing Directive 2005/89/EC of the European Parliament and of the Council (‘Risk Preparedness Regulation’).

They take note of the legally non-binding Commission Recommendation (EU) 2020/775 of 5 June 2020 on the key elements of the fair compensation and other key elements to be included in the technical, legal and financial arrangements between EU Member States for the application of the assistance mechanism under Article 15 of the Risk Preparedness Regulation.

Considering:

- existing legal provisions from the Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation, the Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing, the Commission Regulation (EU) 2017/2196 of 24 November 2017 establishing a network code on electricity emergency and restoration, Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity and 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;
- that the Ministers for Energy of Austria, Belgium, France, Germany, Luxembourg, the Netherlands and Switzerland have signed a memorandum of understanding of the Pentalateral Energy Forum on emergency planning and crisis management for the power sector on 26 June 2017, that these countries have been closely cooperating within the Pentalateral Energy Forum in order to prevent electricity crises, and that they concur to assist each other in case of an electricity crisis, without exclusion, and in a spirit of solidarity and trust as laid down in the Risk Preparedness Regulation;
- that the “market-first” principle should apply in managing crisis situations and that all market-based measures should be given priority to mitigate the effects of a potential supply disruption. Non-market-based measures shall be activated in an electricity crisis only as a last resort if all options provided by the market have been exhausted or where it is evident that market-based measures alone are not sufficient to prevent a further deterioration of the electricity supply situation;

- that a signatory should only request assistance to prevent or manage electricity crises if all national measures in the requesting Penta country's risk preparedness plan and inter-TSO (Transmission System Operator) support measures have been exhausted or where it is evident that these measures are not sufficient to prevent a further deterioration of the electricity supply situation;
- that security of supply, including risk preparedness in particular, is a national responsibility but national decisions can impact the EU internal electricity market, neighbouring countries and the Penta region;
- that cross-border and national grid infrastructure is essential for the security of supply in the Penta region;
- that a better mutual understanding of national concerns (energy mix, resource adequacy, flexibility needs, peak capacity, emergency plans, risk management plans) and common measures are necessary for efficient crisis mitigation;
- that mid- and long-term adequacy assessments on a national, regional and European level as well as the continuous improvement of their respective methodologies contribute to a better mutual understanding of security of supply and help identifying and mitigating security of supply issues from a regional perspective at an early stage;
- that common measures are helpful to ensure risk preparedness on a national and regional level in an effective and efficient manner;
- that this Memorandum of Understanding replaces the Memorandum of Understanding of 26 June 2017 on emergency planning and crisis management for the power sector;

with the intention to:

- lay down a framework for cooperation in the Pentalateral Region with a view to preventing, preparing for and managing electricity crises in a spirit of solidarity and transparency and fully respecting the requirements of a competitive internal market for electricity and the operational security procedures of the transmission network operators. This should also include simultaneous crisis situations affecting more than one Penta country;
- bring together the relevant representatives from Ministries, Transmission System Operators (TSOs), National Regulatory Authorities (NRAs) and potentially other stakeholders;
- strive for a joint coordination of regional measures to be implemented in case of a crisis situation, including possible implementation of rules for curtailment of interconnection capacities and load shedding, while ensuring compatibility with the internal energy market;
- prepare for the occurrence of a situation which may not be solved with market-based measures or existing operational procedures of the transmission system operators alone and which may require competent authorities to take non-market based measures;
- refer to the Memorandum of Understanding as part of the national risk preparedness plans of the signatories in accordance with Article 10 of the Risk Preparedness Regulation;

have agreed the following:

Definition of an electricity crisis

- All countries share a common understanding that an electricity crisis is constituted by a present or imminent situation in which there is a significant involuntary electricity shortage.
- A regional electricity crisis is an electricity crisis simultaneously affecting more than one country within the region of the Pentalateral Energy Forum at the same time.

#### Confidential common contact list

- All countries will share a confidential common contact list with names and contact details of all entities involved in crisis prevention and management, which contains at least the competent authority, the crisis coordinator, as well as the National Regulatory Authority (NRA) (if involved in crisis situations) and the Transmission System Operators (TSOs) of each country, and which will be updated annually by the Benelux Secretariat, unless circumstances warrant more frequent updates.
- All countries pledge to keep the others informed of their organisation and the evolution of their organisation.
- When communicating with another Penta country, a communication protocol will be followed. Unless detailed otherwise in this communication protocol, representatives of Ministries, TSOs, NRAs communicate with their respective peers, with the exception of early warnings that should be issued by the relevant Competent Authorities to all contacts of the confidential common list.

