Global Energy Crisis and the Risk of Blackout: Interdisciplinary Analysis and Perspectives on Energy Infrastructure and Security

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Review

Global Energy Crisis and the Risk of Blackout: Interdisciplinary Analysis and Perspectives on Energy Infrastructure and Security

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Abstract

The current global energy crisis is one of the most pressing challenges of the 21st century, it highlights the fragility of an old power system based on fossil fuels, geopolitical dependencies and often the precariousness and age of equipment and installations, affecting the economy, security and social stability on a national, regional and world scale. The risk of blackout thus becomes not only a technological threat, but a symbol of the need for a paradigm shift. The energy future must be sustainable, collaborative and adaptable—to guarantee not only the continuity of services with electricity, but also the stability of modern society. This paper provides an intrinsic interdisciplinary analysis on the causes, implications and possible solutions related to major imbalances in contemporary power systems, emphasizing the growing risk of blackout (large power outages). The main causes of crises are analyzed interdisciplinary, such as: insecurity in the functioning of the National Power System, terrorist attack on the National Power System, extreme weather condition, natural calamity, energy insecurity and political/military insecurity. The paper highlights the interdependence between energy infrastructure and energy security, as well as the vulnerability of power grids to cyberattacks, natural disasters and consumer pressures. In addition, socio-economic, technological and political issues are addressed, providing an integrated view of the phenomenon. Finally, national, regional and bilateral mitigation, limitation and restoration (resilience) procedures and measures are proposed in the event of an electricity crisis—blackout.

Keywords: energy crisis; blackout; energy infrastructure; energy security

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1. Introduction

1.1. Essential Information on the Power System in Romania

The National Power System functions as an interconnected system to the European Power System—ENTSO-E, which represents the European Network of Transmission System Operators for Electricity, according to Figure 1.

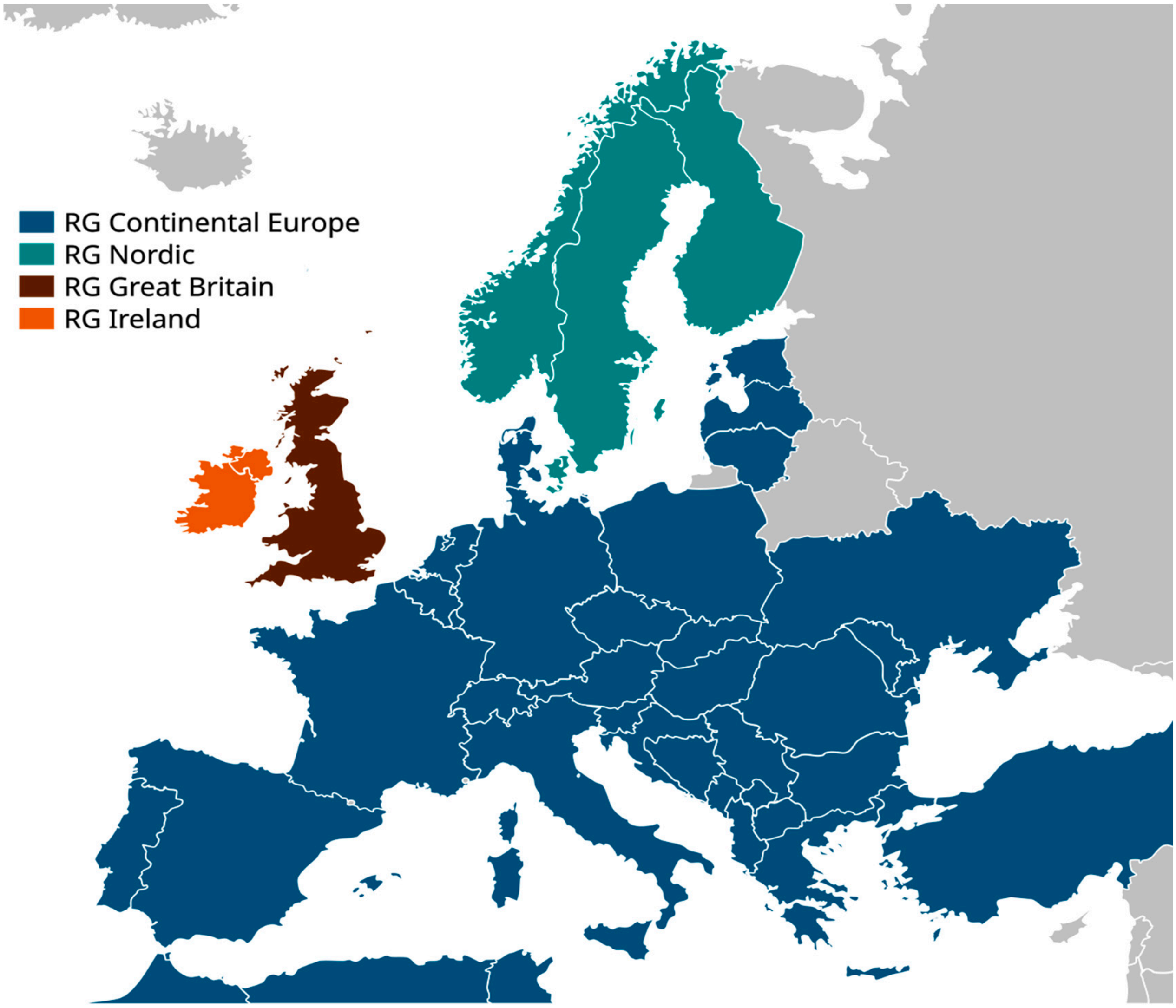

Figure 1. ENTSO-E Map (source: ENTSO-E).

Romania, through the national electricity transmission company, Transelectrica, which is a national transmission and system operator (TSO), has an active and essential role within ENTSO-E, being a full member. It manages and operates the electricity transmission system, ensuring electricity exchanges between Romania and the countries of the European Union and the neighbouring countries that are not part of the European Union (Serbia, Ukraine and the Republic of Moldova).

The National Power System, through the Electricity Power Transmission Grid, is composed of the following critical energy infrastructures:

- 82 power substations, of which: 1 power substation in a gauge of 750 kV, but functioning at 400 kV; 38 power substations of 400 kV; 43 power substations of 220 kV.
- 8834.4 km overhead power lines, of which: 3.1 km—750 kV; 4915.2 km—400 kV; 3875.6 km—220 kV; 40.4 km—110 kV (interconnection Serbia, Ukraine and the Republic of Moldova).
- 216 transformation units totaling 38 058 MVA.
- 1 National Energy Dispatch—NED;
- 5 Territorial Energy Dispatchers—TED [1].

As a member of ENTSO-E, Transelectrica contributes to: The security and coordination of the European electrical system: it participates in maintaining the security and stability of the interconnected power grid of Europe, one of the largest in the world; The grid planning and development: it collaborates to the elaboration of the long-term development plans of the European power grid, contributing to the integration of renewable energy sources and the achievement of climate neutrality targets by 2050; The implementation of grid codes: it participates in the development and application of the European grid codes, which establish technical and commercial rules for the functioning of the internal electricity market; The regional security coordination: it is involved in regional security coordination initiatives aimed at optimizing the functioning of power grids at regional level.

Through active participation in ENTSO-E, Romania benefits from: Access to an integrated energy market: it facilitates cross-border exchanges of electricity, contributing to security of supply and price stability; Integration of renewable sources: it supports the efficient integration of renewable energy sources into the national and European electrical system; Development of energy infrastructure: the participation in ENTSO-E allows access to funds and expertise for the modernization and expansion of the power grid.

The NPS interconnection is one of the main ways to increase its reliability and security without affecting energy independence.

Through these interconnections, damage aid is provided without the need to install and maintain in warm reserve, an important power.

The ENTSO-E recommendations concern 6 major aspects of the functioning of a power system: consumption coverage; power primary adjustment; frequency—power secondary adjustment; voltage regulation; functioning safety at criterion (N-1) elements; anti-damage measures [2].

International interconnections of the Romanian NPS, according to Table 1 and Figure 2 [1]:

Table 1. International interconnections of the National Power System (own elaboration).

Country	Connection Type (Overhead Power Line)	Voltage Level
UKRAINE	Rosiori—Mukacevo Isaccea—South Ukraine	400 kV—EU connection 400 kV (750 kV gauge)—decommissioned line
HUNGARY	Nadab—Bekescsaba Arad—Sandorfalva Arad—Sandorfalva	400 kV—EU connections
SERBIA	Resita—Pancevo 2 Porțile de Fier—Djerdap Iron Gates—Djerdap	400 kV—EU connections
BULGARIA	Tantareni—Kosloduy Rahman—Dobrudja Stupina—Varna	400 kV—EU connections 400 kV (750 kV gauge)—EU connection
MOLDOVA REPUBLIC	Isaccea—Vulcanesti	400 kV

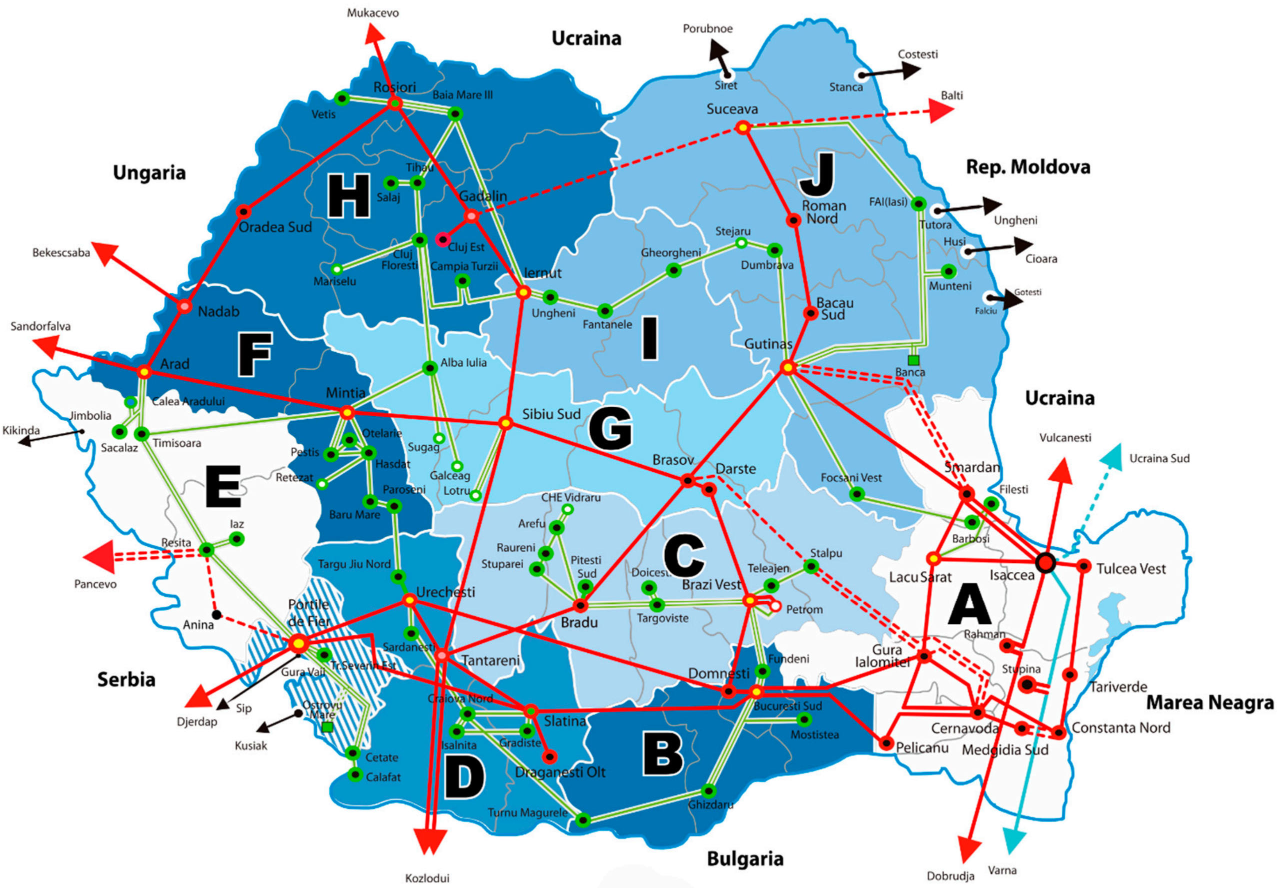

Figure 2. National Power System map (source: Transelectrica), (blue line is 750 kV OHL, red line is 400 kV OHL, green line is 220 kV OHL).

1.2. Strategic Importance of the National Power System

The National Power System—NPS is the backbone of the functioning of the Romanian economy and society. It ensures electricity and heat supply to the population, state institutions and the entire economic sector. Through its continuous, stable and efficient functioning (power plants, power substations and overhead power lines), the NPS becomes a strategic element of energy security and, implicitly, of national security, according to Figure 3.

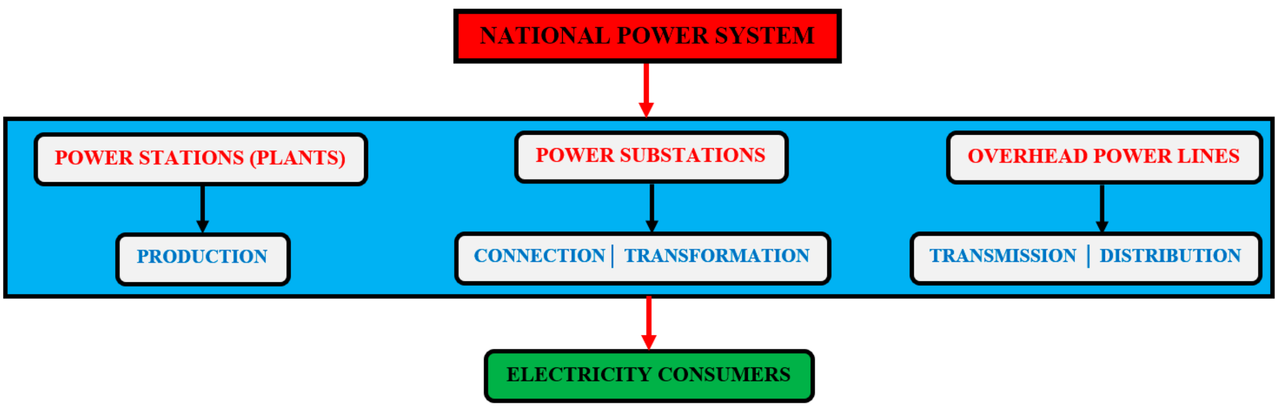

Figure 3. The interdependence Power plants—Power substations—Overhead power lines (own elaboration).

Energy security involves: Availability of energy sources: diversification of sources (renewable, nuclear, gas, coal); Energy independence: reducing dependence on imports, especially from unstable regions; Infrastructure resilience: the capacity to withstand disruptions (natural or provoked); Energy efficiency: reducing losses and optimizing consumption [3].

The NPS contributes to the energy security through: Diversified and modernized production capacities; Interconnection with European grids (ENTSO-E), which allows the import/export of energy; Strategic stocks and system balancing mechanisms [3].

The NPS is a pillar of national welfare and security, by the following formula, according to Figure 4:

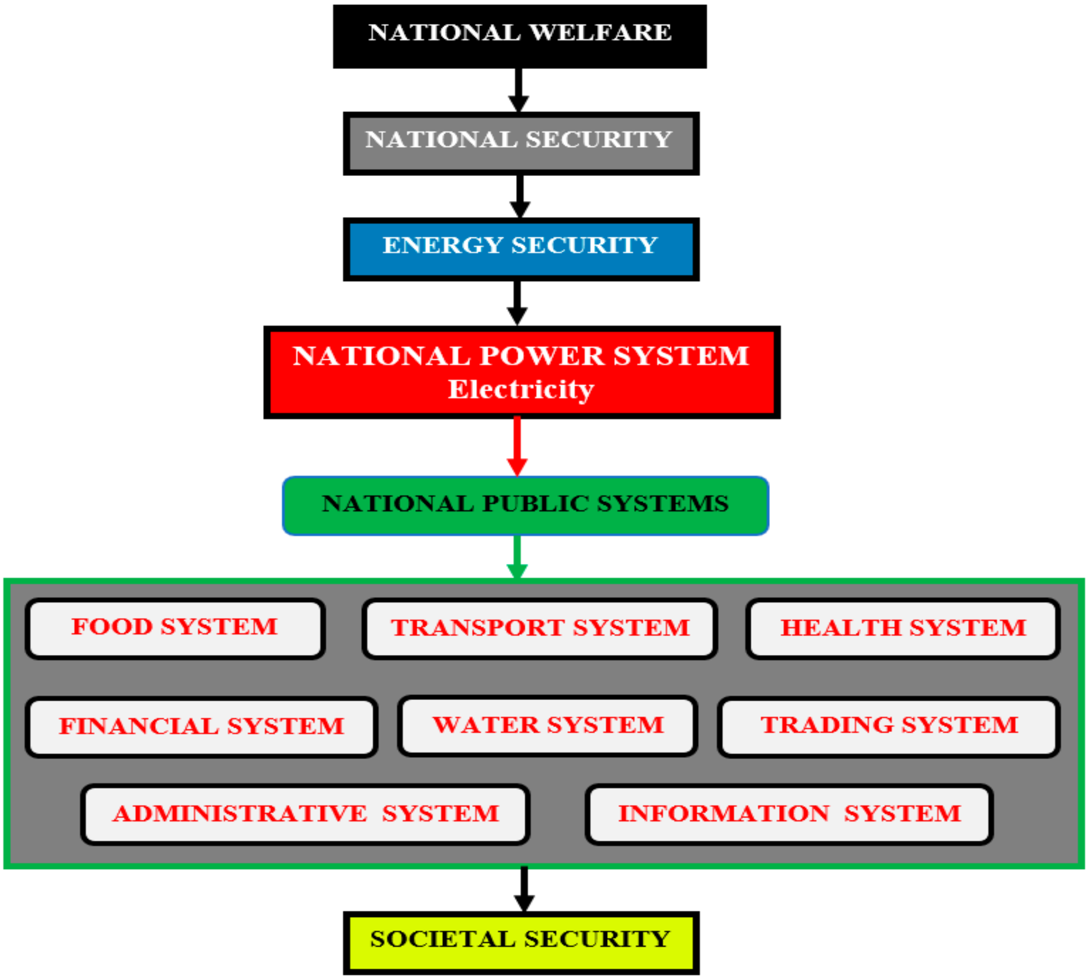

Figure 4. National welfare and security formula for the NPS (own elaboration).

