TAB

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AT THE GERMAN BUNDESTAG

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Hazards and vulnerability in modern societies – using the example of a large-scale outage in the electricity supply

Summary

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SUMMARY

In today's modern and highly technical society, which is characterized by a division of labor, the population is supplied with goods and services it needs by means of a highly developed and closely linked network of components constituting our critical infrastructure. These include information technology and telecommunications, transportation and traffic, energy supply, and the health care system. The internal complexity and great interdependence of these components make them extremely vulnerable. It has not just been in the past decade that terror attacks, natural disasters, and extremely grave accidents have made apparent which far-reaching consequences the impairment of our critical infrastructure can have for our entire society.

Due to the fact that electrically powered equipment has almost completely penetrated the environments in which we live and work, the consequences of *a prolonged and widespread power outage* would amount to a particularly serious hazardous situation. It would affect each component of our critical infrastructure, and it would be nearly impossible to prevent a collapse of all of society. Despite the potential impact of these dangers and disasters, the social awareness of these risks is still in its infancy.

The office of Technology Assessment at the German Bundestag (TAB) was commissioned of the Committee on Education, Research, and Technology Assessment to analyze the consequences of a prolonged and widespread power outage. Another objective was to demonstrate the possibilities and the limitations of the national system of disaster management to cope with such a large-scale emergency.

DISASTER MANAGEMENT IN GERMANY

The highly developed German system of disaster management is characterized by the division of tasks between the federal and state governments that is anchored in the German Constitution. A consequence of the fact that the responsibility for disaster managment is shared by the federal government and the states, with the former responsible for civil protection and the latter for disaster protection in peacetime, is a field of policy that consists of several tiers and numerous governmental bodies (federal, state, county, municipal), relief organizations, and support groups.

Numerous laws and regulations define the fields of responsiblity and possible measures. An important foundation for operative disaster management is the federal law on civil protection and disaster relief (*Gesetz über den Zivilschutz und die Katastrophenhilfe des Bundes*). Its latest version, from July 29, 2009, attempts to achieve a closer integration of federal and state resources. The federal government supplements the states' structures for disaster relief in numerous areas. At the same time, the states' institutions and staffs can also be employed to defend against dangers to national defense. A number of laws featuring protective and preventive measures provide extensive options for managing scarce structures, goods, and services, for example in the areas of nutrition, traffic, postal services, and telecommunications. Also of particular importance are the state laws regulating emergency assistance and civil defense. They regulate in particular the organization and tasks of the civil defense authorities and list the measures that can be taken in response to an emergency. Since an estimated 80% of the components of our critical infrastructures are privately owned, it is desirable for there to be a strong security partnership between government and companies.

Also relevant might be Germany's membership in the European Union's (EU) civil protection mechanism, which was established in 2002 to promote cooperation in emergency responses within the EU. Germany has furthermore concluded numerous bilateral agreements on disaster relief.

The initial response to the consequences of a power outage is the task of the local authorities, institutions, and organizations. Due to the situation (going beyond the regional level) and its development (prolonged with significant consequences), gradually the next higher levels up to federal ministries become active. Responsibility thus resides with the higher disaster protection authorities, who assign the (operative) execution of the necessary measures to the lower (local) disaster protection authorities.

To coordinate this heterogeneous constellation of actors with their different styles of leadership and communication in a widespread and prolonged power outage, a crisis team has to be created at every level (municipal, state, and federal). Coordination across state borders is necessary to harmonize the different activities of relief organizations (e.g., the German branch of the Red Cross, the Maltese Aid Service, and fire departments) and of support organizations (The Federal Agency for Technical Relief (THW), the federal police, and the German army). It is presumably inevitable that at least the coordinating activities will be at the federal level.

To this end, there are various systems and procedures for obtaining, processing, and distributing information. One example is the Internet-based German Emergency Preparedness Information System (deNIS), which serves to provide information to the public (deNIS I) and to directly manage information about major disasters (deNIS II plus). Another is a satellite-based warning system (SatWaS), which makes it possible for warnings to be distributed nationwide to all the situation rooms, civil protection liaison offices, radio broadcasters, and other media. The joint reporting and incident centre (GMLZ) of the federal government and states essentially serves to establish a uniform overview of the situation.

THE CONSEQUENCES OF A PROLONGED AND WIDESPREAD POWER OUTAGE

The possible causes of a prolonged and multiregional power outage include technical and human failure, criminal or terrorist action, an epidemic, a pandemic, or an extreme weather event. Many expect that the probability of an outage will increase in the future, for example because of the increased danger of a grid breakdown caused by a terrorist attack or climate-related extreme weather events. On the basis of experience gained from previous national and international power outages, substantial damage can be expected. Although previous outages did not last longer than a few days, some have caused expenses estimated at several billion US dollars. The damages caused by a multiweek power outage are expected to be several magnitudes higher.