#### Exchange on security of supply situation and the functioning of crisis management policies

- Experts from the Ministries, NRAs and TSOs of the Pentalateral Region will meet regularly to discuss the security of supply situation on a national and regional level as well as the functioning of national and regional electricity crisis management policies.
- Upon request of one of the above entities, a meeting or call will be organized at short notice.
- If deemed necessary by one of the signatories, an invitation to the meeting can be extended to other entities, provided that all other regular participants accept this.

#### Penta regional scenarios

- Relevant regional electricity crisis scenarios for the Penta region will be identified by the Pentalateral Energy Forum, included in the national risk preparedness plans and revised every four years, unless circumstances warrant more frequent updates.
- These regional scenarios for the Penta region should be consistent with and complementary to the national electricity crisis scenarios as identified by the countries of the Pentalateral Energy Forum.

#### Information on an electricity crisis

- In case of an imminent crisis, or when confronted with a crisis, the competent authority of the affected country will inform all competent authorities of the Pentalateral Region of the situation, the measures taken and planned at national level and the possible regional measures identified.
- The competent authority of the country, having faced a crisis, will, provide an ex-post evaluation report during a dedicated meeting with experts from Ministries, NRAs and TSOs of the Pentalateral Region. The meeting should result in a list of lessons learnt and may result in an adaptation of the risk preparedness plans.

#### Assistance in case of an electricity crisis

- The signatories intend to, where they have the necessary technical ability, offer each other assistance by means of regional measures. To that end, and with the purpose of protecting public safety and personal security, signatories aim to decide as quickly as possible on regional measures of their choice in order to deliver electricity in a coordinated manner.
- Therefore, the signatories will assess possible measures such as cross-border usage of reserve capacities and flexible loads; exchange about demand disconnection plans; surveillance of the short-term security of electricity supply; coordinated information regarding saving appeals to the public; support with electric equipment, knowledge and expertise; and usage of mobile generators.
- Conditions under which support can be requested and provided should be clear, objective and harmonised. They should build upon and go beyond existing rules and measures for inter-TSO assistance.
- Signatories intend to agree on the necessary technical, legal and financial arrangements for the implementation of the regional measures. Such arrangements should specify, inter alia, the maximum quantity of electricity to be delivered at regional level, the trigger for any assistance and for suspension of assistance, how the electricity will be delivered, and provisions on fair compensation between signatories.
- With regard to fair compensation, the signatories will strive for an agreement covering at least:
  - (a) the cost of the electricity delivered into the territory of the affected country requesting assistance as well as the associated transmission costs; and
  - (b) any other reasonable costs incurred by the country providing assistance, including reimbursement for assistance prepared without effective activation, as well as any costs resulting from judicial proceedings, arbitration proceedings or similar proceedings and settlements.
- In the event of an electricity crisis in which the signatories have not yet decided on regional measures and technical, legal and financial arrangements, they will apply existing measures of cooperation, such as the dedicated Penta Standing group on electricity scarcity, or decide on ad hoc measures and arrangements that are most suitable to address the crisis.
- Possible measures of assistance will need to be coordinated with the concerned national TSOs before such assistance is activated.

#### Crisis exercises

- With the involvement of relevant stakeholders, the competent authorities of the signatories intend to periodically test the effectiveness of the procedures developed in risk preparedness plans for preventing electricity crises, and carry out biennial simulations of electricity crises.
- A calendar for the preparation and the execution, as well as a proposal for the format and goals of the upcoming crisis exercises will be presented in Q4 2021.

**This Memorandum of Understanding does not create any rights or obligations under international law and does not intend to replace or modify any existing legal obligations between the signatories.**

## **Annex II : Catalogue of Measures**

### **Catalogue of regional measures in the framework of the EU Risk Preparedness Regulation and the Penta Risk Preparedness MoU of 2 December 2021**

The Following catalogue of regional measures was drawn up to prevent and alleviate the impact of electricity crisis situations in the region, as identified in the Memorandum of Understanding of the Pentalateral Energy Forum on Risk Preparedness in the Electricity Sector (Penta Risk Preparedness MoU) signed on 2 December 2021. The descriptions below shall serve as a tangible and concrete basis for further elaboration, and are meant to be neither exhaustive nor restrictive.

