Blackout: Challenges and Preparedness

Blackouts, which are large-scale and long-lasting power outages, can significantly impact society. Planning for their consequences requires continuous attention from the state, its citizens, and the private sector. Due to the catastrophic potential of a blackout and the expected extent of its damage, unpreparedness can be extremely costly.

By Leonard Schliesser

Neither Switzerland nor the EU are directly threatened by large-scale and prolonged power outages this winter; Ukraine is. The issues surrounding the security of power grids, energy supply, and energy security have received increased media and academic attention due to the recent crises as well as discussions about the energy transition. Nevertheless, the risk of a blackout continues to be largely underestimated in public discourse.

Preparing for such an extreme event is both possible and necessary. However, this requires a strategic and collaborative effort from all parts of society to conserve resources as well as the political will to think broadly and continuously about security. This analysis first describes what a blackout scenario entails and then examines the consequences before turning to preparedness measures that require the joint involvement of the state, citizens, and the private sector.

Enlarged view of Europe at night with a resolution of 750 meters per pixel, 2012.
Suomi National Polar-orbiting Partnership Satellite / NASA

Blackout Scenario

The blackout is not a regular power outage. It is the blacking out of parts, or all, of the transmission grid. Due to the interconnected and interdependent European power system, a blackout could cascade and extend to supra-regional or continental proportions. In the definition of the term "blackout", the factor of time rarely plays a role. However, the duration of the blackout is decisive for its possible catastrophic potential. As a possible extreme event that is widespread (regional to continental) and long-lasting (days to weeks), it deserves special attention and preparedness. As a scenario, the blackout can only be judged by its plausibility, not its likelihood.

A blackout scenario is plausible and has been outlined in academic literature and by government entities. In a 2011 analysis conducted by the Office of Technology Assessment at the German Bundestag, the magnitude of a blackout quickly overwhelms the state's emergency and civil protection services. Due to the dependence of critical infrastructures such as water, sewage treatment, telecommunication, and transportation on the uninterrupted flow of electricity, the supply of "existential provisions" quickly becomes almost impossible. Even the ability to supply the population with

only essential provisions, as well as safety and security might no longer be guaranteed.

As a low-probability, high-impact event, raising awareness and preparing for a blackout is fraught with difficulties. These difficulties stem from the hard-to-imagine scale of such an event and a multiplicity of cognitive biases. People are biased in recognizing the risk of cascading events whose consequences would grow exponentially – based on experience, they linearly project the future, ignoring the possibility of radical change (continuity bias). People are overly optimistic about their ability to handle a situation and prevail (optimism bias). These biases can also be reinforced by "groupthink" or the "bandwagoning" of individuals based on the predominant opinion of others in a group. In terms of a blackout scenario, this can be translated into perceived unlikeliness.

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Unlikely Event, but…

While there have been blackouts in Europe and globally in the past decades, there are too few comparable events to calculate a return interval or likelihood. Furthermore, although there have been repeated large-scale blackouts of entire European regions in recent decades (2003 Italy/Switzerland, 2006 Western Europe, 2024 Adriatic Sea), these were usually short-lived and resolved within hours. Due to their quick resolution, they did not escalate and cascade into a catastrophic extreme. The impact and damage they, therefore, caused was minimal.

In rare cases, such as in 2005 in Münsterland and 2014 in Slovakia, regional blackouts lasted more than 72 hours due to physical damage to the electricity transmission infrastructure. In these cases, however, massive external assistance was brought in to minimize the consequences of the blackout. Help from emergency services, civil protection, and the military arrived from regions not affected, and in the case of Slovakia, relief was also provided from other European countries.

The Münsterland blackout case further highlights the possibilistic nature of blackouts. The Federal German government performed a blackout exercise a year earlier, despite experts assuring its unlikeliness. A year later, however, the scenario became a reality. The blackout is also a concern for the Swiss Federal Office for Civil Protection (FOCP) and is included in the Swiss national risk analysis (see text box) as a "major" event. As a major rather than an extreme event, the empirical evidence (USA 2003, Italy 2003, Münsterland 2005, Slovakia 2014) shows that such a blackout scenario is still relatively manageable if resources can be pooled together and the provision of relief to the affected areas is possible.

The excellent energy supply in Europe contributes to perceiving the blackout as an unlikely event. The System Average Interruption Duration Index (SAIDI) measures the power supply's quality and describes the duration of average planned and unplanned power outages per person per year in minutes. In 2023, a Swiss citizen experienced around 18 minutes without power; for a German citizen, it was 10.4 minutes. According to these values, both countries have some of the highest-quality electricity supply in Europe.