The dependence of the different sectors of the critical infrastructure on a continuous power supply is comprehensive. The consequences of a scenario of a power outage that lasts at least two weeks and affects an area made up of several German states would come close to being a catastrophe. We will describe this in detail in the following section.

INFORMATION TECHNOLOGY AND TELECOMMUNICATION

The consequences of a widespread and prolonged power outage for information technology and telecommunications would have to be characterized as dramatic. Some of the telecommunications and data services would be lost immediately, and the rest would be after just a few days.

In the complex topology of information and telecommunications networks, there are different degrees of dependence on an external power supply. In the

landline telephone networks, (digital) terminal devices and the customer connection are lost immediately, followed by the local exchanges. In the mobile phone networks, the terminal devices are less affected, which might be able to function for several days if they are loaded and used in moderation, than the base stations that make it possible for anyone to dial into the network. As a result of the increased volume of calls, these stations are usually overloaded within a few minutes, or they are lost entirely because the emergency power supply is only available short term. The mass media are of special significance for communication with the public during a crisis. Some newspaper publishers and printers have emergency power systems, enabling them to contribute to providing information to the public to a certain degree. The public broadcasting stations are better prepared for a power outage and can continue broadcasting. Yet without electricity the public will not be able to view any programs on their televisions. In the event of a crisis, radio will consequently become one of the most important channels for providing the public with information since there are millions of radios that run on standard or rechargeable batteries.

For communication between the authorities, no one estimate can be made that is equally accurate for all participants and networks. For example, the federal government's communication networks, such as the information network Berlin–Bonn (IVBB) and the information network of the federal government (IVBV), can continue functioning as a rule for two to three days by using emergency power generators. This is insufficient however to sustain communication on a broad scale.

Vulnerability and coping capacities

The capacities of the mobile radio technology and of the landline means of communication of the army, the Federal Agency for Technical Relief, and the telecommunications companies that are equipped with emergency power sources are presumably primarily planned to meet their own needs. They are not designed for guaranteeing the ability of the authorities, the public, and companies to communicate over a broad area.

Just the first few days of a prolonged and widespread power outage will show that the telecommunications providers will not be able to provide the minimal level of telecommunications services that is planned and legally required for an emergency. The reserve capacities maintained for central communication institutions, such as uninterrupted power supply (UPS) and emergency power generation, will be exhausted after just a few hours or days or have no effect because terminal devices will have stopped working.

Thus the possibility for the public to communicate actively and in dialogue by means of telephone and Internet will be lost within a very short period of time. The multitude of electrically powered network nodes, switching stations, and radio antennas for landline and mobile phone services and use of the Internet means that their widespread reactivation will be practically impossible. This would require thousands of storage batteries to be charged and fuel tanks to be supplied. At the very most, it is conceivable that there is a partial reactivation of individual components of the infrastructure at the fringes of the area affected by the power outage. The loss of the communications infrastructure will also affect the authorities and emergency workers, who will demand priority in using any remaining or locally reestablished possibilities for communication.

Currently it is presumably economically and technically impossible to ensure sustainable functioning of the communications networks that would make it possible to maintain a stable and comprehensive range of services for customers. As far as is visible, no plans have been developed for at least offering a specified minimum level of service if there is a prolonged power outage.

The need for information and action

The above evaluation of the vulnerability of the information technology and telecommunications sector and of the capacities at its disposal for coping with a prolonged and widespread power outage is fraught with numerous uncertainties. There is thus obviously a need for further information and research.

> In principle, the minimum level of communication needed in the situation described here must be evaluated, in order to be able to then determine the technical boundary conditions for different levels of service.The respective subordinate issues would include an estimate of the customary volume of the communication and data streams and the determination of the redundancies that are present and of the network segments and nodes that are critical for its operation.
> Furthermore, the existing plans for emergency service in the field of information technology and telecommunications could be examined and new, improved approaches developed. To achieve this, it would be necessary to prepare an overview of the emergency power supplies available to the various communications networks and services. The same is true for the capacities and usage options of the emergency standby telecommunications systems that can be employed on a mobile basis and supplied with emergency power. This would make it possible to specify the technical parameters that are necessary for maintaining crisis-related communication in a network that is limited to larger cities and central nodes.

- Moreover, possible adjustments to the legally prescribed preparedness measures are to be examined. The goal of such legal analyses should be to identify approaches for strengthening the resilience of the information technology and telecommunications sector during a power outage.
- Finally, prospective analyses of the sector's underlying conditions should be considered. Topics should include technological innovation (e.g., electromobility, intelligent networks) as well as political (e.g., liberalization, privatization, and deregulation), economic (e.g., the multitude of competing providers, the rapid changes in products), and sociocultural changes (e.g., modified forms of communication and the use of media by the public). To be studied in this context would be whether research and development processes could be sponsored in order to develop applications of information technology and telecommunications that are less dependent on the power grid.

