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BlackAUT: Concepts for Blackout Resilience from a Comprehensive Strategic Exercise in Austria

Stefan Schauer, Martin Latzenhofer, Sandra König, Manuela Kos, Manuel Egger

Center for Digital Safety & Security, AIT Austrian Institute of Technology, Austria. E-mail: {stefan.schauer; martin.latzenhofer; sandra.koenig; manuela.kos; manuel.egger}@ait.ac.at

A widespread and long-lasting power outage, i.e., blackout, is one of the most severe threats for society at a national level and possibly evolving to an international incident. Due to the cross-sectoral function of electrical energy, almost all parts of society will be directly affected by a blackout, including most of the critical infrastructures (CIs) in the concerned regions. Therefore, relevant measures to prepare for and to recover from a blackout require structural coordination in advance between national government, municipalities, local authorities, and the CI. In late 2022, a comprehensive strategic exercise (BlackAUT) has been carried out by the Competence Center for a Safe & Secure Austria (KSOe), the Austrian Institute of Technology (AIT) and the Federation of Austrian Industries (IV) in Austria, involving about 80 experts from CI operators of multiple domains and the public administration. Additionally, a Cascading Effects Simulation (CES) was implemented as part of the strategic exercise to provide the participants a better overview on the potential side effects a blackout might have throughout the country. In this paper, we present an overview on the scenario setting, describe the integration and aimed benefits of the CES. We will discuss in detail the main reactions of the CI operators from the different domains, highlight particular dependencies among them that have been identified during the exercise and sketch the main findings and take-aways from this strategic exercise. As a main result, we will discuss the future implications these findings have on the preparation efforts to increase the resilience of critical infrastructures in Austria and all over Europe.

Keywords: Blackout, Power Outage, Cascading Effects, Strategic Exercise, Simulation.

1. Introduction

The global crises of the last three years, i.e., the pandemic (2020ff) (Coccolini et al. 2021), the Ukraine war (2022f) (Bigg 2023), the resulting energy crisis in Western Europe (2022f) as well as regional events like shipwrecks at sensitive locations such as the Suez Canal (2021) (Samaan et al. 2021; Russon 2021) illustrate the complex interdependencies of goods and services. Critical infrastructures are under particular pressure. On the one hand, the supply of society depends on their services, on the other hand, disruptive upheavals in the framework conditions make their provision difficult or impossible. This complexity became visible in the above cases of filling up the available gas storages (Mavrokefalidis 2022; European Council 2023), shortages of medicines (World Economic Forum 2023; Fick and Grover 2023), food (European Council 2023) or simple delays in the delivery of primary products and components (LaBelle and Santacreu 2022; Demirkıran 2023). In such situations, the CI operators have to shift from a competitive to a cooperative approach and include the interests of the public administration in the situation analysis, action setting and restart.

Well-known experts from the energy sector expect a blackout to occur in Europe in the next few years (Sanchez 2021). Some near-misses also illustrate this high probability (ENTSO-E 2021). In Austria, experts proactively tried to assess this situation across sectors, to deal with the possible impacts, to push the practical interaction of all stakeholders and to explore practical ways to deal with a blackout situation. Therefore, the national strategic exercise BlackAUT was organized at the end of November 2022 by the Competence Center for a Safe & Secure Austria (KSOe), the Austrian Institute of Technology (AIT) and the Federation of Austrian Industries (IV). The aim of the exercise was to test the emergency management procedures of the organizations, to strengthen communication and cooperation in case of failure of the usual communication infrastructures, to stimulate interaction and coordination between organizations both within a sector and across sectors and with authorities, and finally to ensure discussion, awareness raising and elaboration of new perspectives among stakeholders.

2. Scenario Overview

Due to the cross-sectoral importance of electrical energy, almost all parts of society will be directly affected by a blackout, including most of the CIs in the affected regions. Therefore, relevant measures to prepare for and to recover from a blackout require structural coordination in advance between national government, municipalities, local authorities, and the CI operators. The following scenario was developed to put the participants of the BlackAUT exercise in this situation for training purposes.