National welfare = National security + Economic security + Energy security (safe and stable National Power System) + Continuous electricity (critical, domestic and industrial consumers) + Societal security.

The NPS influences: The functioning of state institutions: supplying critical infrastructure (hospitals, army, communications); The public order: supply interruptions can lead to social instability; The defense capacity: the army and the defense system depend on the energy infrastructure; The economic development: without energy, the economy stagnates. Thus, a robust NPS is a strategic national shield.

Romania faces challenges such as: Energy transition (phasing out of coal—according to EU policy); The need for investment in infrastructure and green technologies; War in the proximity of borders (Ukraine)—increased energy risks; Increase of consumption and digitization.

Future prospects aim at: The development of renewable energy; The implementation of green hydrogen and new nuclear technologies (SMR); The digitization of the NPS for better control and rapid reactions; Creating strategic energy storage capacity.

The National Power System is more than a technical mechanism—it is an instrument of sovereignty, stability and development, and by protecting, modernizing and consolidating it, Romania ensures a secure future both from an energy and national point of view [3].

1.3. Staging of Preventive Measures on Managing an Electricity Crisis (Blackout)

Necessary and mandatory stages to manage an electricity crisis (blackout): [4–6]

Stage 1—Risk scenarios identification, assessment and manifestation:

- Risk scenario: Insecurity in functioning of the NPS: Local technical incidents; Multiple technical incidents caused by extreme weather conditions; Simultaneous technical incidents; Complexity of control mechanisms of power systems; Unwanted power movements; Serial faults of equipment; Human errors; Strikes, riots, protest actions of employees; Unusually large errors in the forecast of power produced in renewable energy plants; Pandemic.
- Risk scenario: Terrorist attack on the NPS: Internal cyberattack on critical infrastructure within the National Power System or Power Transmission Grid: power plants, power substations, overhead power lines, dispatchers, etc.; External cyberattack on critical infrastructures that are not part of the National Power System or Power Transmission Grid: power plants, power substations, overhead power lines, dispatchers, etc.; External terrorist attack on critical infrastructure within the National Power System or Power Transmission Grid: power plants, power substations, overhead power lines, dispatchers, etc.; Internal terrorist attack on the management centers within the National Power System or Power Transmission Grid; Sabotage actions by an internal employee on critical infrastructure within the National Power System or Power Transmission Grid: power plants, power substations, overhead power lines, dispatchers, etc.
- Risk scenario: Extreme weather condition: Extreme low temperature (cold); Storm; Heavy rainfall and flooding; Winter weather conditions (snow, ice, frost); Heat wave; Drought; Forest/vegetation fires.
- Risk scenario: Natural calamity: Solar storm; Earthquake.
- Risk scenario: Energy insecurity: Crisis in the provision of fossil fuels (coal, oil and natural gas); Crisis in provision of nuclear fuels; Industrial/nuclear accident; Unforeseen interactions in the energy market.
- Risk scenario: Political/military insecurity: Military conflict, war.

Stage 2—National, regional and bilateral procedures and measures:

- National procedures and measures: Measures regarding the functioning of the energy market; Measures regarding manual interruption of consumption; Special protection against disconnection; Prevention and preparedness measures; Mitigation and restoration measures; The entity responsible for declaring the crisis; The main stages of action in case of a crisis situation.
- Regional and bilateral procedures and measures: Agreed mechanisms to cooperate within the region; Regional and bilateral action measures in the event of a crisis; Mutual aid agreements to cooperate and coordinate actions before and during the energy crisis; Measures to mitigate the crisis, containment measures and restoration.

Stage 3—Role and tasks of competent authorities for securing electricity supply:

- The Romanian Competent Authority for Electricity Supply Assurance;
- Transmission and System Operator (TSO)—Transelectrica;
- Distribution operators (DO);

- Electricity production companies;
- Economic operators providing system services.

1.4. Theoretical Support

A. The global energy crisis and the increasing risk of blackouts are complex phenomena rooted in interdisciplinary frameworks. To provide a robust theoretical foundation for this analysis, we draw from systems theory, energy security theory, resilience theory, political economy perspectives, risk society theory and complex system theory. These frameworks allow for a multidimensional examination of energy infrastructure vulnerabilities, security risks, and policy responses:

- Systems Theory: Systems theory posits that energy infrastructure functions as a complex, interconnected system composed of physical, cyber, economic, and social subsystems. A disruption in one part—whether due to technical failure, cyberattack, fuel shortage, or natural disaster—can cascade across the entire system. Applying systems thinking helps identify feedback loops, bottlenecks, and failure points that can escalate localized energy issues into national or global crises;
- Energy Security Theory: Energy security theory emphasizes the availability, accessibility, affordability, and acceptability of energy resources. Under this model, energy crises are not merely about physical shortages but also geopolitical tensions, economic volatility, and environmental constraints. The theory supports the argument that energy security is foundational to national security, social stability, and economic performance;
- Resilience Theory: Resilience theory focuses on the capacity of systems to absorb shocks and maintain function. In the context of energy infrastructure, resilience refers to the ability of power grids and fuel supply chains to anticipate, withstand, and recover from disruptions. This perspective supports the importance of decentralized energy systems, grid modernization, and redundancy as critical components of blackout prevention;
- Political Economy of Energy: From a political economy perspective, energy crises are influenced by market dynamics, regulatory frameworks, and power relations among stakeholders. The global energy crisis is shaped by fossil fuel dependency, uneven access to renewables, and the financialization of energy markets. This framework also considers how international institutions, governments, and corporations shape energy policy and investment patterns, often privileging short-term economic gain over long-term sustainability and equity;
- Risk Society Theory: Risk Society theory provides a sociological lens, arguing that modern societies are increasingly preoccupied with managing risks—especially those resulting from technological and industrial development. Energy blackouts are emblematic of manufactured risks in modern infrastructure systems. The theory supports the need for interdisciplinary governance and public engagement in managing systemic energy risks;
- Complex systems Theory: The theory of complex systems is an interdisciplinary field that studies the behavior of systems composed of many interconnected components, whose local interactions can lead to the emergence of complex and often unpredictable global patterns. This field has applications in the natural sciences, social sciences, economics, technology, and computer science.

B. The research method (qualitative/quantitative) presented in the paper is derived from the International Standard Organization 31000 which provides principles and guidelines for risk management, including a structured risk assessment process. It does not prescribe a single method, but outlines a framework that can be adapted to different organizations and contexts.

Risk Assessment Process:

Risk assessment is a core part of the risk management process. It includes three key steps:

1. Risk Identification
    - Objective: Find, recognize, and describe risks that could affect objectives;
    - Should identify: Sources of risk (internal/external), Events or hazards, Causes and potential consequences, Existing controls;
    - Tools/techniques: Brainstorming, Checklists, Historical data review, SWOT analysis, Process mapping
2. Risk Analysis
    - Objective: Understand the nature of the risk and determine its level;
    - Analysis considers: Likelihood (how likely is the event?), Consequences (what are the impacts?), Level of risk (often shown in a matrix), Effectiveness of existing controls, Uncertainty/sensitivity;
    - Tools/techniques: Qualitative scales (e.g., high/medium/low), Quantitative models (e.g., statistical, financial models), Risk matrices or heat maps, Monte Carlo simulations.
3. Risk Evaluation
    - Objective: Compare the results of risk analysis with criteria to determine whether the risk is acceptable or needs treatment;
    - This step: Compares the risk level to thresholds, Ranks/prioritizes risks Supports decision-making (Accept the risk, Treat the risk, Monitor it);
    - Outputs of Risk Assessment: A risk register or risk log, Prioritized list of risks, Information to support risk treatment planning.

Note: this standard emphasizes that risk is the effect of uncertainty on objectives, and this process must be integrated into decision-making and tailored to the organization.

1.5. Uniqueness of the Paper and Innovative Aspects

The uniqueness of this paper innovative aspects lies in its interdisciplinary approach, which integrates and analyzes a broad spectrum of risks, threats, and vulnerabilities. These include technical incidents, human accidents, natural disasters, human errors, protests, strikes, internal staff sabotage, pandemics, cyberattacks (both internal and external), terrorist attacks, energy crises (involving coal, natural gas, uranium, oil, etc.), nuclear accidents, disruptions in energy markets, and the impacts of military conflicts or wars.

The paper explains very carefully each risk, threat and vulnerability and the manifestation on the National Power System, as well as the attributions of each entity, in case of a blackout. This intrinsic approach and analysis comes to the aid of the decision makers operating and managing the National Power System, a system that is a generator of energy security, national and European implicitly.

2. State of Art

Global energy crises are one of the biggest challenges of the XXI century, with major implications on the energy, economic, political and social security of states. Phenomena such as fossil resource depletion, supply and demand imbalances, geopolitical conflicts and climate change have highlighted the vulnerabilities of international power systems. In this context, the risk of blackout—complete or partial shutdown of electricity supply on large areas—is becoming more real and dangerous. Studying these crises and finding efficient solutions for their prevention and management is a strategic global necessity.

Energy crises can be caused by a number of interconnected factors: Dependence on non-renewable resources—oil, coal and natural gas still dominate the global energy mix. These resources are finite and geographically concentrated, which creates energy dependence on certain unstable regions; Growing global demand—rapid economic development in emerging countries (such as China and India) has led to a massive demand for energy, putting pressure on existing infrastructures; Climate change—extreme weather events affect the energy infrastructure (for example, droughts reduce the capacity of hydro power plants, and storms destroy power grids); Geopolitical conflicts—wars or international sanctions (e.g., the Russia-Ukraine conflict) can disrupt energy supply chains; Terrorist attacks—cyber and/or bomb attacks on energy objectives within power systems; Energy insecurity [7–9].

A major blackout can have devastating consequences: Economic effects—industrial production shutdown, massive financial losses, interruption of trade and services; Social impact—lack of access to electricity affects hospitals, transportation, communications and can lead to panic and chaos among the population; Vulnerabilities in national security—in lack of energy, the defense, monitoring and intervention systems can become inoperative.

Recent examples, such as the blackouts in Spain and Portugal (2025), Texas (2021), South America (2019), demonstrate how fragile the energy infrastructure can be and how rapidly such collapses can occur.

In order to prevent energy crises and associated risks, a preventive, complex and interdisciplinary approach is needed: Diversification of energy sources—investments in renewable sources (solar, wind, hydro, geothermal) can reduce dependence on fossil fuels; Energy efficiency—infrastructures modernization and energy efficient technologies promotion can reduce excessive consumption; International cooperation—technology exchange, establishment of common standards and regional energy agreements can strengthen energy security; Grids digitization—smart grids, energy storage and artificial intelligence can contribute to a more flexible and resilient management of power systems [7–9].

Global energy crises are no longer mere assumptions, but increasingly common realities. In an interconnected world, any imbalance at a point in the system can have chain effects. Therefore, in-depth study of these phenomena and the implementation of proactive policies are imperative. Only an integrated, sustainable and internationally coordinated approach can reduce the risk of blackout and ensure a safe transition to a sustainable energy future.

The phenomenon of energy blackouts is studied extensively worldwide by a diverse community of specialists in the fields of electrical engineering, physics, computer science and energy policies. These experts analyse the causes, dynamics and solutions for the prevention and management of these critical events.

Global reference researchers and experts:

- Prof. Dr. C. Göran Andersson—professor emeritus at ETH Zürich, is recognized for his research on the stability of power grids, the integration of renewable sources and the cybersecurity of SCADA systems; [10]
- Dr. Keywan Riahi—director of the Department of Energy at the International Institute for Applied Systems Analysis (IIASA) and UN Energy Policy Advisor. He is one of the most influential scientists in the field of climate change and energy transition; [11]
- Prof. Giovanni Sansavini—researcher at ETH Zürich, he coordinates studies on vulnerabilities in electricity transmission systems in Europe, analyzing empirical data to identify blackout risks and recommending preventive measures; [12]

- Dr. José Matas—professor at the Polytechnic University of Catalonia, editor of a special edition of the journal Energies dedicated to lessons learned from recent blackouts on the Iberian Peninsula; [13]
- Dr. Pablo Moya—physicist at the University of Chile, specializing in space meteorology. He warned of the risk of global blackout caused by intense geomagnetic storms [14].

Relevant academic contributions:

- Yakup Koç and collaborators—have investigated how the topology of power grids influences phase transitions in the case of cascading faults, providing insights into how to design grids in order to prevent blackouts; [15]
- Tommaso Nesti and his team—have demonstrated that blackout sizes follow a "scale-free" distribution similar to city size distribution, suggesting that power grids are susceptible to rare major events; [16]
- Joe Gorka and collaborators—have developed models based on graphical neural networks to predict the severity of cascading blackouts, providing rapid tools for risk assessment in modern grids [17].

Global perspectives:

Recent blackouts in Spain and Portugal have highlighted the vulnerabilities of modern power grids, particularly in the context of the integration of renewable energy sources. Experts stress the need to invest in grid stabilization technologies such as storage batteries and advanced grid management systems to ensure resilience against various threats, including extreme weather events and cyberattacks.

For the deepening of energy blackouts, the special edition of the journal Energies entitled "Extreme Events and Power Grid Resilience: Lessons from Iberian Blackouts" can be consulted, which brings together recent research and relevant case studies (MDPI) [18].

Comparisons and similar studies:

A. International Energy Agency's IEA report on grid resilience

1. "Electricity 2025"—Increased Security and Reliability
    - The IEA highlights that the expansion of electricity consumption, combined with generation from variable sources (solar, wind), increases the need for grid flexibility, robustness, and resilience.
    - Extreme weather events—such as storms, heatwaves, or droughts (impacting hydropower)—have caused major outages in 2024–2025, with regions like Texas, Australia, Mexico, Ecuador, and the U.S. being severely affected.
2. Risk of Blackouts and High Economic Cost
    - In the "Grid Delay Case" scenario, the IEA warns that power outages could cost around USD 100 billion annually, equivalent to 0.1% of global GDP.
    - Lack of investment not only increases CO_2 emissions but also threatens climate targets due to delays in connecting 3000 GW of renewable capacity.
3. The Iberian Lesson (April 2025 Blackout)
    - The grid failure in Spain and Portugal on 28 April 2025, was triggered by voltage fluctuations, where poor management of reactive power amplified massive disconnections.
    - IEA comments emphasized that renewables were not to blame for the blackout, but rather the lack of digitalization, interconnection, and modern stabilization tools.
4. Key Elements: Digitalization & Flexibility
    - Smart grids with stabilization technologies (synchronous condensers, valves, etc.), digital control, and storage (batteries, hydro) are crucial for integrating large volumes of renewables.

- The IEA estimates that, to reach climate neutrality, global grid investments must double to over USD 600 billion per year by 2030.

5. IEA-Recommended Policies and Regulations
    - Updating regulations to promote reliability and performance, rewarding operators for advanced services (ancillary services).
    - Integrated planning, aligning the energy transition with distribution/transmission infrastructure and the demands of electrification (EVs, heat pumps, etc.).
    - Community involvement and transparency to ensure social acceptance and predictability in permitting.

Conclusion:

- The IEA prioritizes grid modernization and digitalization to avoid costly and potentially devastating blackouts.
- The Iberian Peninsula example highlights that the issue is not the growth of renewables, but outdated infrastructure.
- The main recommendation: sustained investments, clear regulations, interoperability, and supportive grid technologies—these are essential for a safe, resilient, and sustainable energy transition.

- Power System Resilience—Professor Massoud Amin from Electrical and Computer Engineering Honeywell/H. W. Sweatt Chair in Technological Leadership Director, Center for the Development of Technological Leadership (CDTL) University of Minnesota, Minneapolis, MN 55454 USA
- Prof. Massoud Amin is internationally recognized as one of the foremost experts in the field of energy systems resilience and critical infrastructure. Here are some of his key contributions:
- The Concept of Resilience in Electric Grids

Prof. Amin was a pioneer in developing the concept of "resilience" applied to electric grids, clearly distinguishing it from the traditional notion of "reliability" (which focuses only on dependability and security). He emphasized the need for energy systems to be capable of rapid and adaptive recovery after severe incidents such as natural disasters or cyberattacks.

Methodologies for Assessing and Improving Resilience

He developed methods and metrics for evaluating the level of resilience in energy infrastructures, considering not only reliability but also the system's ability to respond and adapt.

Integration of Smart Grid Technologies

Prof. Amin advocated the use of intelligent technologies (smart grids) that can automatically detect, isolate, and remediate issues in the electrical network, thereby contributing to the overall increase of resilience.

Holistic Approach to Interconnected Critical Systems

He highlighted the interdependence between critical infrastructures (energy, communications, transportation) and proposed integrated models for protecting and strengthening their collective resilience.

Global Studies and Consultancy

In addition to his academic work, Prof. Amin has collaborated with governments and international organizations to implement practical resilience solutions in electric grids across various regions, including in the context of cyber threats and climate change.