TRANSPORTATION AND TRAFFIC

In the transportation and traffic sector, the electrically powered elements of the infrastructure related to movement on streets, tracks, in the air or water are lost immediately or within a few hours. This affects both the means of transportation and the infrastructure as well as the control and organization of the respective mode of transportation. The abrupt stoppage of rail traffic and the blockage of motorized private and public transportation in heavily populated areas will create hot spots of emergencies. While the operation of harbors will almost completely come to a halt, that of airports proves to be relatively robust and sustainable.

Immediately after a power outage, *road traffic* is chaotic, particularly in large cities. Intersections are blocked, just as are numerous tunnels and gates. Long backlogs of traffic are the result. There are numerous accidents, some causing injuries and fatalities. It is very difficult for emergency services to do their tasks properly, such as providing care and transportation for the injured or fighting fires. Since most service stations are closed, an increasing number of vehicles have to stop. The amount of motorized personal traffic declines rapidly after the first 24 hours. Because of the shortage of fuel, it is at most possible to maintain a rudimentary form of local public transportation. Traffic on major highways is less affected over the entire period of the power outage.

A power outage abruptly stops electrically powered rail traffic. Many people are trapped in subways and trains. The functioning of control centers, interlockings,

and safety systems are drastically limited. The impairment of *rail traffic* poses a massive obstruction to people's mobility.

In the area of *air transportation*, emergency standby systems and fuel reserves ensure the basic operation of the larger airports for the entire period of the power outage. A limited number of take-offs and landings can ake place.

The extensive consequences of a power outage for shipping are particularly evident in harbors. There the power outage interrupts the loading and unloading of ships since, for example, the conveyer belts and the electrically powered cranes no longer operate. All processes come to a standstill, the entire operation of the harbor comes to a halt, and there are backlogs of goods. While the effect of the stoppage at the inland harbors is primarily regional, the stoppage at seaports is felt throughout Germany and even all over Europe since they are transshipment points for national and international goods.

Vulnerability and coping capacities

The consequences of a power outage occur abruptly and are massive. Substantial restrictions of mobility and of the transportation of goods result from numerous accidents, stranded trains and subways, rerouted flights, and backlogs of trucks and goods in harbors. The backlogs and accidents in road traffic lead to chaotic conditions, particularly in metropolitan and urban areas. Fire fighting, emergency rescues, and ambulance services are massively obstructed, as are efforts to ensure the emergency power supply and numerous other measures for coping with the general situation. Since all service stations are out of order, there is a shortage of fuel for emergency vehicles. There is furthermore the threat of substantial shortages in the supply of, for example, food and medical items to the public.

The authorities and relief organizations are consequently confronted by complex challenges. Locally, the supply of fuel to emergency personel, emergency power generators, and particularly sensitive components of the critical infrastructure (such as emergency control centers, water works, and hospitals) must be arranged. It is necessary for important road and rail arteries to be cleared, for some to be closed, and for some traffic to be banned, to ensure that these routes are cleared and kept free for emergency workers. Finally, it is important to establish supraregional axes of transportation and make transportation capacities available in order to make it possible to supply essential goods, in particular by rail. To achieve this, the relevant authorities have to determine during the course of the power outage, in collaboration with logistic companies and rail operators,

which routes should be kept open and which measures have to be implemented to ensure emergency operation.

In the air traffic subsector, some routine take-offs and landings can take place as a result of an extensive emergency power supply. The German Air Navigation Services will, however, quickly reduce or suspend air movement, and the airlines will reroute flights into regions not affected by the power outage. Basic operations must be maintained in airports, such as maintaining security on their grounds and providing necessities to waiting passengers. Additionally, it is being investigatet whether flights, perhaps under visual flight conditions, can be maintained to provide supplies to the people affected.

In view of the massive obstructions at the inland harbors and seaports in the water subsector, the respective harbor authorities will attempt to reduce activity at the harbors and to resolve backlogs. They will also contact ships and the unaffected harbors in Germany and Europe and communicate with the responsible authorities in order to reroute the transportation of goods and have it transported by road or rail. The fire departments and the Federal Agency for Technical Relief may be employed, for example to erect mobile aggregates to establish a temporary power supply or to act in case there are dangerous situations in connection with hazardous goods. The failure of information and communications technology will cause substantial difficulties in this connection.