Nevertheless, the electricity grid in Switzerland and Germany is under more significant strain at both the transmission and distribution grid. The efforts required to observe the five commandments of network security are increasing. These specifically involve balancing demand and generation, respecting the capacity limits of network assets to avoid overloading (for example, transformers and power lines), and maintaining the security principle of the N-1 redundancy. The latter means that at any time, the grid must be able to compensate an unexpected loss of a network element without breaching the grid components' operational limits. Should these commandments be breached, a seemingly minor event could escalate and cascade toward a catastrophic blackout.

Blackout Impact

A widespread and long-lasting blackout is a moment of (collective) disempowerment and demodernisation. Those affected are disempowered because they are deprived of the comforts of modern life. They are demodernised as they can no longer rely on modern utilities. Without electricity, household appliances do not work. Moreover, the water supply, the internet, mobile telephony, and petrol stations will fail to function.

While the event affects almost everyone equally, the vulnerabilities are distributed unequally. For example, people who are dependent on life-sustaining or life-sustaining technology, such as recent home ventilation or dialysis, are acutely at risk of dying when their backup batteries run out. Generally, children, the elderly, and those with medical conditions are more vulnerable than the average citizen.

In general, the time of infrastructural failure can be delayed by critical infrastructure operators if they are prepared. Likewise, preparedness measures in private households can provide alternatives for losing critical infrastructure services. Nevertheless, these reserves and stockpiles will eventually be exhausted.

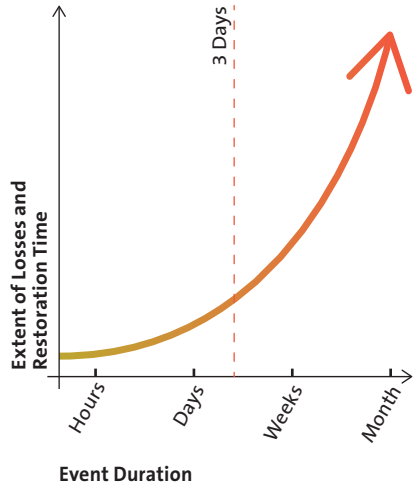
The longer a blackout lasts the greater the extent of the damage and the longer the recovery time following a sudden loss of "normality". The relationship between the extent of damage, recovery time, and event duration is generally exponential (see graph p.3). Due to infrastructural complexity and interactions, the exact course of the failure cascades is difficult to predict.

In the event of a large-scale and prolonged blackout, a critical threshold is set at 72 hours or three days. If the power supply cannot be restored within this period, a massive external relief effort is not possible, and with no other favorable circumstances, such as a high level of civic preparedness, the situation for those affected can be expected to deteriorate rapidly. In surveys, most Germans and Swiss say they have around three days' worth of food and water supplies. Beyond these supplies, however, they depend on functioning infrastructures or, if necessary, on aid deliveries.

2020 Swiss Scenario

In the national Swiss risk analysis *"Katastrophen und nationale Notlagen Schweiz"* from 2020, the major scenario, "power outage", describes a hypothetical scenario with 0.8–1.5 million people affected. They have no electricity for two days or up to four days in the worst-affected area. The event takes place in the summer. Due to physical damage to the grid infrastructure, the successive recovery takes days to weeks.

Losses over Time



Source: Figure designed by the author

It is commonly said that a society is only three days or nine meals away from anarchy. If food, drinking water, medicines, and infant formula become scarce, social cohesion can quickly deteriorate. The history of North American blackouts shows that the general state of society plays a decisive role in how quickly such a situation escalates. If social cohesion is good, extreme situations are more bearable, and the effects are usually dealt with constructively. If social cohesion is weakened or panic spreads, situations escalate faster and more violently.

Apart from the state of society, the three-day mark is also the period for which most operators of critical infrastructures should have made provisions and should at least be able to guarantee emergency operation. If a blackout lasts longer and no help arrives from unaffected areas, the failures of interdependent critical infrastructures reinforce each other and can even lead to irreversible damage. A prolonged water supply and disposal failure due to a blackout, for example, degrades hygiene, especially in cities, and thus further burdens a healthcare system that only operates in emergency mode. The spread of infectious diseases must also be considered during a blackout, illustrating the possible cascading second- and third-order consequences.

The sheer scale of a blackout complicates the relief and recovery efforts of emergency services, the supporting military, and critical infrastructure operators, all of which will be overloaded with the task of providing emergency relief for the population and themselves, including the emergency operation of some of the critical infrastructure. The population, therefore, may not be able to rely on government agencies' immediate and individual help and support.