3. Blackout Scenarios at National and European Level

3.1. Risk Scenarios Estimation and Assessment Algorithm

3.1.1. Likelihood Estimation

Level	Likelihood	Time
1. Very low	It has a very low likelihood of occurring. Normal measures are required to monitor the evolution of the event.	over 20 years
2. Low	The event has a low likelihood of occurring. Efforts are needed to reduce the likelihood and/or mitigate the impact produced.	16–20 years
3. Medium	The event has a significant likelihood of occurring. Significant efforts are needed to reduce the likelihood and/or mitigate the impact produced.	11–15 years
4. High	The event has a likelihood of occurring. Priority efforts are needed to reduce the likelihood and mitigate the impact produced.	6–10 years
5. Very high	The event is considered imminent. Immediate and extreme measures are required to protect the objective, evacuation to a safe location if the impact so requires.	1–5 years

3.1.2. Gravity Estimation

Level	Gravity/Impact
1. Very low	The event produces a minor disturbance in the activity, without material damage
2. Low	The event causes minor material damage and limited disruption to activity
3. Medium	Injuries to staff, and/or certain losses of equipment, utilities and delays in providing the service.
4. High	Serious staff injuries, significant loss of equipment of installations and facilities, delays and/or interruption of service provision.
5. Very high	The consequences are catastrophic resulting in deaths and serious injuries to staff, major losses in equipment, installations and facilities and termination of service provision.

3.1.3. Risk Level Calculation

Likelihood	Very high 5					
	High 4					
	Medium 3					
	Low 2					
	Very low 1					
	0	Very low 1	Low 2	Medium 3	High 4	Very high 5

Gravity/Impact

Note: The risk is given by the product between Likelihood and Gravity/Impact.

3.1.4. Risk Scenario Type

Risk Level: 1–3	Risk Level: 4–6	Risk Level: 7–12	Risk Level: 13–16	Risk Level: 17–25
Very low	Low	Moderate	Bad	Very bad

3.2. Risk Scenarios Identification, Assessment and Manifestation

3.2.1. Source: Insecurity in Functioning of the NPS

The identification, assessment and manifestation are shown in Table 2 [19,20].

Table 2. Risk sceanario—Insecurity in functioning of the PNS (own elaboration).

Risk Scenario: Insecurity in Functioning of the Nps			
1	Local technical incidents	Likelihood: 3 Medium Gravity/Impact: 3 Medium Risk level: 9 Scenario type: 7–12 Moderate	Equipment triggers take place and some equipment becomes unavailable for a very long period of time; The risk of overloads on important lines and transformation units, including interconnection lines, increases and then cascading faults occur; A separation of the system may occur and certain areas may function in island mode; Difficulties arise in ensuring the adequacy of the NPS due to a reduced level of production in power plants. This causes the limitation or total loss of reserves; Major deviations of the NPS functioning parameters are recorded; The N-1 safety criterion is no longer met; Also, the low level of production and loading of certain lines may lead to the impairment of the static and dynamic stability of the NPS; There is a major risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers.
2	Multiple technical incidents caused by extreme weather conditions	Likelihood: 3 Medium Gravity/Impact: 3 Medium Risk level: 9 Scenario type: 7–12 Moderate	Extreme weather leads to accidental failure of several equipment (possibly of the same construction type) in a very short time; Disturbances occur in the road transport network, which leads to delays in carrying out the faults remediation work/repair of equipment; Difficulties may arise in carrying out faults remediation work in substations, caused by the large number of equipment of the same type affected and the lack of equipment in security stocks; Problems arise in ensuring that the N-1 safety criterion is met; Problems arise in supplying some grid areas for a very long period, correlated with the time required to repair/replace destroyed/damaged assets; There is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers.

Table 2. *Cont.*

<table>
<tr><th colspan="4">Risk Scenario: Insecurity in Functioning of the Nps</th></tr>
<tr><td>3</td><td>Simultaneous technical incidents</td><td><table><tr><td>Likelihood</td><td>3
Medium</td></tr><tr><td>Gravity/
Impact</td><td>4
High</td></tr><tr><td>Risk level</td><td>12</td></tr><tr><td>Scenario type</td><td>7–12
Moderate</td></tr></table></td><td>Separation of a grid area may occur where there are not enough production units to ensure consumption of the area;
Deviations of functioning parameters outside the permissible limits shall occur;
The N-1 safety criterion is no longer met;
Difficulties may arise in carrying out faults remediation work in substations, caused by the large number of equipment of the same type affected and the lack of equipment in security stocks;
Problems arise in supplying some grid areas for a very long period, correlated with the time required to repair/replace damaged assets;
Congestions can occur on interconnection lines and even the impossibility of securing electricity exports;
There is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers.</td></tr>
<tr><td>4</td><td>Complexity of control mechanisms of power systems</td><td><table><tr><td>Likelihood</td><td>2
Low</td></tr><tr><td>Gravity/
Impact</td><td>4
High</td></tr><tr><td>Risk level</td><td>8</td></tr><tr><td>Scenario type</td><td>7–12
Moderate</td></tr></table></td><td>As a result of the triggering of some equipment in the PTG, very large power movements appear that completely differ from the movements analyzed when planning the functioning of the NPS;
The risk of overloads on important lines and transformation units, including interconnection lines, and the risk of cascading faults occurring increases;
A separation of the system may occur and certain areas may function in island mode;
Difficulties arise in ensuring the adequacy of the NPS due to a reduced level of production in power plants. This causes the limitation or total loss of reserves;
Major deviations of the NPS functioning parameters are recorded;
The N-1 safety criterion is no longer met;
Also, the low level of production and loading of certain lines may lead to the impairment of the static and dynamic stability of the NPS;
There is a major risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers.</td></tr>
<tr><td>5</td><td>Unwanted power movements</td><td><table><tr><td>Likelihood</td><td>3
Medium</td></tr><tr><td>Gravity/
Impact</td><td>5
Very high</td></tr><tr><td>Risk level</td><td>15</td></tr><tr><td>Scenario type</td><td>13–16
Bad</td></tr></table></td><td>Very large power movements appear that completely differ from the movements analyzed when planning the functioning of the NPS;
The risk of overloads on important lines and transformation units, including interconnection lines, increases;
System operation is hampered by large forecasting errors and cascading equipment triggers and even loss of control over a grid area may occur;
Disturbances can affect all energy markets in the region or across Europe, namely the functioning of the interconnected systems of ENTSO-E members;
Forecast errors/imbalances in different control blocks can lead to incidents/frequency deviations in the synchronous grid area;
Limitations of energy imports/exports may occur;
Extensive damage may occur leading to the failure of supplying electricity to a large number of consumers.</td></tr>
</table>

Table 2. *Cont.*

Risk Scenario: Insecurity in Functioning of the Nps			
6	Serial faults of equipment	Likelihood: 2 Low Gravity/Impact: 3 Medium Risk level: 6 Scenario type: 4–6 Low	Improper operation behavior of multiple equipment leads to equipment triggers or equipment damage. Some equipment is also accidentally withdrawn from operation for remediation or verification; The N-1 safety criterion is no longer met; Separation of a grid area may occur where there are not enough production units to ensure consumption of the area; Deviations of functioning parameters of the NPS outside the permissible limits shall occur; Difficulties may arise in carrying out faults remediation work in substations, caused by the large number of equipment of the same type affected and the lack of equipment in security stocks; Problems arise in supplying some grid areas for a very long period, correlated with the time required to repair/replace damaged assets; There is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers.
7	Human errors	Likelihood: 3 Medium Gravity/Impact: 5 Very high Risk level: 15 Scenario type: 13–16 Bad	The risk of overloads on important lines and transformation units, including interconnection lines, and the risk of cascading faults occurring increases; A separation of the system may occur and certain areas may function in island mode; Difficulties arise in ensuring the adequacy of the NPS due to a reduced level of production in power plants. This causes the limitation or total loss of reserves; Major deviations of the NPS functioning parameters are recorded; The N-1 safety criterion is no longer met; Also, the low level of production and loading of certain lines may lead to the impairment of the static and dynamic stability of the NPS; There is a major risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers.
8	Strikes, riots, protest actions of employees	Likelihood: 2 Low Gravity/Impact: 4 Very high Risk level: 10 Scenario type: 7–12 Moderate	The lack of staff leads to a decrease in fuel reserves for power plants, the quality of operating services decreases, the intervention time for repairing faults increases, and some maintenance works are stopped; Due to the low number of staff there is a risk of mistakes due to insufficient training of the available staff or fatigue; Problems arise in forecasting consumption on the energy market due to the unpredictable nature of the protest events; The occurrence of accidental events in the NPS may lead to extensive damage in the context of lack of qualified staff.
9	Unusually large errors in the forecast of power produced in renewable energy plants	Likelihood: 2 Low Gravity/Impact: 4 High Risk level: 8 Scenario type: 7–12 Moderate	There is a positive or negative imbalance between the forecasted power and that which can be produced in renewable energy plants; Disturbances occur in the electricity market through large variations in the electricity trading price or an insufficient level of offers; Reduced production in certain plants leads to large power movements to deficient areas and results in voltage deviations and difficulties in compensating reactive power; For certain time intervals problems arise in ensuring that the N-1 safety criterion is met; Low production level and loading of certain lines as well as low inertia level can lead to the impairment of the static and dynamic stability of the NPS; In conditions of low production in power plants and large power movements to deficient areas, there is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers.

Table 2. *Cont.*

<table>
<tr><th colspan="5">Risk Scenario: Insecurity in Functioning of the Nps</th></tr>
<tr><td rowspan="4">10</td><td rowspan="4">Pandemic</td><td>Likelihood</td><td>1
Very low</td><td rowspan="4">Operational staff at dispatch centers, power substations and power plants is affected and lead to an acute shortage of qualified staff necessary to ensure the safe functioning of the NPS;
Also, the lack of staff at all entities in the NPS leads to a decrease in fuel reserves for power plants, the increase of the intervention time for repairing faults, the cessation of maintenance works;
Due to the low number of staff there is a risk of mistakes due to insufficient training of the available staff or fatigue;
Problems arise in forecasting consumption on the energy market due to the unpredictable nature of the pandemic events;
The occurrence of accidental events in the NPS may lead to extensive damage in the context of lack of qualified staff and high intervention time.</td></tr>
<tr><td>Gravity/ Impact</td><td>1
Very low</td></tr>
<tr><td>Risk level</td><td>1</td></tr>
<tr><td>Scenario type</td><td>1–3
Very low</td></tr>
</table>

3.2.2. Source: Terrorist Attack on the NPS

The identification, assessment and manifestation are shown in Table 3 [19,20].

Table 3. Source: Terrorist attack on the NPS (own elaboration).

<table>
<tr><th colspan="5">Risk Scenario: Terrorist Attack on the Nps</th></tr>
<tr><td rowspan="4">11</td><td rowspan="4">Internal cyberattack on critical infrastructure within the National Power System or Power Transmission Grid: power plants, power substations, overhead power lines, dispatchers, etc.</td><td>Likelihood</td><td>3
Medium</td><td rowspan="4">The attacker (hacker/cracker) acts as an employee of the National Power System (NPS) and disconnects lines, transformers or changes the functioning instructions of some generation units, modifies power reserves, changes the functioning schedule of dispatcher units;
During a cyberattack, it is possible that computer systems may be blocked for use by people other than the hacker or cracker. This affects the possibilities of taking control and restoration measures for the NPS;
Disturbances occur in the electricity market;
The disconnection of some production units and equipment within the Power Transmission Grid (PTG) and the Power Distribution Grid (PDG), leads to large power movements to deficient areas and results in the overload of some equipment and voltage deviations and difficulties in compensating the reactive power including during a blackout;
For certain time intervals problems arise in ensuring that the N-1 safety criterion is met. Also, the low level of production and loading of certain lines may lead to the impairment of the static and dynamic stability of the NPS;
In conditions of low production in power plants and large power movements to deficient areas, there is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers.
The cyberattack may extend to other computer systems belonging to other Transport Operators (TOs) in the region and may lead to the impossibility of receiving or providing support to other countries in the region.</td></tr>
<tr><td>Gravity/ Impact</td><td>5
Very high</td></tr>
<tr><td>Risk level</td><td>15</td></tr>
<tr><td>Scenario type</td><td>13–16
Bad</td></tr>
</table>

Table 3. *Cont.*

Risk Scenario: Terrorist Attack on the Nps			
12	External cyberattack on critical infrastructures that are not part of the National Power System or Power Transmission Grid: power plants, power substations, overhead power lines, dispatchers, etc.	Likelihood: 3 Medium Gravity/Impact: 5 Very high Risk level: 15 Scenario type: 13–16 Bad	The attacker (hacker/cracker) penetrates the communication and data transmission computer systems of the energy market participants and acts as an employee working with these systems and manipulating the functioning conditions of the energy market (demands and offers on trading platforms, functioning schedules of production units); During the attack, it is possible that computer systems may be blocked for use by people other than the hacker or cracker. Disturbances occur in the electricity market; Changing the functioning schedule may lead to shutdown of some production units and to the production of imbalances which further may lead to frequency deviations or large power movements towards the deficient areas, voltage deviations and difficulties in compensating the reactive power; For certain time intervals problems arise in ensuring that the N-1 safety criterion is met. Also, the low level of production and loading of certain lines may lead to the impairment of the static and dynamic stability of the NPS; In conditions of low production in power plants and large power movements to deficient areas, there is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers. The attack may have very serious consequences in the context in which it occurs against the background of high consumption values in the NPS, periods with extremely high temperatures or amid abundant rainfall.
13	External terrorist attack on critical infrastructure within the National Power System or Power Transmission Grid: power plants, power substations, overhead power lines, dispatchers, etc.	Likelihood: 3 Medium Gravity/Impact: 5 Very high Risk level: 15 Scenario type: 13–16 Bad	The attacker (terrorist) destroys technical equipment (lines, transformers, generators, electrical equipment in substations or plants, servers of central command systems, central telecommunications installations).; In the event of a terrorist attack on power lines, substations or power plants, equipment triggers take place and some equipment becomes unavailable for a very long period of time; In the event of a terrorist attack on the servers of central command systems, central telecommunications installations, the operation and control capacity of the NPS is being affected in the long run; Difficulties arise in ensuring that the N-1 safety criterion is met; Triggering some production units and equipment within the PTG and the PDG, leads to large power movements to deficient areas and leads to large power movements to deficient areas and results in voltage deviations and difficulties in compensating the reactive power; Problems arise in supplying some grid areas for a very long period, correlated with the time required to repair/replace destroyed/damaged infrastructures; In conditions of low production in power plants and large power movements to deficient areas, there is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers.

Table 3. *Cont.*

Risk Scenario: Terrorist Attack on the Nps			
14	Internal terrorist attack on the management centers within the National Power System or Power Transmission Grid	Likelihood: 3 Medium Gravity/Impact: 5 Very high Risk level: 15 Scenario type: 13– 16 Bad	The attacker (terrorist) acts as an employee and disconnects lines, transformers or changes the functioning instructions of some generation units, modifies power reserves, changes the functioning schedule of dispatcher units. These lead to large power movements to deficient areas and result in voltage deviations and difficulties in compensating the reactive power; Also, the goals of the attacker are the destruction of SCADA—EMS, SCADA—DMS systems, regulator f–P, central control systems, planning and operating systems, IT centers, data storage systems, control command systems from major power substations and plants or telemanagement centers. Affected management centers can no longer ensure the management, operation or monitoring of installations. This affects the possibilities of taking some control and restoration measures for the NPS; Disturbances occur in the electricity market; Large power movements to deficient areas can lead to congestion on interconnecting lines and even the impossibility of ensuring electricity exports; There is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers.
15	Sabotage actions by an internal employee on critical infrastructure within the National Power System or Power Transmission Grid: power plants, power substations, overhead power lines, dispatchers, etc.	Likelihood: 3 Medium Gravity/Impact: 5 Very high Risk level: 15 Scenario type: 13–16 Bad	The attacker (saboteur) destroys technical equipment (lines, transformers, generators, electrical equipment in substations or plants) or performs other actions that lead to disconnection or triggers of lines or transformation units, accidental shutdown of the production of groups in power plants; Some equipment become unavailable for a very long period; Difficulties arise in ensuring that the N-1 safety criterion is met; The disconnection of some production units and equipment within the PTG leads to large power movements to deficient areas and results in voltage deviations and difficulties in compensating the reactive power; Problems arise in supplying some grid areas for a very long period, correlated with the time required to repair/replace destroyed/damaged assets; In conditions of low production in power plants and large power movements to deficient areas, there is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers.

3.2.3. Source: Extreme Weather Condition

The identification, assessment and manifestation are shown in Table 4 [19,20].

Table 4. Source: Extreme weather condition (own elaboration).

Risk Scenario: Extreme Weather Condition			
16	Extreme low temperature (cold)	Likelihood: 3 Medium Gravity/Impact: 5 Very high Risk level: 15 Scenario type: 13–16 Bad	Difficulties arise in ensuring the adequacy of the NPS due to a reduced level of production in power plants, this causes the limitation or total loss of reserves; In conditions of very low temperatures, accidental events occur that lead to the unavailability of equipment in the transmission and distribution network; Under these conditions, interconnection capacities are required to the maximum, which can limit the level of electricity imports; Disturbances occur in the electricity market through large variations in the electricity trading price or an insufficient level of offers; Low production in certain plants leads to large power movements to deficient areas, overload of some grid elements and results in voltage deviations and difficulties in compensating reactive power; For certain time intervals problems arise in ensuring that the N-1 safety criterion is met. Low production level and loading of certain lines can lead to the impairment of the static and dynamic stability of the NPS; The impossibility of intervention in some areas appears and increases the time needed for intervention and remediation actions; In conditions of extreme low temperatures, accidental triggers of electrical equipment (power lines, transformers or autotransformers) may occur, which may lead to the overload of other equipment and to the increase of grid congestions; There is a risk of the impossibility of operating some switching equipment, in the event of interventions or maneuvers necessary to maintain the safe functioning of power grids; There is a high media pressure, as well as from the public opinion and the political environment, regarding the rapid resolution of the crisis situation and the provision of energy needs for the population and the stopping of exports; The low temperature can affect the entire region which leads to the impossibility of receiving or providing support to other countries in the region; Low level of domestic production as well as large power movements to deficient areas can lead to congestion on interconnecting lines and even the impossibility of ensuring electricity exports; In conditions of insufficient production in power plants and large power movements to deficient areas, there is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers.