#### **1. Surveillance of the short-term security of electricity supply**

On a national level, transmission system operators (TSOs), distribution system operators (DSOs), national regulatory authorities (NRAs) and Ministries have established specific roles and procedures for security of electricity supply. On a European level, several entities and groups carry responsibilities as well, notably ENTSO-E, regional coordination centres (RCCs), and the Electricity Coordination Group (ECG).

Complementary to the above, the Pentalateral Energy Forum adds value by bringing together experts from TSOs, NRAs and Ministries in a well-established, flexible and trusted regional framework. Timely exchanges of information on the evolution of situation are of great importance for joint coordination. More specifically, in case of an imminent or actual electricity crisis situation, i. e. after an early warning or a declaration of crisis were issued, a standing group can be set up on short notice to, amongst others share the latest information and exchange on (planned) interventions both at an operational and policy level and the impact of the (crisis) situation on the other countries. The standing group can convene on several levels, such as on an expert, crisis coordinator or ministerial level. This tool has proven to be very useful in the past in dealing with stress situations.

#### **2. Coordinated information regarding saving appeals to the public**

Saving appeals can be an important instrument in preventing an imminent crisis.

While communication strategies need to consider local and national specificities, they also benefit from consistency and coordination across borders in order to convince and incentivize people, administrations and business and to align the necessary direction of impact.

On a Penta level, detailed information could be shared and discussed concerning saving campaigns in order to avoid possible inconsistencies which could trigger unwanted cross-border spill-overs, ensure alignment, and identify best practices. If deemed useful and beneficial, an actual common savings campaign could be drawn up.

#### **3. Emergency reserve deliveries beyond the available trading capacities**

Deployment of market power plants that have not been contracted due to a lack of demand in the domestic market (on the electricity market). The prerequisite would then be that transport capacities in the direction of the "sink" exist or can be cleared (a new calculation of the transmission capacities may be necessary - either recalculation of the capacity given to the



market or recalculation of the technically possible transports in order to use this possibly available capacity outside the market for the crisis supply).

#### **4. Cross-border usage of reserve capacities and flexible loads**

In contrast to wholesale and balancing markets, reserve capacities and flexible loads are being organized on a national level. According to a first assessment, national frameworks for those assets currently neither foresee nor allow for cross-border sharing or only allow this under specific conditions. A regional measure could therefore aim to share these assets for supporting other countries in an imminent or actual electricity crisis, and enhance synergies of the crisis prevention and management measures and thus their economic efficiency and overall system reliability. The main questions to be tackled before applying this measure are:

- Assessment of national frameworks to allow cross-border sharing of the assets
- Coordinated procedural rules for activating the assets for a regional deployment
- Analysis and mitigation of possible negative interferences with wholesale and balancing markets
- Location of the assets, availability of sufficient transmission capacity, and estimated impact on system operation
- Estimated duration of activating the assets
- Estimation of costs and benefits, followed by an agreement on allocation principle

#### **5. Exchange about demand disconnection plans**

According to Article 4 (5) of the Network Code electricity emergency and restoration (Regulation (EU) 2017/2196), each TSO is required to prepare a system defence plan that includes, among other things, rules on demand disconnection. From a regional point of view, it is important to understand and, where suitable, to align on the contents and corresponding procedures for critical supply situations. A first step would consist in presenting the respective plans to each other, involving TSOs, NRAs and Ministries. This could help to avoid possible inconsistencies, enhance alignment taking national circumstances into account, and identify best practices. Furthermore, the activity may help to identify “blind spots” and/or pertinent regional measures that go beyond this catalogue.

RCCs (Coreso and TSCNet) should be involved in the elaboration of this measure as their tasks include, amongst other, supporting the consistency assessment of transmission system operators' defense and restoration plans, as well as carrying out regional outage planning coordination.

#### **6. Support with electric equipment, knowledge and expertise**

In case of an electricity crisis, a significant amount of dedicated equipment and workforce is needed that may not be available on a national level. Therefore, similar and complementary to the existing possibilities of international support for civil protection (such as firefighting planes, tracking dogs, etc.), a pool of equipment and experts could be formed and sent to support the most critical places during an electricity crisis. Once implemented, the “Commission Implementing Decision (EU) 2022/1198 of 16 June 2022 amending Implementing Decision (EU) 2019/570 as regards rescEU emergency energy supply capacities” may provide a suitable framework for this, addressing the following main components (Annex Section 13):

- Power generators of various sizes to allow flexibility and scalability.