Preparedness

The expected extent of damages from a large-scale and long-lasting blackout is extreme and represents an unlikely but possible scenario. Precisely because of this possibility, the state and critical infrastructure operators, individual citizens, and the private sector should be prepared.

Preparedness is like insurance, requiring an up-front and sustained investment. Yet, unlike insurance, preparedness can provide tangible relief capacities and capabilities during an event, allowing for a mitigation of its effects rather than aiding only in recovery.

Preparedness aims to minimize the impact of plausible and possible scenarios, such as a blackout. Preparedness should allow the state to continuously provide at least a minimal level of essential supplies to its population, thus ensuring their ability to survive even in extreme situations, such as a blackout. For the private sector, including the critical infrastructure operators, preparedness extends their point of failure. Preparedness gives them time to reduce and shut down their systems in a coordinated manner or to minimize the impact of an event generally. Individual and private sector preparedness reduces the pressure on the state's emergency, civil protection, and military to provide relief.

Today, preparedness for the blackout scenario is fragmented, and security is a co-production between the state, private sector, and citizens. Preparedness is organized via an incomplete mesh of binding laws, legislation, recommendations, and international standards representing minimum requirements. Switzerland, for example, aims to harden its mobile telecommunications against blackouts (for up to 72 hours), while clear and binding standards are missing for other sectors. Furthermore, in following similar "all-hazard approaches", the state prepares by conducting risk analysis and scenario modeling, stockpiling (for example, Swiss Federal Office for National Economic Supply, German National Petroleum Stockpiling Agency), and civil protection forces.

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Thorough preparedness is also important for emergency services, employees in critical infrastructures, the military, and civil servants. The population relies on their willingness to maintain emergency operations, especially over extended periods. This can only happen if the staff and their families have prepared. If they are unprepared, it can be assumed that the ability of these organizations to work and cope will rapidly decline due to staff shortages. The cold-start file drawn up by the German Armed Forces can provide advice, orientation, and guidelines – even to civilian personnel – for preparing for more extended deployments during a crisis.

The crises of recent years have shown that extreme scenarios are possible but that it is also worth being prepared for smaller, more localized events. For individual citizens, this means making active provisions. In addition to material stockpiles such as emergency supplies and equipment, this should include procedures, agreements, and knowledge building. Initial advice on emergency supplies and preparations can be found on the Swiss Federal Office for National Supply websites and the German Federal Office of Civil Protection, among others. Taking precautions is not scaremongering; it is preparing soberly for all possibilities by thinking through different scenarios and "what-if" situations.

The energy transition also opens new opportunities. The possibility of taking over one's own power supply has become feasible with the falling cost of solar energy, particularly home storage systems. However, solar systems are currently useless in the event of a power failure, as they switch off for safety reasons as soon as the public power grid goes dark. Through adapting for island- and black-start capable solar systems the state, private citizens, and the private sector could become better prepared. This requires specific grid disconnection switches, island inverters, and, ideally, a battery system that, once empty, can recharge and turn back on as soon as the sun is up again. In a blackout, these systems would still be able to operate and could support other auxiliary power systems and "emergency meeting points" or "emergency lighthouses".

Outlook

As a large-scale and long-lasting power failure, the blackout is a "maximum credible event". No probability for such an event can be calculated, but it is within the realms of possibility. As our modern society increasingly depends on functioning critical infrastructures such as the power grid, we are reflexively becoming more vulnerable. The growing systemic complexity increases the possibility that internal or external events could lead to escalating or cascading failure. The more dependent a society is on a functioning power supply, the more catastrophic the consequences of a potential blackout are. A long-term and widespread power supply failure poses an existential and catastrophic threat to the state, its citizens, and the private sector.

Due to the potential extent of damage, the blackout scenario should not be neglected. It is the shared responsibility of the state, the private sector, and citizens to prepare for extreme events such as a blackout. Although the "low-probability, high-impact" scenario may initially seem overwhelming, a sober, honest analysis of its consequences offers an initial starting point.

For Switzerland, as for other countries, the potentially catastrophic impact of a blackout cannot be compensated by insurance but requires preparedness. While Switzerland and Germany might be somewhat prepared for "major" events, their preparedness for potentially catastrophic events, such as a blackout, can be improved. More sensibilization could counteract underestimating the risk from blackouts and build more acceptance of preparedness measures.

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Due to the multiple geopolitical crises and the simultaneous need to adapt to climate change, there is a window of opportunity to increase preparedness efforts for extreme events, such as the blackout.

For more on perspectives on socio-technical resilience and disaster preparedness, see CSS core theme page.

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