Table 4. *Cont.*

Risk Scenario: Extreme Weather Condition			
17	Storm	Likelihood: 3 Medium Gravity/Impact: 5 Very high Risk level: 15 Scenario type: 13–16 Bad	Line triggers occur due to electrical discharges, conductor breaks, trees falling on lines, conductor galloping; The triggers can be simultaneous for lines located on the same corridor, the same pillars or on lines located very close together; Damage to insulators, conductors or falling trees can lead to long-term unavailability of lines; Some pillars may fall due to the galloping phenomenon; Triggers occur in substations due to faults in busbar fields caused by materials/branches brought by the wind; Disturbances occur in the road transport network, which leads to delays in carrying out the faults remediation work/repair of the lines; Production in wind power plants is decreasing sharply due to wind intensification; Problems arise in ensuring that the N-1 safety criterion is met; Problems arise in supplying some grid areas for a very long period, correlated with the time required to repair/replace destroyed/damaged assets; Low level of domestic production as well as large power movements to deficient areas can lead to congestion on interconnecting lines and even the impossibility of ensuring electricity exports; There is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers.
18	Heavy rainfall and flooding	Likelihood: 3 Medium Gravity/Impact: 5 Very high Risk level: 15 Scenario type: 13–16 Bad	Equipment triggers occur due to flooding of substations; Triggers or unavailability of some lines occur, caused by landslides or floods affecting the stability of the pillars; There is a reduction in production in the affected hydro power plants; Disturbances occur in the road transport network, which leads to delays in carrying out the faults remediation work/repair of the lines; Problems arise in supplying some grid areas for a very long period, correlated with the time required to repair/replace damaged infrastructures; Congestions can occur on interconnection lines and even the impossibility of securing electricity exports; There is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers.
19	Winter weather conditions (snow, ice, frost)	Likelihood: 3 Medium Gravity/Impact: 5 Very high Risk level: 15 Scenario type: 13–16 Bad	Several line triggers occur, caused by snow, ice or frost, or falling trees on the lines; Production in wind power plants is decreasing or stopping altogether due to ice deposits on turbine blades; Damage to insulators, conductors or falling trees can lead to long-term unavailability of lines; Some pillars may fall due to the galloping phenomenon; Disturbances occur in the road transport network, which leads to delays in carrying out the faults remediation work/repair of the lines; Problems arise in ensuring that the N-1 safety criterion is met; Problems arise in supplying some grid areas for a very long period, correlated with the time required to repair/replace damaged infrastructures; Large power movements to deficient areas can lead to congestion on interconnecting lines and even the impossibility of ensuring electricity exports; There is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers.

Table 4. *Cont.*

<table>
<tr><th colspan="4">Risk Scenario: Extreme Weather Condition</th></tr>
<tr><td>20</td><td>Heat wave</td><td>
<table>
<tr><td>Likelihood</td><td>3
Medium</td></tr>
<tr><td>Gravity/
Impact</td><td>5
Very high</td></tr>
<tr><td>Risk level</td><td>15</td></tr>
<tr><td>Scenario type</td><td>13–16
Bad</td></tr>
</table>
</td><td>Line triggers occur due to the expansion of OHL conductors, equipment triggers due to sealing faults (oil/SF6 gas leaks), incorrect functioning of numerical terminals due to excessive heating of switchbox, shutdown of computer and process systems and communication systems;
Vegetation fires may occur in transformer substations correlated with the production of short circuits in the grid and by melting some materials when passing the fault current through equipment with imperfect contacts;
Vegetation fires may occur in the safety corridor of power lines, leading to equipment triggers or damage;
At peak times, the energy consumption from internal resources is not covered and it is necessary to import a significant amount of energy. Under these conditions, interconnection capacities which may limit the level of electricity imports are maximised;
The appropriate level of voltage in certain grid areas is not ensured due to a reactive power deficit caused by the widespread use of air conditioners (coolers);
Difficulties arise in ensuring the adequacy of the NPS due to a reduced level of production in power plants, which causes the limitation or total loss of reserves;
Disturbances occur in the electricity market through large variations in the electricity trading price or an insufficient level of offers;
Reduced production in certain plants leads to large power movements to deficient areas and results in voltage deviations and difficulties in compensating reactive power;
For certain time intervals problems arise in ensuring that the N-1 safety criterion is met;
The low level of production and loading of certain lines may lead to the impairment of the static and dynamic stability of the NPS;
The drought can affect the entire region which leads to the impossibility of receiving or providing support to other countries in the region;
Low level of domestic production as well as large power movements to deficient areas can lead to congestion on interconnecting lines and even the impossibility of ensuring electricity exports;
In conditions of low production in power plants and large power movements to deficient areas, there is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers.</td></tr>
</table>

Table 4. *Cont.*

Risk Scenario: Extreme Weather Condition			
21	Drought	Likelihood: 3 Medium Gravity/Impact: 5 Very high Risk level: 15 Scenario type: 13–16 Bad	At peak times, the energy consumption from internal resources is not covered and it is necessary to import a significant amount of energy. Under these conditions, interconnection capacities which may limit the level of electricity imports are maximised The appropriate level of voltage in certain grid areas is not ensured due to a reactive power deficit caused by the widespread use of air conditioners; Difficulties arise in ensuring the adequacy of the NPS due to a reduced level of production in power plants, which causes the limitation or total loss of reserves; Disturbances occur in the electricity market through large variations in the electricity trading price or an insufficient level of offers; Reduced production in certain plants leads to large power movements to deficient areas and results in the overload of some grid elements and voltage deviations and difficulties in compensating reactive power; For certain time intervals problems arise in ensuring that the N-1 safety criterion is met; Low production level and loading of certain lines can lead to the impairment of the static and dynamic stability of the NPS; The drought can affect the entire region which leads to the impossibility of receiving or providing support to other countries in the region; Low level of domestic production as well as large power movements to deficient areas can lead to congestion on interconnecting lines and even the impossibility of ensuring electricity exports; In conditions of low production in power plants and large power movements to deficient areas, there is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers. Under the action of heat, accidental triggers of electrical equipment (power lines, transformers or autotransformers) may occur, which may lead to the overload of other equipment and to the increase of grid congestions;
22	Forest/vegetation fires	Likelihood: 3 Medium Gravity/Impact: 5 Very high Risk level: 15 Scenario type: 13–16 Bad	Large areas are covered by fires, and in certain areas violent storms are produced, accompanied by electric discharges that increase the number of fire outbreaks; Line triggers occur, caused by fire flames and line disconnections are required to allow staff to intervene to extinguish or stop the spread of fires; Fires can also spread across substation territory leading to equipment triggers and damage; There is a reduction in production in wind power plants due to wind intensification; Disturbances occur in the road transport network, which leads to delays in carrying out the faults remediation work/repair of affected/damaged equipment; Problems arise in ensuring that the N-1 safety criterion is met; Problems arise in supplying some grid areas for a very long period, correlated with the time required to repair/replace destroyed/damaged assets; There is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers.

3.2.4. Source: Natural Calamity

The identification, assessment and manifestation are shown in Table 5 [19,20].

Table 5. Source: Natural calamity (own elaboration).

<table>
<tr><th colspan="4">Risk Scenario: Natural Calamity</th></tr>
<tr><td>23</td><td>Solar storm</td><td><table><tr><td>Likelihood</td><td>1
Very low</td></tr><tr><td>Gravity/
Impact</td><td>5
Very high</td></tr><tr><td>Risk level</td><td>5</td></tr><tr><td>Scenario
type</td><td>4–6
Low</td></tr></table></td><td>The solar (geomagnetic) storm generates the appearance of the Carrington effect, which leads to widespread damage to transformer units and line insulators;
Protection malfunctions occur;
All computer systems are affected;
Major and long-term disturbances occur in communication systems that significantly hinder the response in a crisis situation;
Equipment triggers take place and some equipment becomes unavailable for a very long period of time;
Controlled disconnects occur to prevent the transformation units from being overloaded;
A controlled blackout may occur due to the evolution at European level;
Coordinated action is taken at ENTSO-E level as the situation has been anticipated and some organizational crisis response measures have been taken.
Problems arise in supplying some grid areas for a very long period, correlated with the time required to repair/replace destroyed/damaged assets;</td></tr>
<tr><td>24</td><td>Earthquake</td><td><table><tr><td>Likelihood</td><td>1
Very low</td></tr><tr><td>Gravity/
Impact</td><td>5
Very high</td></tr><tr><td>Risk level</td><td>5</td></tr><tr><td>Scenario
type</td><td>4–6
Low</td></tr></table></td><td>Damage/triggers of equipment in substations and damage/falls of pillars on lines occur;
Accidental shutdowns of production groups in power plants located in the area affected by the earthquake may occur;
Industrial accidents may occur accompanied by fires, production shutdowns, gas emissions or leaks of hazardous substances;
Damage occurs to GIS buildings in power substations, electrical equipment foundations or transformers;
Disturbances occur in the road transport network, which leads to delays in carrying out the faults remediation work/repair of lines and transformation units;
The functioning of communication systems is disrupted due to the phenomenon of generalized panic;
Rescue or firefighting teams are required;
Difficulties may arise in carrying out faults remediation work in substations, caused by the large number of equipment of the same type affected and the lack of equipment in security stocks;
Problems arise in ensuring that the N-1 safety criterion is met;
Problems arise in supplying some grid areas for a very long period, correlated with the time required to repair/replace damaged assets;
Congestions can occur on interconnecting lines and even the impossibility of securing electricity exports;
There is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers.</td></tr>
</table>

3.2.5. Source: Energy Insecurity

The identification, assessment and manifestation are shown in Table 6 [19,20].

Table 6. Source: Energy insecurity (own elaboration).

<table>
<tr><th colspan="4">Risk Scenario: Energy Insecurity</th></tr>
<tr><td>25</td><td>Crisis in the provision of fossil fuels (coal, oil and natural gas)</td><td><table><tr><td>Likelihood</td><td>1
Very low</td></tr><tr><td>Gravity/
Impact</td><td>5
Very high</td></tr><tr><td>Risk level</td><td>5</td></tr><tr><td>Scenario type</td><td>4–6
Low</td></tr></table></td><td>Initially, production redispatching occurs to other production units that do not depend on fossil fuels, and production units affected by the lack of fossil fuels are kept in operation at a technical level of damage;
The prolongation of the crisis leads to the total shutdown of some production units, as a consequence of which difficulties arise in ensuring the adequacy of the NPS;
Disturbances occur in the electricity market through large variations in the electricity trading price or an insufficient level of offers;
Reduced production in certain plants leads to large power movements to deficient areas and results in the overload of some grid elements and voltage deviations and difficulties in compensating reactive power;
For certain time intervals problems arise in ensuring that the N-1 safety criterion is met;
Low production level and loading of certain lines can lead to the impairment of the static and dynamic stability of the NPS and the crisis can affect the entire region, which leads to the impossibility of receiving or providing support to other countries in the region;
Low level of domestic production as well as large power movements to deficient areas can lead to congestion on interconnecting lines and even the impossibility of ensuring electricity exports;
In conditions of low production in power plants and large power movements to deficient areas, there is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers.</td></tr>
<tr><td>26</td><td>Crisis in provision of nuclear fuels</td><td><table><tr><td>Likelihood</td><td>1
Very low</td></tr><tr><td>Gravity/
Impact</td><td>5
Very high</td></tr><tr><td>Risk level</td><td>5</td></tr><tr><td>Scenario type</td><td>4–6
Low</td></tr></table></td><td>sensitive information</td></tr>
</table>

Table 6. *Cont.*

Risk Scenario: Energy Insecurity			
27	Industrial/nuclear accident	Likelihood: 1 Very low Gravity/Impact: 5 Very high Risk level: 5 Scenario type: 4–6 Low	Access is no longer allowed in the affected area, which leads to the impossibility of intervention or proper operation of the installations in the NPS in that area; The activity of some production units is affected by staff shortages or shortages in fuel supply, and as a result difficulties arise in ensuring the adequacy of the NPS; The distribution grid in the affected area is seriously affected; Some areas of the NPS may function in island mode; In the event of a nuclear accident, disturbances in the electricity market arise through large variations in the electricity trading price or an insufficient level of offers. If the system reaches a state of emergency (defined according to the European Grid Code Emergency & Restoration) it is possible to suspend the electricity market; Reduced production in certain plants leads to large power movements to deficient areas and results in voltage deviations and difficulties in compensating reactive power; For certain time intervals problems arise in ensuring that the N-1 safety criterion is met; Low production level and loading of certain lines as well as low inertia level can lead to the impairment of the static and dynamic stability of the NPS; In conditions of low production in power plants and large power movements to deficient areas, there is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers.
28	Unforeseen interactions in the energy market	Likelihood: 1 Very low Gravity/Impact: 4 Bad Risk level: 4 Scenario type: 4–6 Low	The result of trading on the energy market can lead to volumes and trading directions very different from the usual ones, including very steep variations; The usual methods of analysis and planning of the functioning of the NPS lead to unsatisfactory results, this being correlated with significant forecasting errors when performing transactions on the energy market; The risk of overloads on important lines and transformation units, including interconnecting lines, increases; System operation is hampered by large forecasting errors and cascading equipment triggers and even loss of control over a grid area may occur; Disturbances can affect all energy markets in the region or across Europe, namely the functioning of the interconnected systems of ENTSO-E members; Forecast errors/imbalances in different control blocks can lead to incidents/frequency deviations in the synchronous grid area; Limitations of energy imports/exports may occur; Manual disconnections of some consumers or even extensive damage may occur leading to the failure of supplying electricity to a large number of consumers; Some participants in the energy market experience considerable financial losses due to incorrect decisions or trading mistakes or due to the unpredictable behavior of other participants.

3.2.6. Source: Political/Military Insecurity

The identification, assessment and manifestation are shown in Table 7 [19,20].

Table 7. Source: political/military insecurity (own elaboration).

<table>
<tr><th colspan="5">Risk Scenario: Political/Military Insecurity</th></tr>
<tr><td rowspan="4">29</td><td rowspan="4">Military conflict, war</td><td>Likelihood</td><td>1
Very low</td><td rowspan="4">In the case of regional conflict situations, war, unforeseen events can trigger a crisis in ensuring electricity supply, starting from:
the national/european resource shortages due to deterioration of the supply/logistics cycle;
the difficulty of switching energy production from one fuel type, deficient or missing, to another;
the requests for mutual assistance between member countries in order to maintain the operational safety of the interconnected system;
the unforeseen unavailability of production sources in an area of the NPS and the limited capacity of the power grids to ensure the transmission of the necessary power from other areas, safely.
There is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers.</td></tr>
<tr><td>Gravity/ Impact</td><td>5
Very high</td></tr>
<tr><td>Risk level</td><td>5</td></tr>
<tr><td>Scenario type</td><td>4–6
Low</td></tr>
</table>

4. National, Regional and Bilateral Procedures and Measures in the Event of an Electricity Crisis

4.1. National Procedures and Measures

In accordance with the requirements of the "Law no. 123/2012 on electricity and natural gas" and the "Regulation on technical safeguard measures in exceptional situations arising in the functioning of the National Power System", approved by NAER Order no. 142/2014 a set of safety measures ("of safeguard") is established to prevent or limit the effects of exceptional situations that may occur in the functioning of the NPS [21–25].

4.1.1. Measures Regarding the Functioning of the Energy Market

The basic principle of action in the event of a crisis situation is to allow the electricity market to function even in situations when demand and supply are limited and the price of electricity experiences steep variations.

NAER Order no. 142/2014 provides for two categories of measures that apply both by the Transmission System Operator and the Distribution Operators to final electricity consumers supplied directly from the NPS power substations. The first category consists of technical measures without impact on the electricity market, and the second category is technical and commercial measures, of which the last measure in order of application is the limitation of electricity consumption to certain categories of industrial consumers, without resorting to the interruption of their electricity supply.

The consumption limitation/reduction measure is applied in installments, as a measure of last resort, only to those industrial consumers who have the technical possibility of reducing consumption by appropriately adapting the technological process, being conditioned by the issuance of a Decision of the Government of Romania, at least 5 days before the moment of application and with a prior notification of consumers of at least 24 h. The final customers to whom the consumption limitation measures are applied have provided for this obligation in the transmission or distribution contract, as the case may be.

The measure to suspend the electricity market will be taken only in special situations, as a last resort when all the measures listed below have been exhausted, namely:

Measures without impact on the electricity market:

Measures that are applied to prevent a crisis situation in the functioning of the NPS and do not affect the functioning of the electricity market: loading the groups to the maximum available power (including starting the groups in reserve); increasing the available power of the NPS, by making available the production units under repair (returning to operation ahead of schedule the groups under repair); reducing the dispatchable consumption declared as load offer on the balancing market; requesting emergency assistance from neighboring TSOs; transition to minimum voltage band functioning in the Distribution Power Grid (DPG).

Technical and commercial measures with an impact on the electricity market:

Safeguard measures that apply in crisis situations in the functioning of the NPS—technical and commercial measures that may affect the electricity market: increasing the technological system reserves in production units that can function on alternative fuel, in order to use them as appropriate; reduction/cancellation of available interconnection capacity in the export direction; reduction/cancellation of notified exchanges in the export direction; limitation of electricity consumption in installments, under the conditions established by Government Decision and in accordance with the provisions of the Limitations Norm.