2.1 *Description of the Initial Event*

The BlackAUT scenario was developed closely with Verbund AG, a nation-wide operating energy company. The storyline started in the morning of November 29, 2022, with a desynchronization of the European power grid. Similar to the near blackout in January 2021 (ENTSO-E 2021), this was preceded by an incident at a substation in Hungary. The resulting line shutdown shifted power flows to other lines in the region. This led to an overload (overcurrent) of these power lines, and the lines were automatically shut down to protect them from damage. Resulting cascading effects in Croatia, Bosnia and Herzegovina as well as Serbia and Romania led to a large-scale separation of the synchronous area. Consequently, a production surplus in the southeastern part of the European grid (Balkans, Greece, Bulgaria, Romania, Turkey) caused an increase in the grid frequency. In the scenario, this increase could be absorbed by reducing the production of large generators in Turkey and be balanced in a very short time. In the western part of the grid (Spain, Portugal, France, Germany, Austria, etc.), this led to an undersupply and a drop in the grid frequency.

An additional assumption was that a sufficient disconnection of large consumers in the western part could not be arranged in time, resulting in a further disintegration of the western part of the European power grid into smaller areas. Austria ended up in isolation with Italy, a net importer of electricity, which kept the situation critical. In addition, there were problems with one substation in the Austrian mountains, which suffered severe damage from a persistent storm front the night before. Falling trees and drifts of building components, with part of the roof falling onto the substation, had caused the substation to fail. This further destabilized the grid frequency in Austria. Measures to stabilize the grid, such as automatic load shedding, were not sufficient, and a nationwide blackout occurred in Austria.

As a next stage, the major national power companies are working on restoring supply in individual islands. The starting points for this are storage power plants in the southern and western alpine regions of Austria, which will be interconnected as quickly as possible with hydropower plants along the Danube in the north of Austria, as well as other rivers. Together with these generators, new consumers can gradually be connected. However, the process is proving to be more time-consuming in detail than expected.

2.2 *Setting of the Strategic Exercise*

As starting point for the strategic exercise, it was assumed that the situation was detected at the national energy infrastructure provider, which notified the public authorities. Further, the crisis teams in industrial companies and large organizations had been notified simultaneously. The participants of the strategic exercise came from various critical infrastructure sectors such as energy, telecommunication, mobility, health, finance, food and logistics as well as from public authorities; they played these crisis teams in the CIs. The participants from each of these sectors have been assigned to individual tables in the same room and are allowed to interact both with the participants at the same table and with the participants at the other tables. In addition, the aspect of society was also covered in the strategic exercise by representatives from this domain.

In order to provide the participants with a setting as close to reality as possible, the strategic exercise was set in a real environment. Date and time in the exercise corresponded to the real time (with a small exception in Phase 2, see below). This had the advantage that all external influences on this day, such as the temperature and weather conditions, the current traffic volume and situation, the capacity utilization of the health care system (i.e., hospitals, emergency organizations, etc.), as well as other current events (coincidentally, a strike of the national railway operator took place the day before), were defined by the real conditions.

The strategic exercise was divided into two phases, each of which ran in real time. This allowed the participants to experience their activities and planning as if they were taking place under real conditions. The main task of each of the two phases was to prepare a briefing for the respective decision-makers. This briefing was delivered at the end of each phase by one representative per table, giving all participants an overview of the activities at each table. In addition to the main task, so-called injects, i.e., additional smaller tasks and challenges, were prepared in both phases and introduced by the game makers. These injects described additional events that could occur in the context of the crisis. Further, they were intended to highlight different aspects of the scenario that had not yet been considered by the participants as well as to stimulate discussion at and between the tables.