- Adequate connectivity, synchronization, monitoring and power transfer systems to enable connecting the capacity to the affected facilities as well as paralleling control of units.
- Adequate number of spare parts and other consumables for the functioning of the capacity, such as batteries, energy harvesting equipment, connectivity and synchronizing equipment, fuel, other types of apparatus and related services.
- Adequate procedures to ensure fuel supply for the functioning of the capacity.
- Adequate procedures to transport, handle, assemble, install, operate and maintain the capacity.
- Lighting equipment, including lighting protection systems.
- Adequate storage facilities.
- Appropriately trained personnel and assets to handle, assemble, install, operate and maintain the energy supply capacity.

## 8. Reference documents

- **Bericht über die Versorgungssicherheit im Strombereich in Luxemburg**  
available at <https://mec.gouvernement.lu/dam-assets/le-ministere/fonctions/energie/electricite/20240731-versorgungssicherheitsbericht-strom-2024.pdf>
- **Bestimmungen für die Aussetzung und Wiederaufnahme von Marktaktivitäten und die Bestimmungen für die Abrechnung im Falle einer Aussetzung von Marktaktivitäten gemäß Artikel 36 Abs. 1 und Artikel 39 Abs. 1 i.V.m. Artikel 4 Abs. 2 e und f der Verordnung (EU) 2017/2196 der Kommission vom 24. November 2017 zur Festlegung eines Netzkodex über den Notzustand und den Netzwiederaufbau des Übertragungsnetzes (24. April 2020)**  
available at [https://www.bundesnetzagentur.de/DE/Beschlusskammern/1\\_GZ/BK6-GZ/2018/BK6-18-289/BK6-18-289\\_beschluss\\_vom\\_04.08.2020.pdf?\\_\\_blob=publicationFile&v=1](https://www.bundesnetzagentur.de/DE/Beschlusskammern/1_GZ/BK6-GZ/2018/BK6-18-289/BK6-18-289_beschluss_vom_04.08.2020.pdf?__blob=publicationFile&v=1)
- **Business continuity plans**  
non public
- **Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation**  
available at <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32017R1485>
- **Directive 2012/18/EU of the European Parliament and of the Council of 4 July 2012 on the control of major-accident hazards involving dangerous substances, amending and subsequently repealing Council Directive 96/82/EC**  
available at <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32012L0018>
- **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**  
available at <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019L0944>
- **Electricity system defence plan of the Grand Duchy of Luxembourg**  
consultation document available at [https://www.creos-net.lu/fileadmin/dokumente/downloads/System\\_defence\\_plan\\_Luxembourg\\_\\_Nov2022\\_signed.pdf](https://www.creos-net.lu/fileadmin/dokumente/downloads/System_defence_plan_Luxembourg__Nov2022_signed.pdf)
- **Hochwasserrisikomanagementplan 2021-2027**  
consultation document available at <https://eau.gouvernement.lu/dam-assets/administration/documents/projekthochwasserkaarten2021/hwrm2021/Entwurf-Hochwasserrisikomanagementplan-2021-2027.pdf>
- **Loi modifiée du 1er août 2007 relative à l'organisation du marché de l'électricité**  
available at <https://legilux.public.lu/eli/etat/leg/loi/2007/08/01/n13/jo>

- **Loi du 23 juillet 2016 portant création d'un Haut-Commissariat à la Protection nationale**  
available at <https://legilux.public.lu/eli/etat/leg/loi/2016/07/23/n1/jo>
- **Methodology to Identify Regional Electricity Crisis Scenarios in accordance with article 5 of the REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on risk-preparedness in the electricity sector and repealing Directive 2005/89/EC**  
available at [https://acer.europa.eu/sites/default/files/documents/Individual%20Decisions\\_annex/ACER\\_Decision\\_02-2024\\_RPm\\_Amendment\\_Annex\\_I.pdf](https://acer.europa.eu/sites/default/files/documents/Individual%20Decisions_annex/ACER_Decision_02-2024_RPm_Amendment_Annex_I.pdf)
- **National resilience strategy**  
available at <https://letzprepare.public.lu/dam-assets/images/documents-en/0005-hcpn-bro-snr-letz-prepare-en-a4-screen.pdf>
- **National strategy to strengthen the resilience of critical entities**  
available at <https://letzprepare.public.lu/fr.html#liens-utiles>
- **Network development plan**  
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- **Plan d'essais de Creos Luxembourg SA, en sa qualité de gestionnaire de réseau de transport, conformément à l'article 43, paragraphe 2 du règlement (UE) 2017/2196 de la commission du 24 novembre 2017 établissant un code de réseau sur l'état d'urgence et la reconstitution du réseau électrique**  
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