Once the crisis has been triggered, the TSO may apply technical and commercial safeguard measures to prevent crisis situations affecting the functioning of the electricity market, namely: increasing the technological system reserves in production units that can function on alternative fuel (e.g., fuel oil), in order to use them as appropriate; reduction/cancellation of available interconnection capacity in the export direction; reduction/cancellation of notified exchanges in the export direction.

4.1.2. Measures Regarding Manual Interruption of Consumption

In unforeseen situations that endanger the functioning of the NPS, at the TSO level there is also the possibility of manually disconnecting certain categories of industrial consumers, for a limited period of time, after which these consumers are re-powered at a minimum technological power, so as not to endanger the security of the installations and staff.

The manual interruption of consumption shall be carried out in exceptional circumstances arising in the functioning of the NPS, in accordance with the Operational Procedure (OP)-The method of elaboration and application of the manual disconnection regulations of certain categories of final customers, by instalments, in exceptional situations arising in the functioning of the NPS—hereinafter referred to as "The manual disconnection regulation".

The manual disconnection regulation is applied as a last resort, in situations that could not be anticipated in the functioning of the NPS, situations that endanger the functioning of the NPS or an area of the NPS, in order to prevent the propagation or aggravation of this situation.

The manual disconnection regulation applies to the following exceptional NPS functioning situations: transition to isolated functioning of the NPS, after the activation of the automatic device at decreasing frequency, if the frequency cannot be restored and maintained at values > 49 Hz, due to lack of available active power; isolation of an area of the NPS, where the frequency and/or voltage cannot be restored to values allowing synchronization of some generating groups or synchronization of the area to the NPS, due to the lack of available active power in the area; through the grid supplying an area of the NPS (lines, transformers, autotransformers), loads that exceed the permissible limit values from the point of view of the equipment (thermal limit) occur and these cannot be removed by other measures during the permitted overload functioning; in an area of the NPS or in most of it, after all adjustment measures have been taken, the voltages are maintained at values not more than equal to the value of the sacrifice voltage (360 kV for the 400 kV grid, 180 kV for the 220 kV grid and 85 kV for the 110 kV grid) and this situation may endanger the stability of functioning; the decrease below the normal limits of the reserve against the static circulation stability limit by a characteristic section through which a deficient area is supplied, until the slow tertiary reserve in that area is started or, when it is missing, until the application of the Regulation limiting the electricity consumption, by instalments, in crisis situations arising in the functioning of the NPS; the occurrence of a short-term active power deficit ($4 \div 48$ h) leading to an hourly deviation from the programmed balance, inadmissible according to the ENTSO-E rules, until the mobilization of the slow tertiary reserve or, when it is missing, until the application of the Regulation limiting the electricity consumption, by instalments, in crisis situations arising in the functioning of the NPS.

All consumers to whom the Manual disconnection regulation and the Regulation for limiting/reducing electricity consumption may apply are industrial consumers, household consumers being excluded.

Also, the number of industrial consumers connected to the PTG is low and do not have special protection against disconnection.

4.1.3. Special Protection Against Disconnection

The manual disconnection regulation applies only to final customers included in the current regulation. These final customers are industrial consumers who, through the technological process used, have the capacity to be disconnected for a pre-established period and then need to be re-powered to the minimum technical power.

The manual disconnection regulation applies until the previously provided conditions disappear, as a result of a change in the situation in the NPS or the successful implementation of recovery measures (mobilization of adjustment energy, commissioning of grid elements) or, when this is not possible, until the application of the Regulation for limiting electricity consumption.

The manual limitation of consumption shall be carried out in foreseeable situations in the functioning of the NPS, in accordance with OP No-The method of elaboration and application of the regulation for limiting electricity consumption, by instalments, in crisis situations arising in the functioning of the NPS.

The limitation regulation applies in the following crisis situations of functioning of the NPS: national fuel shortages; energy deficits, determined by the evolution of the international economy; energy deficits, determined by the country's defense needs; energy deficits, determined by environmental protection needs; energy deficits in a deficient NPS area, determined by the unavailability of production sources in the area and limited grid capacity to ensure the safely transmission of necessary power from other areas.

The determination of the likelihood of a crisis situation occurring in the functioning of the NPS is made by the TSO on the basis of the short and medium term adequacy analyses of the NPS, taking into account: the fuel stocks and the conditions for carrying out the economic activities that provide them (extractive industry, transport); the state of the National Natural Gas Transmission System; the volume of water reserves in reservoirs; the availability of electricity production units; the electricity consumption at the level of the NPS or at the level of an area of the NPS; the PTG and PDG availability.

Also, at regional and European level, the STA (Short Term Adequacy forecasts) process is carried out daily for the next seven days by RSCs (Regional Security Coordinator), based on daily analyses for the next seven days.

The regulation for limiting the electricity consumption applies, following the adoption of a Government Decision, as a last safeguard measure taken in crisis situations arising in the functioning of NPS that may be foreseen in the medium and long term, which endangers the functioning of the NPS or of an area of the NPS.

In critical situations in the NPS, the economic operators included in the regulation limiting the electricity consumption are notified in writing by the TSO on the provision for the application of the Regulation limiting the electricity consumption. The regulation applies only to final customers included in the current regulation. These final customers are industrial consumers who, through the technological process used, have the capacity to reduce their electricity consumption.

4.1.4. Prevention and Preparedness Measures

Prevention and preparedness measures at the design and planning stage: Analysis of the operational behavior of electrical equipment (determination of equipment with high failure rate and elimination of non-conformities). Analysis of the operational behavior of the lines (detection of areas where triggers occur frequently due to extreme weather events).; Imposition of specifications for the purchase of electrical equipment to ensure their proper functioning in the event of low temperatures; Imposing, through design regulations increased earthquake safety conditions for lines of maximum importance for the NPS, for substations and control centers buildings, for the foundations of electrical equipment and transformation units; Imposing, through design regulations increased safety conditions for lines of maximum importance for the NPS (use of active conductors with low coefficient of expansion, use of pipe with high degree of mechanical strength); Use of electrical equipment with composite tires instead of porcelain in areas with high seismic activity; Expertise of old generation equipment.

Prevention and preparedness measures in development and investment work: Initiation of investment works/major maintenance to diminish galloping effects, improve the insulation level of lines, etc.); Replacement of concrete pillars with metal pillars; Implementation of the development plan of the Power Transmission Grid; Implementation of the development plan of the Power Distribution Grid; Installation of monitoring systems on lines; Periodic audit and updating/upgrading the safety of computer systems; Use of modern and high-performance forecasting techniques based on multicriterial analysis, leading to a robust dimensioning of NPS power reserves.

Preventive and preparedness measures during maintenance work: Implementation of the maintenance plan of the Power Transmission Grid; Implementation of the maintenance plan of the Power Distribution Grid; Implementation of the maintenance plan for electricity production companies; Maintenance of control systems; Maintenance of system automation; Maintenance of automation in power plants; Maintenance of the automatic device at decreasing frequency, automatic device at decreasing voltage; Maintenance of heating systems; Eliminating weaknesses and deficiencies in transmission and distribution grids; Filling with oil, SF6 gas; Eliminating hot spots; Equipment operation checks; Diesel Groups checks; Batteries checks; Periodic checks on the condition of the foundations of the pillars in the areas adjacent to river streams; Checks on the track of lines where there is a risk of landslides; Checking the functioning of the tap-changer switches at the transformer units; Maintenance of line safety lanes and removal of dry vegetation from the interior of safety lanes; Mowing vegetation inside the substations; Maintaining switching equipment (separators) in proper condition to allow handling in conditions of ice formation on contacts; Maintenance of substation constructions (concrete channels and pillars, equipment foundations) and of the foundations and anchoring systems of the lines pillars; Maintaining the proper functioning condition of AC installations in relay cabins, batteries and telecommunication cameras; Maintaining the proper functioning condition of the cooling systems of the transformer units; Snow removal of roads and access routes in substations.

Prevention and preparedness measures as features: Fuel insurance for Diesel Groups; Backup supply insurance with Diesel Generators, UPSs and batteries; Proper equipment with fire extinguishers in substations; Providing disinfectant materials, masks and gloves for employees.

Prevention and preparedness measures as trainings and courses: Staff training on fire prevention and extinguishing in electrical installations; Staff training on the risks of cybersecurity breaches; Professional training of operational staff.

Other prevention and preparedness measures: Staff information and education programmes on national programmes to combat the pandemic; Vaccination programmes for staff; Measuring the temperature of employees; Individualization of the employee work schedule (work in shifts or with delayed schedule, teleworking programmes); Periodic ventilation, sanitation and disinfection of work spaces; Limitations on access to the command rooms of dispatcher control centers and remote control centers and, respectively, to the command rooms of PTG substations.

4.1.5. Mitigation and Restoration Measures

Response and restoration measures regarding the staff: Instructions charts; Insurance of technical intervention staff; Insurance of auxiliary intervention staff (financial, commercial, logistics); Insurance of operative staff and intervention and technical staff (use of management staff or semi-qualified staff or with similar qualifications to ensure continuity, reduction of the number of shifts, extension of the work schedule, etc.).

Response and restoration measures regarding the need for materials and machinery: Insurance of intervention/reserve pillars and accessories for lines (insulators, clamps, conductors); Provisional insurance of underground power lines; Insurance of mobile cells; Insurance of equipment (electric equipment) from safety/intervention stock; Elaboration of standard quotations for intervention works (replacements of equipment, pillars, transformation units) and assessment of a medium time of replacement/remediation; Insurance for Diesel groups; Insurance for batteries and UPS; Fuel reserves insurance (for diesel groups); Oil and SF6 gas reserves insurance; Winter material insurance (clothing, food, etc.); Fleet insurance.

Other response and restoration measures: Insurance of redundant/independent lines of communication (fail-safe); Providing spaces with special facilities (accommodation, food, sanitation, medical and psychological services) that allow the protection of staff with essential attributions for the functioning of the NPS; Conventions with companies specialized in construction works in the electrical field; Conventions with companies that own machinery for intervention.

4.1.6. The Entity Responsible for Declaring the Crisis

According to the National Disaster Risk Management Plan in Romania, the National Emergency Management System contains the following components: emergency committees; The Department for Emergency Situations; The General Inspectorate for Emergency Situations; professional emergency services and voluntary emergency services; operative centers and intervention coordination and management centers; emergency operative centers; commander of action/intervention.

In the event of a crisis situation, the following entities within the Ministry of Energy shall act: The Ministerial Committee for Emergency Situations, respectively The Ministerial Operative Center, and—as a part of The Ministerial Operative Center—The National Operative Center in the Energy Sector; The entity responsible for declaring the crisis situation is The National Operative Center in the Energy Sector.

The following are part of The National Operative Center in the Energy Sector structure: Representative of the Ministry of Energy—President; President of the Transelectrica S.A. (TSO) Directorate; President of the Hidroelectrica S.A. Directorate; President of the Nuclearelectrica S.A. Directorate; Director of the Transgaz S.A.; Director of Power plants Bucharest S.A.; Director of OMV Petrom S.A.; President of the Oltenia Energy Complex S.A. Directorate; President of the Hunedoara Energy Complex S.A. Directorate; President of the Romania Electricity Distribution S.A. Directorate; President of the Oltenia Electricity Distribution S.A. Directorate; President of the E—Distribution S.A. Directorate; Director of DelgazaGrid S.A.—Director of UNO DEN; Director of the Energy Sector Risk Management and Prevention Department of the Ministry of Energy; Director of the Competent Authority for Ensuring Electricity Supply, within the Ministry of Energy.

The roles and responsibilities of The National Operative Center in the Energy Sector structure: it assesses the crisis situation; it is the entity responsible for declaring/ending a crisis; it ensures the implementation and coordination of the measures contained in the Risk Preparedness Plan (RPP); it interacts with other entities of crisis management organized at national level;—provides support to other national agencies/national departments/ministries; it ensures coordination for the provision of assistance and necessary resources (materials, machinery and work staff) at national level; it allocates the necessary resources for restoration actions; it allocates the necessary financial resources for restoration actions; provides the information office with information on the development of events and measures taken in energy crisis situations.

Other Operative Centers at the level of Entities within the NPS (the Operative Work Center in the Energy Sector): Representative from the administrative management; Manager/director of the operation and maintenance department; The manager of the Department for Emergency Situations; The manager of the Department of labor protection;

The roles and responsibilities of the Operative Work Center in the Energy Sector: it ensures the implementation of the measures decided by the National Operative Center in the Energy Sector in the affected areas with priority on the safety and health of staff, minimizing the damage caused to the assets in the NPS, as well as on the environment and other goods; provides support for intervention staff in case of fires or security incidents; it ensures the evacuation of non-essential (technical or non-technical) staff from the affected areas;—ensures communication points; it reports to the National Operative Center in the Energy Sector all relevant information related to the measures taken and requests assistance/support if necessary; it ensures the recording/preservation of necessary information to be used in the post-factum analysis of the causes that led to the occurrence of the crisis situation and the measures taken; provides coordination with local authorities to ensure medical needs, public order.

4.1.7. The Main Stages of Action in Case of a Crisis Situation

- declaration of crisis situation;
- information/announcement of crisis situation;
- assessment of the situation and risks;
- identification of necessary resources (human, material and machinery);

- adopting a response strategy according to the Risk Prevention Plan;
- implementation of the response strategy;
- field analysis of the effects of the crisis;
- post incident analysis and establishment of measures for prevention in the future;
- ending the crisis.

Appropriate mechanisms for information flows

The management of the crisis situation depends to a very large extent on the quality of the information received (their fairness and promptness) by the deciding factors. In this respect, the information received must have as its source direct on-the-spot observations reported by qualified staff.

The information shall be immediately reported to the National Operative Center in the Energy Sector (directly, or through the Operative Work Center in the Energy Sector).

Depending on the crisis situation, the National Operative Center in the Energy Sector will take the following measures: it will issue a Pre-Alert briefing: providing information on the possible occurrence of a crisis situation; it will issue an Alert notification: informing that although the crisis situation is not imminent, elements have appeared that have worsened/aggravated the previous state; it will issue a Danger notification: informing that the crisis is imminent and the responsible factors must take the necessary measures to minimize the damage/losses that will be caused by the crisis situation; declaration of the Crisis situation.

For information and coordination of actions, the following command centers will be used: National operative center at the level of the Central Energy Dispatch; Local operative centers at the level of Territorial Energy Dispatchers; Local operative centers at the level of Territorial Units within Transelectrica S.A.; Local operative centers at the level of Energy Distribution Dispatchers; Local operative centers at the Regional Unit level within the Distribution Operators; Local operative centers at the level of Energy Dispatchers of Production Units; Local operative centers at the level of Energy Dispatchers of Large Consumption Units.

Through these command centers, all relevant information will be transmitted, regarding: the state and operating mode of the NPS; measures ordered by the National Operative Center in the Energy Sector; implementation mode of the actions/measures ordered by National Operative Center in the Energy Sector; aspects of the crisis situation.

All information available in the territory shall be centralized at the central command center (at the level of the Central Energy Dispatch) which shall carry out the National Operative Center in the Energy Sector information.

Informing the public opinion, the mass media will be centralized through a press officer designated by the National Operative Center in the Energy Sector.

At the time of the onset of the crisis, the Operative Work Center in the Energy Sector organizes intervention teams including key staff, teams that will act in the following directions:

- Operational: identifies potential hazards that may arise and acts to eliminate them; takes the measures of safe disconnection/withdrawal from operation of damaged equipment; takes measures to stop production units safely (if necessary); takes measures arranged according to the events and the peculiarities of the crisis situation.
- Maintenance: intervenes to repair equipment failures; identifies potential hazards that may arise and act to eliminate them; takes measures arranged according to the events and the peculiarities of the crisis situation. o Security; restricts access to non-essential staff; ensures access for essential staff; ensures access to vehicles for evacuation or for ambulances.

- Administrative: provides assistance for rescue and transport operations to first aid centers or medical centers; ensures records of staff actively participating in the crisis; takes measures arranged according to the events and the peculiarities of the crisis situation.
- Labor protection: ensures the necessary measures in terms of labor protection; provides assistance for measuring gas emissions/concentrations; identifies and collects evidence, information related to labor protection aspects necessary for post incident analysis/investigation; takes measures arranged according to the events and the peculiarities of the crisis situation.
- Occupational medicine: ensures rapid access and intervention of medical staff for providing first aid; ensures the delivery of medical assistance; requests specialized medical assistance; takes measures arranged according to the events and the peculiarities of the crisis situation.
- Firefighting: intervenes rapidly to identify and extinguish fires; requests the intervention of the fire teams within the Emergency Situations Inspectorate; evacuates staff from fire areas; takes measures arranged according to the events and the peculiarities of the crisis situation.
- Transport: ensures the availability of the entire fleet for intervention and evacuation actions; ensures the presence of specialized staff at the site of the incident to ensure intervention in case of minor malfunctions to the intervention vehicles, ambulances, etc.; provides fuel supply to vehicles, machinery, Diesel Groups; provides assistance in organizing transport conditions; takes measures arranged according to the events and the peculiarities of the crisis situation. o communications; ensures the functionality of the communication network; intervenes in order to repair the failures occurring in the communication equipment; takes measures arranged according to the events and the peculiarities of the crisis situation.
- Communications: ensures the functionality of the communication network; intervenes in order to repair the failures occurring in the communication equipment; takes measures arranged according to the events and the peculiarities of the crisis situation.