Since the communication (or lack of it) and the exchange of information among the organizations in the event of a blackout was one of the main objectives of the strategic exercise, this aspect was also anchored accordingly in the structure of the exercise. In this context, a basic distinction was made between communication at the tables and among the tables: on the one hand, representatives of the different organizations in a sector could speak directly with each other, which would not be true in reality, since most sectors do not have cross-organizational crisis teams. However, in the strategic exercise, the participants were given the advantage of short exchanges to strengthen the coordination between the organizations.

On the other hand, classic means of communication (i.e., mobile and data networks) would be severely affected by a blackout and supposed to fail to a significant extent in the first 30 minutes. In the beginning of the exercise, it was possible to go back and forth between the tables to exchange information with the participants of the other sectors; but after 30 minutes, communication was strongly limited, and one walkie-talkie per table was used as a backup medium. The assumption in the scenario was that the individual sectors had emergency radio or similar technical capabilities. Consequently, only a point-to-point connection was allowed between the tables and one walkie-talkie was provided per table. However, to simplify the situation at the table, communication between the organizations of one sector was still possible. The assumption here was that the individual organizations would have TETRA-based emergency radio (Terrestrial Trunked Radio Standard) (ETSI 2016) or similar technical capabilities.

2.3 *Execution of the Scenario*

Phase 1 in the strategic exercise started with the initial event that led to the blackout (see Section 2.1) and lasted for two hours. This first phase focused on those activities and measures that were necessary immediately after the event and at the beginning of the crisis and emergency planning. The participants could fall back on existing processes and the individual procedures from crisis management were to be applied. The goal in this phase was to evaluate whether there were any potential open issues in each organization's plans that had not yet been considered for a blackout.

Phase 2 in the exercise started in the afternoon and evening hours of the scenario day and covered 90 minutes in real time. The starting point for Phase 2 was a status update on the situation, which indicated an uncertain duration of the blackout. Therefore, the focus was on planning activities and measures for the next 24, 48, and 96 hours and thus concerned the more advanced parts of the crisis and emergency plans in the individual organizations. Key aspects in this phase were to maintain ongoing operations for the specified time periods, to plan for the resource supply, to coordinate for support and assistance from other organizations, and to provide the public with information and resources.

At the end of each phase, the results from the discussions at the tables on the different activities were presented as short management briefings. In the scenario, decision-makers were to be addressed, as they need a status report on the current situation for the respective national crisis management both after two hours and at the end of the day. These briefings were held by one representative of each table and offered an additional channel for information exchange between the tables on the measures taken but also on the challenges of the respective phase.

3. Cascading Effects Simulation

3.1 *Underlying Mathematical Model*

The Cascading Effects Simulation (CES) is built on a graph representation of the CIs and relevant parts thereof and the interdependencies relevant for the scenario of the strategic exercise. Nodes in this graph can represent various elements, ranging from entire critical infrastructures to individual objects such as laptops or sensors, but also cyber-domain elements such as databases or firewalls. In order to incorporate behavioral patterns of these elements into the model, nodes are represented as Mealy automata. Mealy automata can produce an output based on a specific input and together with its current state. In our model, an input to the Mealy automaton corresponds to an incident or other scenario the represented element is facing, e.g., "power outage" or "fire". The output of the Mealy automaton shows how the element responded to the incident, e.g., by a "server failure" due to the input "power failure". In the context of the simulation, the state of the Mealy automaton is interpreted as a risk state. Any number of states can be used, each one with associated meanings. For example, a model with three possible states could be defined as follows:

- State 1 = no problems; element works as expected.
- State 2 = element works but with certain problems/limitations.
- State 3 = severe problems; element not working.

These states are used on the one hand to be able to react differently to inputs depending on the constraints already present, and on the other hand for visualization and analysis purposes.

In order to properly describe the behavior of a Mealy automaton, transitions must be defined that cover the possible inputs for each risk state together with the respective outputs. Due to the high complexity of interdependent CIs, the transitions in our model are probabilistic, i.e., an input may cause different effects depending on external influences. Figure 1 shows a simple Mealy automaton for a node X. In State 0, the automaton changes to either State 1 (corresponding to "limited operation") or State 2 (corresponding to "no operation") and each transition has a probability attached to it. For example, a less severe event would bring the node into State 2 with a higher probability, whereas a more severe event would bring it into State 3 with a higher probability.

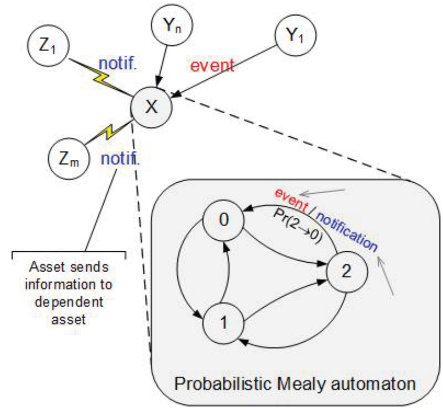

Figure 1: Node with inner Mealy automaton model describing the reaction to an event (König et al. 2020)

3.2 *Simulation of Cascading Effects*

As described in Section 3.1, nodes in the graph model react to inputs and generate outputs if the state changes. This feature is used to simulate cascading effects: the nodes are connected by edges that represent dependencies in the model and across which inputs and outputs are exchanged with each other. Thus, an edge from a node Y_i to node X means that incidents that occur on Y_i can also influence X. Figure 1 shows how a node reacts to input events form nodes Y_i and notifies its dependent nodes Z about possible problems.

The simulation of cascading effects starts with one or more initial events faced by the first nodes. When this generates output, it is packaged into an event. The event contains the output as new input and the dependent node, which receives this event as input in the next time step. If no transition exists that matches the input event and the current state or the probabilistic transition is not performed, no output is generated. In this way, each simulation step generates a collection of events that are processed in sequence in the next step, potentially generating new events. The simulation ends as soon as there are no new events (or a previously defined limit of time steps is reached). Since the stochastic model usually generates different results for each simulation run, the overall simulation result consists of several runs. Thus, different scenarios and output possibilities can be analyzed.

3.3 *Implementation of the CES*

The CES is implemented as a Node.js based web application that assists in creating, editing and simulating the models with various functions. In the background, the model is encoded as a graph including other information such as the events to be simulated and other simulation parameters as a JSON file. This file is simulated and evaluated via REST API in a separate backend. The tool thus provides an intuitive way to edit this JSON file before simulation and to visually display and further evaluate the simulation results. In addition to visualizing the graph, the tool also provides the ability to locate nodes on a map. In order to work on actual maps, the Leaflet framework with OpenStreetMap is used. Thus, nodes and edges, i.e., different objects or critical infrastructures, can be intuitively edited in the map view.

The internal transitions can also be edited for the individual nodes, which, depending on the use case, represent entire critical infrastructures down to individual objects (computer, door, etc.) and cyber components (database application, firewalls, etc.). These are grouped by their triggers in order to get an overview of which events a node reacts to, even in large models. For these triggers, individual transitions can then be defined in the detail tables, which specify to which risk states a node changes state with how large probabilities and what the resulting problem is. Models may or may not be processed in the tool environment from the beginning. For an easy integration of information on new models from various sources, Microsoft Excel files can be used.

In the simulation section, a simulation can be started for the current model and the result can be displayed. The first selection contains all nodes with the corresponding triggers to initiate a simulation. The simulation result usually consists of several individual simulation runs. Since the model can generate different results with several runs due to the probabilistic nature of the transitions, only one run would not be representative. Consequently, all simulation runs can be considered separately in the tool. For each run, a chronologically sorted table is displayed that lists all events with additional information. Such a table entry gives information about the logical time, affected nodes, handled events, new risk states and the name of the node that triggered the event. Next to the table, there is a visual representation of the model. In the model, one time step after the other can be viewed with matching coloring of the nodes.