Essential staff, criteria for determining it:

The heads of each organizational unit within the NPS entities shall establish the key staff in crisis management. The following categories of essential staff will be identified:

- technical and non-technical management staff;
- operational staff (operative management, operative service, maintenance);
- communications staff;
- maintenance staff;
- staff for supply;
- staff to ensure the transport and handling of materials;
- staff responsible for emergency situations;
- staff responsible for labor protection;
- staff responsible for occupational medicine and occupational health;
- external communication staff.

4.2. Regional and Bilateral Procedures and Measures

4.2.1. Agreed Mechanisms to Cooperate Within the Region

Ensuring coordination before and during the electricity crisis.

Regional Coordination Centers (RCCs) currently provide a set of mandatory services for all TSOs to which they are affiliated, in accordance with EU legislation such as: [26–30]

- establishing common grid models;
- coordinated security analysis;
- coordinated capacity calculation;
- coordination of the decommissioning programme;
- short-term adequacy forecast;
- support for the coordination of defense and restoration plans;

In addition to the above, the RCC "TSCNET" works with TSOs and other RCCs on an early warning system to identify and mitigate potentially critical grid situations (CGS).

Starting with 2010, the EAS (ENTSO-E Awareness System by SCADA/EMS and GIS software platform was developed at the ENTSO-E level, which offers all partner TSOs a real-time global picture of the European transmission grid, a better understanding of the problem, in case of an emergency situation, of some disturbances.

The EAS platform provides the opportunity for TSOs to:

- develop the ability to assess the type and size of a disturbance;
- make the decision to act or not, without aggravating the state of the system;
- coordinate measures to solve problems related to consumption/production/power grid and system restoration;
- option to cooperate with other TSOs.

Throughout the crisis situation, the European information platform EAS (ENTSO-E Awareness Systems) will be used, the ENTSO-E and the Regional Coordination Centers will be informed and the coordinated measures established by them according to the procedures, regulations and international agreements in force will be taken.

Thus, the crisis situation is managed in collaboration and coordination with all TSOs in the region, through entities within the ENTSO-E and the Regional Security Coordination Centers, applying the dedicated procedures in force (Critical Grid Situation Procedure, coordination on Short Term Adequacy, and monitoring of frequency and cross-border exchanges by Regional Coordination and Monitoring Centers organized within AMPRION—Germany and SwissGrid—Switzerland).

4.2.2. Regional and Bilateral Action Measures in the Event of a Crisis

- announcement of the crisis situation at ENTSO-E level;
- urgent communication and consultation with counterpart entities at regional and/or bilateral level to analyze the effects caused by the crisis situation;
- synchronization at bilateral/regional level with the purpose of implementing the response strategy;
- acting in the sense given by the strategy to manage and eliminate the crisis.

Other measures:

- improving the adequacy indicators of the power systems in the region with the help of the shared power reserve and the additional reserve available at the interface with neighboring regions, as well as establishing the maximum quantities of electricity to be delivered at regional or bilateral level;
- improving security of supply (SoS) by eliminating congestion;
- substantial increase in net interconnection capacity;
- post incident analysis and establishment of measures for prevention in the future.

The trigger for assistance:

- major disturbances in the NPS in a certain part of the country, and the Tranmission System does not have the capacity to support the deficit from one area to another;
- difficulties arise in ensuring the adequacy of the NPS as a result of unscheduled outages of production capacities;
- trigger elements specific to risk scenarios with regional effects appear;
- the restoration activity of the neighboring power system requires this.

4.2.3. Mutual Aid Agreements to Cooperate and Coordinate Actions Before and During the Energy Crisis

Within the region of which Romania is part, the following bilateral operational agreements are in force:

- Mutual Aid Convention (Agreement on Provision of Mutual Emergency Energy Assistance for Ensuring the Reliable Operation of Power Systems of Bulgaria and Romania) that provides for the granting of a quantity of electricity between the two countries for the purpose of helping one of the countries in crisis.
- Mutual Aid Convention (Agreement on Provision of Mutual Emergency Energy Assistance for Ensuring the Reliable Operation of Power Systems of Serbia and Romania) that provides for the granting of a quantity of electricity for the purpose of helping one of the countries in crisis.
- Mutual Aid Convention (Agreement on Provision of Mutual Emergency Energy Assistance for Ensuring the Reliable Operation of Power Systems of Ukraine and Romania) that provides for the granting of a quantity of electricity for the purpose of helping one of the countries in crisis.
- Exploitation Convention (Operational Agreement) concluded between the TSOs of Romania and Serbia provides for the granting, as appropriate, of aid in the framework of the NPS restoration actions, through the 400 kV OHL Iron Gates—Djerdap interconnection line.
- Exploitation Convention (Operational Agreement) concluded between the TSOs of Romania and Bulgaria provides for the granting, as appropriate, of aid in the framework of the NPS restoration actions, through the interconnecting lines between the two countries.
- Exploitation Convention (Operational Agreement) concluded between the TSOs of Romania and Hungary provides that, as far as possible, support shall be given to restoring the neighbouring system by maintaining the voltage on the interconnecting lines and providing a quantity of electricity through the lines between the two countries.

4.3. Measures to Mitigate the Crisis, Containment Measures and Restoration

4.3.1. Source: Insecurity in Functioning of the NPS

The identification of the risk scenario, trigger event and mitigation/containment and restoration measures, are shown in Table 8 [31–34].

Table 8. Source: Insecurity in functioning of the NPS (own elaboration).

Risk Scenario: Insecurity in Functioning of the Nps			
1	Local technical incidents	A fault occurs on an equipment or a substation very important for the functioning of the NPS (explosion of a transformer, functioning of the DRRI, fault on the busbars of a substation in the PTG) exceeding the level N-1 taken into account when planning the functioning of the NPS.	Actions will be initiated immediately to restore triggered equipment and repair/replace damaged equipment. The measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. The groups will be loaded to the maximum available power (including starting the groups in reserve). The dispatchable consumption declared as load offer on the balancing market will be reduced. An increase in the available power of the NPS will be requested, by making available the production units under repair (pre-term release of the groups under repair). Measures are being taken to increase the availability of PTG and PDG equipment (cancellation of withdrawals from operation of some equipment for maintenance or investment works). In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine). The reduction/cancellation of the available interconnection capacity (ATC) in the export direction will be ordered, as well as the reduction/cancellation of notified exchanges in the export direction.
2	Multiple technical incidents caused by extreme weather conditions	Extreme weather events are taking place that affect large areas (extreme winds, hail, intense rainfall, ice deposits, temperatures far outside the usual limits).	Actions will be initiated immediately to repair/replace destroyed/damaged assets using equipment from security stocks or ways of functioning of the equipment in provisional schemes will be ensured. The measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. The groups will be loaded to the maximum available power (including starting the groups in reserve). The dispatchable consumption declared as load offer on the balancing market will be reduced. An increase in the available power of the NPS will be requested, by making available the production units under repair (pre-term release of the groups under repair). Measures are being taken to increase the availability of PTG and PDG equipment (cancellation of withdrawals from operation of some equipment for maintenance or investment works). In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine). The reduction/cancellation of the available interconnection capacity (ATC) in the export direction will be ordered, as well as the reduction/cancellation of notified exchanges in the export direction.

Table 8. *Cont.*

Risk Scenario: Insecurity in Functioning of the Nps			
3	Simultaneous technical incidents	Simultaneous equipment triggers due to faults in substations or due to incorrect functioning of protections during cascade operation.	Urgent measures are being taken to restore the disconnected/triggered transmission and distribution grid equipment to service. Actions will be initiated immediately to repair/replace destroyed/damaged assets using equipment from security stocks or ways of functioning of the equipment in provisional schemes will be ensured. The measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. The groups will be loaded to the maximum available power (including starting the groups in reserve). The dispatchable consumption declared as load offer on the balancing market will be reduced. An increase in the available power of the NPS will be requested, by making available the production units under repair (pre-term release of the groups under repair). Measures are being taken to increase the availability of PTG and PDG equipment (cancellation of withdrawals from operation of some equipment for maintenance or investment works). In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine). The reduction/cancellation of the available interconnection capacity (ATC) in the export direction will be ordered, as well as the reduction/cancellation of notified exchanges in the export direction.
4	Complexity of control mechanisms of power systems	A sequence of independent events occurs (trigger caused by vegetation of a line, malfunctions of some protections, failure of a circuit breaker upon anchoring or triggering) that correlate in an unpredictable way.	Actions will be initiated immediately to restore triggered equipment and repair/replace damaged equipment. The measures and provisions set out in OP TEL-07.III AV-DN "Action of the D.E.C. Dispatcher in case of major disturbances in the continental—European interconnection" and OP TEL—07.III RS—DN/92 "Communication in crisis situations with partners in the interconnected transmission grid" apply. The measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. The groups will be loaded to the maximum available power (including starting the groups in reserve). The dispatchable consumption declared as load offer on the balancing market will be reduced. An increase in the available power of the NPS will be requested, by making available the production units under repair (pre-term release of the groups under repair). Measures are being taken to increase the availability of PTG and PDG equipment (cancellation of withdrawals from operation of some equipment for maintenance or investment works). In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine). The reduction/cancellation of the available interconnection capacity (ATC) in the export direction will be ordered, as well as the reduction/cancellation of notified exchanges in the export direction.

Table 8. *Cont.*

Risk Scenario: Insecurity in Functioning of the Nps			
5	Unwanted power movements	There are major differences between planned power movements and those that are recorded in the NPS. The event is favored either by the forecasting errors regarding the production of wind and photovoltaic plants or by some external conditions (redispatching the power transit between different European regions).	The measures and provisions set out in OP TEL-07.III AV-DN "Action of the D.E.C. Dispatcher in case of major disturbances in the continental—European interconnection" and OP TEL—07.III RS—DN/92 "Communication in crisis situations with partners in the interconnected transmission grid" apply. The measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. The groups will be loaded to the maximum available power (including starting the groups in reserve). The dispatchable consumption declared as load offer on the balancing market will be reduced. An increase in the available power of the NPS will be requested, by making available the production units under repair (pre-term release of the groups under repair). Measures are being taken to increase the availability of PTG and PDG equipment (cancellation of withdrawals from operation of some equipment for maintenance or investment works). In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine). The reduction/cancellation of the available interconnection capacity (ATC) in the export direction will be ordered, as well as the reduction/cancellation of notified exchanges in the export direction.
6	Serial faults of equipment	Abnormal operating behavior of equipment of the same construction type (caused by design deficiencies, maintenance, material faults, inadequate quality of the insulating medium)	Actions will be initiated immediately to repair damaged components and restore triggered equipment. The measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. The groups will be loaded to the maximum available power (including starting the groups in reserve). The dispatchable consumption declared as load offer on the balancing market will be reduced. An increase in the available power of the NPS will be requested, by making available the production units under repair (pre-term release of the groups under repair). Measures are being taken to increase the availability of PTG and PDG equipment (cancellation of withdrawals from operation of some equipment for maintenance or investment works). In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine). The reduction/cancellation of the available interconnection capacity (ATC) in the export direction will be ordered, as well as the reduction/cancellation of notified exchanges in the export direction.

Table 8. *Cont.*

Risk Scenario: Insecurity in Functioning of the Nps			
7	Human errors	A human error occurs that leads to triggers of important equipment for the functioning of the NPS.	Actions will be initiated immediately to restore triggered equipment and repair/replace damaged equipment. The measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. The groups will be loaded to the maximum available power (including starting the groups in reserve). The dispatchable consumption declared as load offer on the balancing market will be reduced. An increase in the available power of the NPS will be requested, by making available the production units under repair (pre-term release of the groups under repair). Measures are being taken to increase the availability of PTG and PDG equipment (cancellation of withdrawals from operation of some equipment for maintenance or investment works). In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine). The reduction/cancellation of the available interconnection capacity (ATC) in the export direction will be ordered, as well as the reduction/cancellation of notified exchanges in the export direction.
8	Strikes, riots, protest actions of employees	There are strikes, riots or other demanding actions affecting the availability of staff to several entities in the NPS.	The necessary staff for key positions in the NPS will be ensured (dispatch centers, operational staff in important substations, maintenance staff). Actions will be initiated immediately to restore triggered equipment and repair/replace damaged equipment. The measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. The groups will be loaded to the maximum available power (including starting the groups in reserve). The dispatchable consumption declared as load offer on the balancing market will be reduced. An increase in the available power of the NPS will be requested, by making available the production units under repair (pre-term release of the groups under repair). Measures are being taken to increase the availability of PTG and PDG equipment (cancellation of withdrawals from operation of some equipment for maintenance or investment works). In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine). The reduction/cancellation of the available interconnection capacity (ATC) in the export direction will be ordered, as well as the reduction/cancellation of notified exchanges in the export direction.

Table 8. *Cont.*

Risk Scenario: Insecurity in Functioning of the Nps			
9	Unusually large errors in the forecast of power produced in renewable energy plants	There are large errors in the forecasting of production in renewable power plants (photovoltaic and wind), errors caused by the way the forecast is made or by sudden changes in weather conditions. There are major differences between planned power movements and those that are recorded in the NPS. Events may be aggravated by a reduced level of consumption in the NPS.	The measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. The groups will be loaded to the maximum available power (including starting the groups in reserve). The dispatchable consumption declared as load offer on the balancing market will be reduced. An increase in the available power of the NPS will be requested, by making available the production units under repair (pre-term release of the groups under repair). Measures are being taken to increase the availability of PTG and PDG equipment (cancellation of withdrawals from operation of some equipment for maintenance or investment works). In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine). The reduction/cancellation of the available interconnection capacity (ATC) in the export direction will be ordered, as well as the reduction/cancellation of notified exchanges in the export direction.
10	Pandemic	An epidemic/pandemic affects European countries.	The necessary staff for key positions in the NPS will be ensured (dispatch centers, operational staff in important substations, maintenance staff). The necessary measures are being taken to isolate and sanitize work spaces and to provide staff with the necessary materials to prevent infection in the workplace. Actions will be initiated immediately to restore triggered equipment and repair/replace damaged equipment. The measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. The groups will be loaded to the maximum available power (including starting the groups in reserve). The dispatchable consumption declared as load offer on the balancing market will be reduced. An increase in the available power of the NPS will be requested, by making available the production units under repair (pre-term release of the groups under repair). Measures are being taken to increase the availability of PTG and PDG equipment (cancellation of withdrawals from operation of some equipment for maintenance or investment works). In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine). The reduction/cancellation of the available interconnection capacity (ATC) in the export direction will be ordered, as well as the reduction/cancellation of notified exchanges in the export direction.

4.3.2. Source: Terrorist Attack on the NPS

The identification of the risk scenario, trigger event and mitigation/containment and restoration measures, are shown in Table 9 [35,36].

Table 9. Source: Terrorist attack on the NPS (own elaboration).

Risk Scenario: Terrorist Attack on the Nps			
11	Internal cyberattack on critical infrastructure within the National Power System or Power Transmission Grid: power plants, power substations, overhead power lines, dispatchers, etc.	A cyberattack takes place on the communications and data transmission infrastructure of dispatch centers, power plants and substations, or important consumers; The targets of the attack are SCADA—EMS, SCADA—DMS systems, the f–P regulator, central control systems, planning and operation systems, IT centers, data storage systems, command and control systems in major power substations and power plants or from remote control centers.	The functionality of the systems that have been taken over by the attacker is blocked by temporarily shutting down the SCADA systems. The operation of the NPS will be carried out according to OP TEL-07.III/123 AV-DN_The NPS management in the event of partial or total unavailability of the EMS—SCADA teleinformation system. Urgent measures are being taken to restore the disconnected/triggered transmission and distribution grid equipment to service. Urgent measures are being taken to repair faults/malfunctions in the equipment in the transmission and distribution grid and ensure their availability. The assistance of specialized departments within the entity or other governmental structures (MIA, RIS) is requested to eliminate the attacker and establish the necessary actions for the safe re-commissioning of the affected systems. In this regard, action is taken according to OP TEL-19-01_Combating cyberattacks announced by third parties. Ways are identified to ensure the operative control of the NPS installations in safe conditions (manual control of equipment from the protection box, control desks). The additional staff necessary for operation in power substations and plants will be ensured. If the cyberattack has led to the lack of electricity supply to some consumers, urgent measures are taken to restore their supply, including through interventions at the installation level, if necessary. If a production deficit is reached, the measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. The groups will be loaded to the maximum available power (including starting the groups in reserve). The dispatchable consumption declared as load offer on the balancing market will be reduced. An increase in the available power of the NPS will be requested, by making available the production units under repair (pre-term release of the groups under repair). Measures are being taken to increase the availability of PTG and PDG equipment (cancellation of withdrawals from operation of some equipment for maintenance or investment works). In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine). The reduction/cancellation of the available interconnection capacity (ATC) in the export direction will be ordered, as well as the reduction/cancellation of notified exchanges in the export direction.
12	External cyberattack on critical infrastructures that are not part of the National Power System or Power Transmission Grid: power plants, power substations, overhead power lines, dispatchers, etc.	A cyberattack is taking place on the information, communications and data transmissions infrastructure of energy market participants.	The functionality of systems that have been taken over by the attacker is blocked. The assistance of specialized departments within the entity or other governmental structures (MIA, RIS) is requested to eliminate the attacker and establish the necessary actions for the safe re-commissioning of the affected systems. The measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. The groups will be loaded to the maximum available power (including starting the groups in reserve). The dispatchable consumption declared as load offer on the balancing market will be reduced. An increase in the available power of the NPS will be requested, by making available the production units under repair (pre-term release of the groups under repair). Measures are being taken to increase the availability of PTG and PDG equipment (cancellation of withdrawals from operation of some equipment for maintenance or investment works). In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine). The reduction/cancellation of the available interconnection capacity (ATC) in the export direction will be ordered, as well as the reduction/cancellation of notified exchanges in the export direction.