3.3 Application of the CES in the Tool

The CES can be applied to better understand the possible effects of a blackout. Based on a graph model of the relevant components and their dependencies, the CES mimics the propagation of the problem through the network. This provides two key insights: first, how the event propagates, i.e., not just showing the direct effects to the neighboring nodes but also the indirect consequences which are often unknown. Second, it shows statistics for individual nodes that provide information about how frequently a node is affected and to which degree. Figure 2 shows an example of the simulation where the nodes are colored according to their state (green, amber, red).

Figure 2: Illustration of the simulation results for the BlackAUT Scenario

4. Main Findings from the Sectors

4.1. *Energy*

The crisis teams in the Austrian energy organizations are highly trained and can be activated very quickly. This results from a high professionalism and awareness of the operators towards the topic of a blackout. Additionally, there are communication channels within the operators and to national and international authorities in place. A restart after a blackout can begin about one hour after the initial incident. One main difficulty here is to maintain the balance between generation and consumption in the grid. Alternative energy sources, e.g., wind power or photovoltaic, that are mostly distributed across a wide area, are considered a challenge in this restart process, as their generation cannot be controlled.

4.2. *Mobility*

An organized shutdown of long-distance and regional trains is possible because emergency power supplies are available. Thus, the blocking of stations and consequently accumulations of people can be avoided to a large degree. Similar to the energy sector, separate communication channels within public transport service providers are available. However, a collapse of public transportation as well as individual traffic is to be expected the longer the duration of the blackout takes. As a direct implication, commuters and tourists are stranded in bigger cities; a respective concept to supply them with necessities (water, food, beds, etc.) is required. Not every single train station in Austria is equipped with emergency power. The fuel supply (Diesel) for the emergency power generators is a key aspect but might become critical the longer a blackout lasts.

4.3. *Communication*

The communication networks (mobile and data networks) will fail to a significant extent in the first 30 minutes of a blackout due to limited capacity of power supplies in the cell towers. In that context, one major problem is that emergency numbers cannot be reached any more. A main priority for the crisis teams is to keep the core components for the communications networks operational; in case they need to be restarted after a complete shutdown, the overall recovery time of the communication sector will be significantly increased.

4.4. *Health*

In the health sector, hospitals go into isolation mode in the event of a power outage and can sustain themselves for 72 hours using existing emergency generators. Key stations, e.g., intensive care, surgeries, etc., can be shut down in an orderly fashion, if required. The operational capacities will be largely focused on providing emergency care, e.g., from accidents due to the expected chaotic traffic situation. Additionally, treatments and surgeries that are not immediately necessary will be postponed. Furthermore, contamination and germs can occur via wastewater and thus the operation of wastewater disposal should be ensured by emergency-powered pumps.

4.5. *Finance*

In case of a blackout, bank subsidiaries are immediately closed, and no customer traffic is possible. Further, the subsidiaries follow an organized shutdown of their systems both at subsidiaries themselves as well as in the headquarters. This implies that there are no plans to supply cash for the duration of a blackout, as this is not feasible from a logistical point of view since supplying subsidiaries with new cash by means of appropriately secured transport is hardly possible due to traffic chaos and fuel shortages. Also, from a security point of view the supply of cash is not feasible since the physical safety of employees cannot be ensured.

4.6. *Food and Logistics*

A recent coordinated contingency plan among the major food retailers in Austria states that supermarkets are closed when a blackout occurs, and customers are not able to buy goods. The stores will the open the next day and packaged bags of food will be distributed to the population. Payment is intended to be made in cash, although, there is no more supply of cash to the population (see financial sector above). In agriculture, roughly 40% of farms have emergency power supply and thus can look after their livestock. However, a bottleneck is the transportation of goods and the adherence to the cold chain (e.g., for meat, milk etc.). In this context, the emergency power supply of large facilities, e.g., in meat processing, is considered as a big challenge.

In logistics, freight trains can be brought to the next station in an orderly manner since the national train operator has its own electricity generation and network to operator their tracks and signals. Nevertheless, other areas such as goods traffic are heavily affected by traffic problems and the drastically reduced fuel supply during a blackout. However, the capacities of logistic companies could be used to supply the population in remote areas or people with limited mobility with food and water.

4.7 *Society*

From the perspective of society, major feedback was that due to the crisis, the breakdown of communication networks and the associated uncertainty about the well-being of their own families, many employees will leave the workplace to take care of their families. This will also affect the voluntary emergency organizations (e.g., fire fighters, paramedics, nurses, etc.) with an estimated loss of around 50% of staff in the stationary and up to 75% in the mobile care domain.

Mobile and home care will be difficult to sustain in the event of a prolonged power outage due to lack of fuel and the chaotic traffic situation. Consequently, a triage approach would need to be applied in the days following the initial incident. In that context, the reduced staff capacities would make it even more difficult to manage important care activities such as mobile care or home care in the first phase.

One issue that has been particularly discussed was that a large number of people will be stuck in elevators as only a small number of elevators have emergency power supply. Due to the failure of the communication networks, it is also impossible to guarantee that the emergency calls in the elevators will work. Hence, several thousand people will be stuck, tying up firefighters for a long time.

Another important issue is that a significant proportion of people will be stranded in a city since they are either commuting with public transport or are visiting the city as tourists. Those people won't be able to get home particularly in the first phase of a blackout and will need to be taken care of, i.e., receiving food, drinks, and maybe even a place to sleep. Although hotels could have the capacities to take care of stranded people, the overall responsibilities are unclear.

4.8 *Authorities and Governmental Bodies*

The ministries that were involved in the strategic exercise had quite evolved emergency plans; the key personnel have been identified and notified and also necessary rotations for the people have been arranged. This also includes the regulations for deputies, because decision makers might not be reachable after a short period of time, but the formal chain of command needs to be maintained, e.g., when emergency decrees need to be issued quickly.

However, the governmental organizations are facing a dilemma: one the one hand, they need to make decisions quickly since most communication channels will be down after 30 minutes. On the other hand, an assessment of a blackout situation is roughly possible after one and a half hours. At that time, communication will be severely limited, and the traffic situation will make it even more difficult to organize crisis teams. Additionally, a lack of information provided to the public will increase the uncertainty in the population.

Maintaining the information flow to the population was also one of the main issues that have been discussed during the strategic exercise. After the breakdown of the communication networks, the national broadcasting has the only possibility to inform the population. In many countries such as Austria, the operator of the national broadcasting is not a government agency, must follow journalistic principles and is therefore not allowed to draw conclusions or give advice to the public on its own. The exchange between the ministries and the operator of national broadcasting takes place via one of the backup communication infrastructures, emergency radio or satellite telephones.

5. Implications on CI Resilience

Based on the findings from the individual sectors as described in the previous Section 4, several direct conclusions can be drawn from the results of the strategic exercise. First, one of the major aspects in such a complex crisis is communication and it needs to be addressed from a technology, personnel and content perspective. It is important to have a backup system (e.g., TETRA or satellite communication) but it is more important that people know who to contact and which detail of information to communicate. From a resilience perspective, this means that only focusing on a technological back-up won't increase a CI's resilience a lot. Rather, the people that will be using the system have to be included in the preparation and they need to know which are the necessary pieces of information that need to be transmitted to make the communication resilient.

Directly related to that, another finding from the exercise is that the human factor is a key aspect for the resilience of CIs. The relevant personnel in a crisis not only needs to be informed that they are relevant, but they also need to be available physically and mentally. Whenever it is possible to reduce the worries they might have (e.g., by bringing their families into the organization), they are more focused on solving the crisis. Consequently, this will also directly increase the resilience and therefore should be covered in each resilience plan. In that context, it is also important to keep relevant personnel trained for crisis situations. A continuous preparation increases the effectiveness of measure and the coordination among the people (particularly when mobile communication is no longer available).