Table 9. *Cont.*

Risk Scenario: Terrorist Attack on the Nps			
13	External terrorist attack on critical infrastructure within the National Power System or Power Transmission Grid: power plants, power substations, overhead power lines, dispatchers, etc.	A physical attack occurs on dispatch centers, power substation command centers, or power plant command centers.	The functionality of the systems that have been taken over by the attacker is blocked (temporary shutdown of SCADA systems). The operation of the NPS will be carried out according to OP TEL-07.III/123 AV-DN_The NPS management in the event of partial or total unavailability of the EMS—SCADA teleinformation system. Urgent measures are being taken to restore the disconnected/triggered transmission and distribution grid equipment to service. Urgent measures are being taken to repair faults/malfunctions in the equipment in the transmission and distribution grid and ensure their availability. The assistance of specialized departments within the entity or other governmental structures (MIA, RIS) is requested to eliminate the attacker and establish the necessary actions for the safe re-commissioning of the affected systems. Ways are identified to ensure the operative control of the NPS installations in safe conditions (manual control of equipment from the protection box, control desks). The additional staff necessary for operation in power substations and plants will be ensured. The measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. The groups will be loaded to the maximum available power (including starting the groups in reserve). The dispatchable consumption declared as load offer on the balancing market will be reduced. An increase in the available power of the NPS will be requested, by making available the production units under repair (pre-term release of the groups under repair). Measures are being taken to increase the availability of PTG and PDG equipment (cancellation of withdrawals from operation of some equipment for maintenance or investment works). In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine). The reduction/cancellation of the available interconnection capacity (ATC) in the export direction will be ordered, as well as the reduction/cancellation of notified exchanges in the export direction.
14	Internal terrorist attack on the management centers within the National Power System or Power Transmission Grid	A physical attack occurs on power lines, substations or plants, or on central control systems, IT or telecommunications centers.	Actions will be initiated immediately to restore the triggered equipment to service, respectively to repair/replace the destroyed/damaged assets using equipment from security stocks or ways of functioning of the equipment in provisional schemes will be ensured. In case of unavailability of information or communication systems, the operation of the NPS will be carried out according to OP TEL-07.III/123 AV-DN_The NPS management in the event of partial or total unavailability of the EMS—SCADA teleinformation system. The measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. The groups will be loaded to the maximum available power (including starting the groups in reserve). The dispatchable consumption declared as load offer on the balancing market will be reduced. An increase in the available power of the NPS will be requested, by making available the production units under repair (pre-term release of the groups under repair). Measures are being taken to increase the availability of PTG and PDG equipment (cancellation of withdrawals from operation of some equipment for maintenance or investment works). In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine). The reduction/cancellation of the available interconnection capacity (ATC) in the export direction will be ordered, as well as the reduction/cancellation of notified exchanges in the export direction.

Table 9. *Cont.*

Risk Scenario: Terrorist Attack on the Nps			
15	Sabotage actions by an internal employee on critical infrastructure within the National Power System or Power Transmission Grid: power plants, power substations, overhead power lines, dispatchers, etc.	Sabotage actions take place from an internal employee (of the TSO, of a TSO subsidiary or of a company that provides services or works for the TSO on a contractual basis) directly on the TSO assets or indirectly on the NPS, by taking control of the dispatch centers, remote control centers or command rooms of the substations.	The assistance of specialized departments within the entity or other governmental structures (MIA, RIS) is requested to to isolate and eliminate the attacker. Actions will be initiated immediately to restore the triggered equipment to service, and to repair/replace the damaged equipment. The measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. The groups will be loaded to the maximum available power (including starting the groups in reserve). The dispatchable consumption declared as load offer on the balancing market will be reduced. An increase in the available power of the NPS will be requested, by making available the production units under repair (pre-term release of the groups under repair). Measures are being taken to increase the availability of PTG and PDG equipment (cancellation of withdrawals from operation of some equipment for maintenance or investment works). In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine). The reduction/cancellation of the available interconnection capacity (ATC) in the export direction will be ordered, as well as the reduction/cancellation of notified exchanges in the export direction.

4.3.3. Source: Extreme Weather Condition

The identification of the risk scenario, trigger event and mitigation/containment and restoration measures, are shown in Table 10 [37,38].

Table 10. Source: Extreme weather condition (own elaboration).

Risk Scenario: Extreme Weather Condition			
16	Extreme low temperature (cold)	A cold wave occurs with temperatures ranging from −10 °C to −20 °C below the seasonal average. Frozen water in reservoirs, rivers and streams leads to low water levels in reservoirs, which results in reduced production in hydro power plants and production limitations in coal/gas thermal power plants due to the inability to provide adequate cooling. Energy production also decreases or stops completely in wind power plants due to the lack of wind. Consumption increases significantly due to the increased need for heating from electrical sources, especially in urban areas. The phenomenon can be accentuated in large cities due to the lack of heating from the district heating grid. The cold wave leads to disturbances in the road, rail, sea and air transport grid, affecting the fuel supply of power plants, operative interventions in installations and the entire national economic activity.	Actions will be initiated immediately to restore the unavailable assets to service by repairing them or using equipment from security stocks or by the functioning of the equipment in provisional scheme. The measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. The groups will be loaded to the maximum available power (including starting the groups in reserve). The dispatchable consumption declared as load offer on the balancing market will be reduced. An increase in the available power of the NPS will be requested, by making available the production units under repair (pre-term release of the groups under repair). Measures are being taken to increase the availability of PTG and PDG equipment (cancellation of withdrawals from operation of some equipment for maintenance or investment works). Urgent measures are being taken to repair faults/malfunctions in the equipment in the transmission and distribution grid and ensure their availability. The transition to functioning in the minimum voltage band in the distribution grid will be ordered. The population will be asked, through the media and mass communication means, to reduce electricity consumption during peak hours. The increase of system technological reserves in production units will be ordered, that can operate on alternative fuel (for example, fuel oil), in order to use them as appropriate. In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine). The reduction/cancellation of the available interconnection capacity (ATC) in the export direction will be ordered, as well as the reduction/cancellation of notified exchanges in the export direction.

Table 10. *Cont.*

Risk Scenario: Extreme Weather Condition			
17	Storm	There is an intensification of the wind, gusting to speeds exceeding 150 km/h. Tornadoes appear and numerous electrical discharges occur. The storm can last for several hours or even days and affects a large area. Very high precipitation amounts can be recorded.	Actions will be initiated immediately to restore the triggered equipment to service, respectively to repair/replace the destroyed/damaged assets using equipment from security stocks or ways of functioning of the equipment in provisional schemes will be ensured. The measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. The groups will be loaded to the maximum available power (including starting the groups in reserve). The dispatchable consumption declared as load offer on the balancing market will be reduced. An increase in the available power of the NPS will be requested, by making available the production units under repair (pre-term release of the groups under repair). Measures are being taken to increase the availability of PTG and PDG equipment (cancellation of withdrawals from operation of some equipment for maintenance or investment works). In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine). The reduction/cancellation of the available interconnection capacity (ATC) in the export direction will be ordered, as well as the reduction/cancellation of notified exchanges in the export direction.
18	Heavy rainfall and flooding	High amounts of precipitation are recorded leading to flooding of power substations and plants, blocking of water intake to turbines due to alluvium, debris, trees, etc., landslides leading to damage to some lines, destruction of dams.	Urgent measures are being taken to restore the disconnected/triggered transmission and distribution grid equipment to service. Actions will be initiated immediately to repair/replace the affected pillars and restore the unavailable lines. Measures will be initiated immediately to remove water from the power substations and repair the affected buildings. Actions will be initiated immediately to repair the blockages that led to power limitations in the affected hydro power plants. Actions will be initiated immediately to repair/replace the destroyed/damaged assets using equipment from security stocks or ways of functioning of the equipment in provisional schemes will be ensured. The measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. The groups will be loaded to the maximum available power (including starting the groups in reserve). The dispatchable consumption declared as load offer on the balancing market will be reduced. An increase in the available power of the NPS will be requested, by making available the production units under repair (pre-term release of the groups under repair). Measures are being taken to increase the availability of PTG and PDG equipment (cancellation of withdrawals from operation of some equipment for maintenance or investment works). In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine). The reduction/cancellation of the available interconnection capacity (ATC) in the export direction will be ordered, as well as the reduction/cancellation of notified exchanges in the export direction.

Table 10. *Cont.*

Risk Scenario: Extreme Weather Condition			
19	Winter weather conditions (snow, ice, frost)	Temperatures are below average for winter periods and are accompanied by significant amounts of precipitation in the form of snow in some areas, and frost and ice in other areas. Local wind intensifications lead to galloping and falling trees on power lines.	Actions will be initiated immediately to restore the triggered equipment to service, respectively to repair/replace the destroyed/damaged assets using equipment from security stocks or ways of functioning of the equipment in provisional schemes will be ensured. The measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. The groups will be loaded to the maximum available power (including starting the groups in reserve). The dispatchable consumption declared as load offer on the balancing market will be reduced. An increase in the available power of the NPS will be requested, by making available the production units under repair (pre-term release of the groups under repair). Measures are being taken to increase the availability of PTG and PDG equipment (cancellation of withdrawals from operation of some equipment for maintenance or investment works). In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine). The reduction/cancellation of the available interconnection capacity (ATC) in the export direction will be ordered, as well as the reduction/cancellation of notified exchanges in the export direction.
20	Heat wave	A heat wave occurs, covering a large part of Europe for a long period of time with extremely high temperatures. There is a low level of water in reservoirs which results in a reduced production in hydro power plants but also limitations of production in coal/gas thermal power plants and nuclear power plants caused by the impossibility of ensuring adequate cooling. Consumption is very high due to the need for air conditioning. There are limitations in the functioning of equipment caused by very high temperatures.	The heat wave can be accompanied by a long period of drought. Also at the end of the heat wave extreme weather phenomena can be recorded (storms/tornadoes or intense precipitation that can lead to flooding). Actions will be initiated immediately to restore the unavailable equipment. The necessary cooling systems will be ensured for the proper functioning of the command, control and protection systems in power substations, plants and dispatcher control centers. Measures to prevent the spread of fires in transformer substations will be initiated immediately. Actions will be initiated immediately to repair/replace the destroyed/damaged assets using equipment from security stocks or ways of functioning of the equipment in provisional schemes will be ensured. The measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. The groups will be loaded to the maximum available power (including starting the groups in reserve). The dispatchable consumption declared as load offer on the balancing market will be reduced. An increase in the available power of the NPS will be requested, by making available the production units under repair (pre-term release of the groups under repair). Measures are being taken to increase the availability of PTG and PDG equipment (cancellation of withdrawals from operation of some equipment for maintenance or investment works). In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine). The reduction/cancellation of the available interconnection capacity (ATC) in the export direction will be ordered, as well as the reduction/cancellation of notified exchanges in the export direction.

Table 10. *Cont.*

Risk Scenario: Extreme Weather Condition			
21	Drought	Low rainfall amounts lead to a low water level in reservoirs resulting in reduced production in hydro power plants but also production limitations in coal/gas thermal power plants and nuclear power plants caused by the impossibility of ensuring adequate cooling. Energy production is decreasing or missing in wind power plants due to lack of wind.	The drought can be accompanied by extreme temperatures (very high during the summer or very low during the winter period). Also, at the end of the drought period, extreme weather phenomena can be recorded (storms/tornadoes or intense rainfall that can lead to flooding). The measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. The groups will be loaded to the maximum available power (including starting the groups in reserve). The dispatchable consumption declared as load offer on the balancing market will be reduced. An increase in the available power of the NPS will be requested, by making available the production units under repair (pre-term release of the groups under repair). Measures are being taken to increase the availability of PTG and PDG equipment (cancellation of withdrawals from operation of some equipment for maintenance or investment works). The transition to functioning in the minimum voltage band in the distribution grid will be ordered. In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine). The reduction/cancellation of the available interconnection capacity (ATC) in the export direction will be ordered, as well as the reduction/cancellation of notified exchanges in the export direction.
22	Forest/vegetation fires	Forest/vegetation fires occur rapidly, favored by dry weather. In addition, the occurrence of wind intensification leads to the rapid and uncontrolled spread of fires.	Urgent measures are being taken to restore the disconnected/triggered transmission and distribution grid equipment to service. Actions will be initiated immediately to repair/replace the affected pillars and restore the unavailable lines. Measures to prevent the spread of fires in transformer substations will be initiated immediately. Actions will be initiated immediately to repair/replace the destroyed/damaged assets using equipment from security stocks or ways of functioning of the equipment in provisional schemes will be ensured. The measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. The groups will be loaded to the maximum available power (including starting the groups in reserve). The dispatchable consumption declared as load offer on the balancing market will be reduced. An increase in the available power of the NPS will be requested, by making available the production units under repair (pre-term release of the groups under repair). Measures are being taken to increase the availability of PTG and PDG equipment (cancellation of withdrawals from operation of some equipment for maintenance or investment works). In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine). The reduction/cancellation of the available interconnection capacity (ATC) in the export direction will be ordered, as well as the reduction/cancellation of notified exchanges in the export direction.

4.3.4. Source: Natural Calamity

The identification of the risk scenario, trigger event and mitigation/containment and restoration measures, are shown in Table 11 [37,38].

Table 11. Source: Natural calamity (own elaboration).

Risk Scenario: Natural Calamity			
23	Solar storm	A solar storm (coronal mass ejection) is occurring, seriously affecting the areas of Northern and Central Europe, as well as the rest of the European regions. This event was forecasted by space agencies a few days earlier and measures were taken at the national level and at the ENTSO-E level.	Coordinated action is being taken at the ENTSO-E level, given that the situation was anticipated and some crisis response measures have been taken. Actions will be initiated immediately to repair/replace the destroyed/damaged assets using equipment from security stocks or ways of functioning of the equipment in provisional schemes will be ensured. The measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. The groups will be loaded to the maximum available power (including starting the groups in reserve). The dispatchable consumption declared as load offer on the balancing market will be reduced. An increase in the available power of the NPS will be requested, by making available the production units under repair (pre-term release of the groups under repair). Measures are being taken to increase the availability of PTG and PDG equipment (cancellation of withdrawals from operation of some equipment for maintenance or investment works). In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine). The reduction/cancellation of the available interconnection capacity (ATC) in the export direction will be ordered, as well as the reduction/cancellation of notified exchanges in the export direction.
24	Earthquake	A high-magnitude earthquake is recorded that affects a large area. Alerts are issued a few seconds before the earthquake occurs and do not allow for protective measures to be taken. Panic occurs among the population in the area affected by the earthquake, influencing the course of events.	Actions will be initiated immediately to repair/replace the affected pillars and restore the unavailable lines. Actions will be initiated immediately to repair/replace the affected transformer units. Mobile cells will be used to ensure the functioning of substations affected by the earthquake. An immediate inspection of buildings and structures (related to lines, power substations, power plants, dispatch centers) located in the seismic zone will be carried out to assess the possibility of their safe functioning. The measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. The groups will be loaded to the maximum available power (including starting the groups in reserve). The dispatchable consumption declared as load offer on the balancing market will be reduced. An increase in the available power of the NPS will be requested, by making available the production units under repair (pre-term release of the groups under repair). Measures are being taken to increase the availability of PTG and PDG equipment (cancellation of withdrawals from operation of some equipment for maintenance or investment works). In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine). The reduction/cancellation of the available interconnection capacity (ATC) in the export direction will be ordered, as well as the reduction/cancellation of notified exchanges in the export direction.

4.3.5. Source: Energy Insecurity

The identification of the risk scenario, trigger event and mitigation/containment and restoration measures, are shown in Table 12.

Table 12. Source: Energy insecurity (own elaboration).

		Risk Scenario: Energy Insecurity	
25	Crisis in the provision of fossil fuels (coal, oil and natural gas)	The crisis in the fossil fuel supply occurs during the year with high consumption and low stocks of fuels. Production, fossil fuel supply of power plants (for weather, technical, economic reasons, or as a result of demanding and protest actions) or imports of fossil fuels (for technical, weather or political reasons) are disrupted over a long period of time. This period coincides with a period when it is not possible to supplement national energy production from other sources.	The measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. The groups will be loaded to the maximum available power (including starting the groups in reserve). The dispatchable consumption declared as load offer on the balancing market will be reduced. An increase in the available power of the NPS will be requested, by making available the production units under repair (pre-term release of the groups under repair). Measures are being taken to increase the availability of PTG and PDG equipment (cancellation of withdrawals from operation of some equipment for maintenance or investment works). Urgent measures are being taken to repair faults/malfunctions in the equipment in the transmission and distribution grid and ensure their availability. The transition to functioning in the minimum voltage band in the distribution grid will be ordered. The increase of system technological reserves in production units will be ordered, that can operate on alternative fuel (for example, fuel oil), in order to use them as appropriate. In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine). The reduction/cancellation of the available interconnection capacity (ATC) in the export direction will be ordered, as well as the reduction/cancellation of notified exchanges in the export direction.
26	Crisis in provision of nuclear fuels	Lack of nuclear fuel (UO_2 powder), caused by: A deficit of supply resources at national and international level; Delayed delivery of fuel, or non-compliant fuel; Dependence on suppliers	Sensitive informations.