Finally, the active exchange across CI domains that was fostered in the exercise was indicated as a major benefit of the event. The players got to know their counterparts in organizations from other sectors and establish valuable relations for a real crisis. This is of particular importance when considering the complex interdependencies among the CIs and the cascading effects stemming from them. Analysis tools such as the CES help to identify these effects and support the crisis teams in finding more effective measure. From a resilience perspective, this indicates that the more people from different domains have the chance to interact and communicate with each other before a crisis takes place (e.g., during cross-sectoral training events or large-scale exercises), the higher the resilience of the respective organization will be during a crisis.

6. Conclusion

In this paper, we presented the main findings from the strategic exercise BlackAUT in Austria. Based on a realistic scenario, almost 80 experts from eight CI sectors have discussed the first steps and important measures directly after a blackout takes place. The participants were able to test their emergency plans and, more importantly, exchange with experts from other sectors on strategies to counter that situation. Particularly, this cross-sectoral exchange was one of the main benefits they took away from the exercise. Additionally, the findings from the BlackAUT exercise directly led to strategies and concepts that will support CIs to increase their resilience against a blackout in the future. Hence, a next step would be to extend the identified concepts, discuss a way to integrate them into the preparation and emergency response processes and evaluate them together with the CI experts to estimate their effectiveness.

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References

Bigg, M. M. 2023. “How Russia’s War in Ukraine Has Unfolded, Month by Month.” *The New York Times*, 2023.

Coccolini, F., E. Cicuttin, C. Cremonini, D. Tartaglia, B. Viaggi, A. Kuriyama, E. Picetti, et al. 2021. “A Pandemic Recap: Lessons We Have Learned.” *World Journal of Emergency Surgery* 16 (1): 46.

Demirkıran, Y. 2023. “COVID-19 Pandemic-Related Supply Chain Disruptions and Impacts on the Global Economy.” In *Managing Inflation and Supply Chain Disruptions in the Global Economy*, edited by U. Akkucuk.

ENTSO-E. 2021. “Final Report on the Separation of the Continental Europe Synchroneous Area Separation on 08 January 2021.” ENTSO-E.

ETSI, European Telecommunications Standards Institute. 2016. “ETSI EN 300 392-2 V3.8.1 Terrestrial Trunked Radio (TETRA).”

European Council. 2023. “How EU Countries Are Addressing the Global Food Crisis.” European Council. 2023.

Fick, M., and N. Grover. 2023. “Why Europe’s Drug Shortages May Get Worse.” *Reuters*, 2023.

König, S., A.s Gouglidis, S. Rass, N. Adams, P. Smith, and D. Hutchison. 2020. “Analyzing Disaster-Induced Cascading Effects in Hybrid Critical Infrastructures: A Practical Approach.” In *Guide to Disaster-Resilient Communication Networks*, edited by J. Rak and D. Hutchison, 769–89. Comp. Comm. and Networks. Springer.

LaBelle, J., and A. M. Santacreu. 2022. “Global Supply Chain Disruptions and Inflation During the Covid-19 Pandemic.” SSRN Scholarly Paper. Rochester, NY.

Mavrokefalidis, D. 2022. “Germany and Austria Forge Plan to Fill up Gas Storage Facilities ‘More Quickly.’” Energy Live News. July 13, 2022.

Russon, M.-A. 2021. “The Cost of the Suez Canal Blockage.” *BBC News*, 2021, sec. Business.

Samaan, M., S. Deng, S. El Sirgany, M. Salem, and L. Said-Moorhouse. 2021. “Suez Canal Blocked by Traffic Jam after Massive Container Ship Runs Aground.” CNN. March 24, 2021.

Sanchez, R. 2021. “Austria Prepares Its Citizens for a Possible Large-Scale Blackout.” Spain’s News. 2021.

World Economic Forum. 2023. “Why Are There Medicine Shortages and What Is the Solution?” World Economic Forum. 2023.