Table 12. *Cont.*

Risk Scenario: Energy Insecurity			
27	Industrial/nuclear accident	A nuclear accident or industrial accident occurs at a chemical plant. Nuclear radiation or chemical emissions affect a large area, leading to the evacuation of the population from the affected area and to a state of panic. Transport, supply and communications services are affected in the affected area and in adjacent areas. The accident may be caused by technical failures, earthquakes, sabotage or terrorist actions and may have cross-border effects.	Dispatcher or remote control centers must be relocated to protected locations. Measures are being taken to evacuate the operative staff. Intervention in the affected areas will be ensured for the operation of substations and plants or for the remediation of failures together with specialized teams within the Emergency Situations Inspectorate. If the impossibility of operating the installations has led to the lack of electricity supply to some consumers, measures are taken to re-supply them through interventions at the installations level, with the help and under the protection of specialized Emergency Situations Inspectorate teams. In the event of a production deficit, the measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. The groups will be loaded to the maximum available power (including starting the groups in reserve). The dispatchable consumption declared as load offer on the balancing market will be reduced. An increase in the available power of the NPS will be requested, by making available the production units under repair (pre-term release of the groups under repair). Measures are being taken to increase the availability of PTG and PDG equipment (cancellation of withdrawals from operation of some equipment for maintenance or investment works). Urgent measures are being taken to repair faults/malfunctions in the equipment in the transmission and distribution grid and ensure their availability. In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine). The reduction/cancellation of the available interconnection capacity (ATC) in the export direction will be ordered, as well as the reduction/cancellation of notified exchanges in the export direction.
28	Unforeseen interactions in the energy market	Inappropriate actions by energy market participants occur as a result of unforeseen situations (which create panic among participants). The event is favored either by some manifestations produced on an energy market in another country that produce unforeseen effects on other energy markets, including the Romanian energy market, or by extreme weather situations or an unusually high/low demand on the Romanian energy market.	The use of algorithms for automated trading by some participants on the Romanian energy market increases the risk of significant disturbances. The measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. The groups will be loaded to the maximum available power (including starting the groups in reserve). The dispatchable consumption declared as load offer on the balancing market will be reduced. An increase in the available power of the NPS will be requested, by making available the production units under repair (pre-term release of the groups under repair). Measures are being taken to increase the availability of PTG and PDG equipment (cancellation of withdrawals from operation of some equipment for maintenance or investment works). In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine). The reduction/cancellation of the available interconnection capacity (ATC) in the export direction will be ordered, as well as the reduction/cancellation of notified exchanges in the export direction.

4.3.6. Source: Political/Military Insecurity

In the context of a blackout—whether regional or national—a country's political and military insecurity can become more pronounced due to a number of sanctions (meaning consequences or impacts in this case, not punitive international sanctions).

Below is an overview of how a blackout can aggravate political and military instability, with specific sanctions or effects outlined:

Sanctions (Consequences) of Political and Military Insecurity in Case of a Blackout:

1. Breakdown of Command and Control Systems
    - Military operations rely heavily on communication networks, power grids, and digital command structures;
    - A blackout can disable encrypted communications, radar systems, and air defense grids, making a country vulnerable to internal disorder or external attack.
2. Loss of Surveillance and Intelligence Capabilities
    - Power loss affects satellite communication, drones, and intelligence gathering tools;
    - Blind spots can occur in border surveillance and cybersecurity systems, increasing the risk of incursions, smuggling, or cyberattacks.
3. Public Disorder and Civil Unrest
    - Blackouts often lead to panic, hoarding, looting, and riots, especially in urban areas;
    - In politically unstable regions, this can trigger anti-government protests or even coup attempts, especially if the government is perceived as weak or unprepared.
4. Disruption of Emergency and Military Response
    - Hospitals, police forces, fire departments, and military installations may operate at reduced capacity or become non-operational if generators fail;
    - Troop mobilization becomes difficult; airports and rail systems may be down.
5. Heightened Vulnerability to Foreign Adversaries
    - Adversaries may see a blackout as a strategic opportunity to conduct hybrid warfare: misinformation, cyberattacks, or limited military strikes;
    - Border incursions or proxy conflicts may intensify during periods of national weakness.
6. Damage to Political Legitimacy
    - Prolonged or poorly managed blackouts erode public trust in the government and civil institutions.
    - Can spark political crises, especially in authoritarian regimes or fragile democracies where stability relies on control and perceived strength.
7. Cybersecurity Breaches
    - Blackouts caused by cyberattacks (e.g., on power grids) often accompany data breaches or manipulated military systems.
    - A digitally paralyzed military is unable to respond in real-time to threats.

Real-World Examples

- Venezuela (2019): A national blackout led to widespread chaos, hospital failures, and looting, exacerbating the country's political crisis.
- Ukraine (2015): Cyberattack-induced blackouts by suspected Russian actors highlighted vulnerabilities in critical infrastructure.
- Iraq (2003): During the U.S. invasion, targeted blackouts were used to degrade command/control and disorient military forces.

Mitigation Measures

- Hardened infrastructure (EMP-resistant and redundant systems);
- Decentralized energy generation (solar, microgrids);
- Cybersecurity for critical sectors;
- Real-time crisis communication protocols;
- Military readiness drills under blackout conditions.

Sanctions can lead to a power blackout through several interconnected pathways, particularly in countries that rely heavily on imports or international cooperation to maintain their energy infrastructure. Here's how it can happen:

1. Disruption of Fuel Supply

If sanctions target the energy sector—such as oil, gas, coal, or nuclear fuel—they can prevent a country from importing the fuel it needs to generate electricity. This can cause:

- Shortages of fuel at power plants;
- Reduced electricity generation, especially if there's no domestic substitute.

Example: Iran and Venezuela have faced difficulties in refining or exporting oil due to sanctions, which impacted domestic energy availability.

2. Block on Critical Equipment or Spare Parts

Modern power grids rely on imported technologies, spare parts, and maintenance tools. Sanctions can block access to:

- Turbines, transformers, and control systems;
- Smart grid technology or software updates;
- Maintenance services from foreign companies.
- This can lead to:
- Breakdowns in existing infrastructure;
- Delays in repairs;
- Greater risk of cascading failures.

3. Loss of Foreign Investment and Technical Expertise

Energy infrastructure often depends on foreign investment and international technical collaboration, especially in developing or post-conflict countries. Sanctions can deter:

- Companies from funding or completing energy projects;
- Engineers or contractors from working in sanctioned regions.

Result:

- Stalled power plant projects
- Incomplete grid upgrades
- Over-reliance on aging, less reliable systems

4. Cybersecurity Vulnerabilities

Sanctions can limit access to cybersecurity tools and partnerships. This can leave grids more exposed to:

- Cyberattacks;
- Malware targeting industrial control systems.

Such attacks can trigger blackouts, either by disabling controls or damaging equipment.

5. Economic Collapse Leading to Power Cuts

Sanctions can lead to a broad economic crisis, reducing a government's ability to:

- Pay for fuel and electricity imports;
- Subsidize utilities;

- Maintain infrastructure.

Governments may then:

- Cut electricity to manage costs
- Prioritize critical sectors, leaving homes or rural areas in darkness

Real-World Examples

- Iraq (1990s): UN sanctions after the Gulf War severely limited access to equipment and spares, contributing to power shortages;
- North Korea: Long-term sanctions have forced it to ration electricity and rely on inefficient systems;
- Venezuela: While not caused solely by sanctions, the collapse of the electric grid was worsened by economic sanctions that reduced access to maintenance resources.

The identification of the risk scenario, trigger event and mitigation/containment and restoration measures, are shown in Table 13 [37,38].

Table 13. Source: Political/military insecurity (own elaboration).

Risk Scenario: Political/Military Insecurity			
29	Military conflict, war	Regional conflict states, the need to defend the country.	Dispatcher or remote control centers must be relocated to protected locations. Measures are being taken to evacuate the operative staff. Intervention in the affected areas will be ensured for the operation of substations and plants or for the remediation of failures together with specialized teams within the Emergency Situations Inspectorate. If the impossibility of operating the installations has led to the lack of electricity supply to some consumers, measures are taken to re-supply them through interventions at the installations level, with the help and under the protection of specialized Emergency Situations Inspectorate teams. In the event of a production deficit, the measures provided for in NAER Order no. 142/3.12.2014_Regulation on the establishment of safeguard measures in crisis situations arising in the functioning of the National Power System, are taken. In order to ensure the production deficit, damage aid will be requested from neighbouring TSOs according to bilateral agreements (Operational Agreements and the Mutual Aid Agreements signed with Bulgaria, Serbia, Hungary and Ukraine)

5. Role and Tasks of Competent Authorities for Securing Electricity Supply

Role and tasks of competent authorities for securing electricity supply.

5.1. The Romanian Competent Authority for Electricity Supply Assurance

The Romanian Competent Authority for Electricity Supply Assurance has the following specific tasks:

- identifies and assesses the risks to the safety of electricity supply according to national and international methodology and regulations;
- ensures cooperation with the Transmission System Operator (TSO), distribution operators (DO), electricity production companies, The National Authority for Energy

Regulations (NAER), the Electricity Coordination Group (ECG), the European Network of Transmission System Operators for Electricity (ENTSO-E), and Regional Coordination Centers (RSCs) and other relevant stakeholders, as necessary;
- prepares and periodically updates the Risk Preparedness Plan (RPP) based on regional and national electricity crisis scenarios, in collaboration with entities in the electricity sector;
- ensures, through the Director of the Competent Authority for Ensuring Electricity Supply within the Ministry of Energy, participation in the Group for the management of energy crisis situations at national level;
- ensures the fulfillment of the measures established in the Risk Preparedness Plan (RPP), in order to prevent the occurrence of energy crisis situations;
- completes the formalities necessary to fulfill the tasks of the Competent Authority, as provided for in Regulation (EU) 2019/941;
- completes the formalities necessary for the adoption of the Risk Preparedness Plan (RPP) and for the organization of electricity crisis tests/simulations in cooperation with the Transmission System Operator (TSO) and other relevant stakeholders;
- develops and establishes procedures for the implementation and monitoring of Operational Procedures (OPs) in the field of risk prevention and management in the electrical sector.

5.2. Transmission and System Operator (TSO)—Transelectrica

The Transmission and System Operator (TSO) has the following specific tasks:

- Assesses the possibility of a crisis situation occurrence through short and medium-term analysis of the adequacy in the NPS;
- Informs the National Operative Center in the Energy Sector on the possibility of a crisis situation occurrence;
- Ensures the functioning of the electricity market;
- Takes measures to prevent crisis situations that do not affect the functioning of the electricity market;
- Requests NAER to suspend the energy market;
- Takes technical and commercial safeguard measures in crisis situations affecting the functioning of the electricity market;
- Ensures the adequacy of the NPS;
- Ensures the compliance with the N-1 safety criterion;
- Ensures the static and dynamic stability of the NPS;
- Ensures the power reserves;
- Ensures the restoration of the NPS;
- Ensures the remediation of failures/damage produced in the transmission grid;
- Ensures the lines of communication to implement control and restoration actions;
- Implements the measures ordered by the higher decision-making structures.

5.3. Distribution Operators

Distribution operators have the following specific tasks:

- Participate in the restoration of the NPS;
- Implement the measures ordered by the higher decision-making structures;
- Ensure the compliance with the N-1 safety criterion;
- Ensure the interventions for the remediation of failures/damage produced in the distribution grid;
- Ensure the lines of communication to implement control and restoration actions.

5.4. Electricity Production Companies

The Production Operators have the following specific tasks:

- Participate in the restoration of the NPS;
- Implement the measures ordered by the higher decision-making structures;
- Ensure the maintenance of production units in operation at the level notified on the energy market, respectively at the level ordered by dispatcher orders;
- Ensure the system technological services necessary to maintain the operational safety of the NPS;
- Ensure fuel reserves necessary to keep production units running;
- Ensure the remediation of failures/damage produced in the production units;
- Ensure the lines of communication to implement control and restoration actions.

5.5. Economic Operators Providing System Services

Operators providing system services have the following specific tasks:

- Ensure power reserves at the level notified on the electricity market, respectively at the level ordered by dispatcher orders;
- Ensure the lines of communication to implement control and restoration actions.

5.6. Flexible Measures: Short-Term/Long-Term Solutions (Such as Costs, Technological Barriers, and Obstacles to International Cooperation) Is Case of Blackout

In the case of a blackout, especially large-scale or prolonged ones, there are both short-term and long-term solutions that must address costs, technological barriers, and obstacles to international cooperation.

A. Short-term solutions:

1. Emergency Power Supply:
    - Description: Use of backup generators, battery systems, or microgrids for hospitals, communication centers, and critical infrastructure;
    - Costs: Moderate to high, depending on scale and fuel;
    - Barriers: Limited fuel supply, maintenance, and deployment speed;
    - International Obstacles: Cross-border support may be slow or tied up in regulations (e.g., customs delays);
2. Load Shedding & Demand Management:
    - Description: Controlled, rotating outages to prevent grid collapse;
    - Costs: Low to medium;
    - Barriers: Requires real-time grid management tools and communication infrastructure;
    - International Obstacles: Hard to coordinate across borders due to different grid setups and policies.
3. Public Communication & Preparedness:
    - Description: Distribute emergency information via radio, text alerts, or community networks;
    - Costs: Low;
    - Barriers: Dependent on remaining infrastructure; public may not be well-prepared;
    - International Obstacles: Language differences, different emergency protocols.

B. Long-term solutions:

1. Grid Modernization & Smart Grids:
    - Description: Upgrading infrastructure for resilience, automation, and quicker fault detection;
    - Costs: High initial investment, long ROI;

- Barriers: Funding, aging infrastructure, cybersecurity concerns;
- International Obstacles: Standards vary by country; interoperability issues;

2. Energy Storage & Decentralized Systems:
   - Description: Batteries, pumped hydro, or flywheels; solar-plus-storage systems;
   - Costs: High, but declining with tech improvements;
   - Barriers: Material shortages (e.g., lithium), land use, regulatory issues;
   - International Obstacles: Competition for tech exports (e.g., China controlling rare earths).
3. Cross-border Energy Agreements:
   - Description: Shared grids, backup arrangements between countries (e.g., EU electricity sharing);
   - Costs: Medium to high;
   - Barriers: Political distrust, legal complexity, grid incompatibilities;
   - International Obstacles: Sovereignty concerns, regional rivalries;
4. Cybersecurity Investments:
   - Description: Protecting grid from cyberattacks (a common cause of blackouts);
   - Costs: Medium;
   - Barriers: Talent shortages, underinvestment, outdated legacy systems;
   - International Obstacles: Limited trust in sharing vulnerabilities or defense strategies.

6. Conclusions

In this paper, the authors have developed 3 mandatory stages that the operators and managers of the National Power System must strictly comply with in the context of prevention and system behavior in case of a blackout.

In stage 1, 6 blackout risk scenarios were developed: insecurity in functioning of the NPS, terrorist attack on the NPS, extreme weather condition, natural calamity, energy insecurity and political/military insecurity.

In stage 2, 2 procedures and measures were developed: national procedures and measures, and regional and bilateral procedures and measures.

In stage 3, the role and tasks of competent authorities for securing electricity supply, were developed: The Romanian Competent Authority for Electricity Supply Assurance, Transmission and System Operator, Distribution operators, Electricity production companies and Economic operators providing system services.

The interdisciplinary analysis of energy infrastructure and security, through the identification, assessment and manifestation of blackout risk scenarios (total or partial interruptions of electricity supply) are essential aspects in managing the energy security of a NPS.

The importance of each component is briefly explained below: It allows the recognition of critical situations that can lead to major electricity interruptions (technical failures, cyberattacks, natural disasters, lack of production capacity, imbalances between supply and demand, etc.); It provides the basis for planning preventive measures; It helps NPS operators understand and model vulnerable points in the grid; It measures the likelihood of a blackout occurrence and the gravity of the consequences (economic, social, health impact); It allows risk classification by likelihood, gravity and urgency; It substantiates decisions regarding investments in infrastructure, maintenance and backup technologies; Description of how the risk may materialize which helps prepare rapid and effective response protocols; Provides clarity regarding the sequence of events (fault cascading); It is essential for the training and instruction of the operative staff;

The identification, assessment and manifestation of blackout risk scenarios are critical to ensuring the NPS resilience, protecting critical infrastructure and reducing impact on the population and economy. These steps enable authorities, operators and decision makers to take proactive measures and develop efficient continuity and crisis response plans.

The main contribution of this paper (findings) is the interdisciplinary approach, integration, and analysis of risks, threats, and vulnerabilities related to: technical incidents, human accidents, climate disasters (natural calamities), human errors, protests, strikes and staff sabotage, pandemics, cyberattacks (both internal and external), terrorist attacks, energy crises (coal, natural gas, uranium, oil, etc.), nuclear accidents, energy markets, military conflicts, or wars.

Future Research Directions in the case of blackouts can be approached from multiple perspectives: Technological, Economic, Societal, and Security-Related.

Below are some relevant and promising directions:

1. Resilience and Flexibility of Power Grids: Smart grids and decentralized power networks; Integration of automatic backup systems (UPS, smart generators); Autonomous microgrids that can operate independently during a blackout; Real-time self-reconfiguration algorithms for the grid.
2. Digitalization and Early Detection: AI systems for forecasting and detecting blackout risks; Internet of Things (IoT) for real-time consumption monitoring; Digital simulations (digital twins) of energy networks.
3. Renewable Energy Sources and Storage: Advanced energy storage technologies (flow batteries, graphene-based batteries, hydrogen); Integration of prosumers (consumers who also produce energy) into the grid; Hybrid energy production models: renewable + nuclear + storage.
4. Human Behavior and Social Planning: Studying population behavior in the event of blackouts; Public alert systems and preventive education; Research on the psychological and social impact of prolonged blackouts.
5. Cyber and Physical Security: Protecting critical infrastructure against cyberattacks; Developing incident response protocols for blackouts caused by attacks; Worst-case scenario simulations (e.g., continental blackout).
6. Public Policy and Economic Models: Economic models for investments in grid resilience; Government strategies for long-term energy planning; Cost-benefit studies of prevention technologies.

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Abbreviations

The following abbreviations are used in this manuscript:

NPS	National Power System
NED	National Energy Dispatch
TED	Territorial Energy Dispatchers

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