WATER SUPPLY AND SEWAGE DISPOSAL

Nutritionally water cannot be replaced, and it is a guarantee for a minimum standard of hygiene. As such, it is a resource that is essential for satisfying basic human needs. Water is also of major significance for business, trade, industry, and public facilities. Without electricity, it becomes impossible after a very short period of time to operate the water infrastructure systems. The consequences of their failure, especially for supplying the public with potable water, would be catastrophic.

In the field of *water supply*, electric power is necessary to raise, process, and distribute water. Electrically powered pumps are especially critical for ensuring each of these functions. If they fail, it is no longer possible to pump ground water, and getting water from surface sources is then at least strongly obstructed. Furthermore, processing plants and the distribution system can only be fed if there is a natural gradient (i. e., a difference in elevations), so that significantly less water can be made available and higher regions cannot be supplied at all.

The reduced supply of water also affects s*ewage disposal*. For example, the amount of waste water itself declines, and its composition changes. There is consequently a danger that the highly concentrated sewage might lead to the creation of deposits in the sewage system and resultin blockages and odors. Since the pumps that raise sewage to a higher elevation are frequently not backed up by emergency power generators, new sewage can escape from the pipes. Sewage treatment plants as a rule do have emergency power generators that can support full-load operation. If the emergency power generators fail, the sewage will have to be diverted from the treatment plants and fed into surface waters. This results in immediate damage of the environment.

An interruption of the water supply has a comprehensive effect on *home* life. Customary body care cannot be carried out, and in the majority of households there is no warm water. The preparation of food and drinks is strongly limited, and it is impossible to flush a toilet. We have to expect these problems to become more severe as the length of the power outage increases. Soon people will not have any clean clothes, and hygiene becomes precarious. Toilets are clogged. There is a growing danger that illnesses will spread. Another, less immediate consequence of the power outage is an increasing risk of fires. They may occur in industry, e.g., as a consequence of the loss of cooling systems and process control systems, and in households as a result of attempts to cook, heat, or make light without any electricity. A consequence of the reduced water supply or its complete loss is that fire fighting is obstructed. This raises the danger in cities – because of the population density – that fires might spread to blocks of houses or possibly even to entire districts of cities.

Vulnerability and coping capacities

The consequences of a power outage for the water infrastructure systems in Germany will vary greatly by location. Yet it can be said that a large number of the reservoirs for freshwater that are presently connected to the networks and available atplants as well as the emergency power capacity is at most designed to bridge supply disturbances lasting less than a few hours.

To cope with the immediate and mediate consequences of a power outage, measures are needed that entail great efforts in terms of staff, organization, time, and material. This includes supplying the public by resorting to emergency wells (5.200 in Germany) and the use of mobile sanitary vehicles. Further steps concern the maintenance of the operational status of the supply and sewage networks at a low level of performance through the use of stop-gap measures and the functional replacement of individual power-dependent components and

plants. This depends in particular on the mobile use of emergency power generators. They have to be operated at changing locations, such as with lifting systems in the sewage system or with the electrical pumps responsible for supplying water. As long as an emergency power supply is available, it is possible to maintain the supply of water at a limited level of performance, given limited availability in the water system, and/or with a reduced quality of water. The water can then be made drinkable by consumers, such as by the use of sterilization agents. It is doubtful however whether these measures for coping with the catastrophe can be sustained for a longer period of time, particularly in view of the limited capacities of emergency power generators.

The need for information and action

In view of the paramount significance of the water infrastructure systems for the supply of the public, the security plans should be further developed. It is true that the regulations of the German Technical and Scientific Association for Gas and Water (*Deutscher Verband für das Gas- und Wasserfach*, DVGW) already contain numerous elements of the potable water plan of the World Health Organization. Yet since the aspect of risk evaluation has hardly been implemented in the areas of water raising, water processing, water storage, and water distribution, there is a need for analyses to make it possible to set priorities regarding the measures to be developed. With regard to the existing analyses of vulnerability, it can be said that the consequences of a prolonged power outage on the water infrastructure have hardly been studied using models. Those models could prove to be particularly suitable that conceive of the water infrastructure systems as one component of a mesh of interacting infrastructure systems. Their results could be of assistance in developing a preventive disaster management system.

The aspects of vulnerability and resilience should be given more prominence in plans for future systems. For example, in the area of *sewage treatment plants*, research and development are already being increasingly pursued with the goal of increasing energy efficiency and the local production of energy using biogas electricity production in combined heat and power plants (CHP). If there is a continous growth in the field, even with today's technology, an autarkic supply of conenery is conceivable. Decentralized power generation that is viable as an island network could constitute a contribution to an improved resilience in this sector after a power outage. The goal of such systems should be to enable sewage treatment plants to operate independently and safely in an uncomplicated manner. Energy autarky and island network viability should be central elements of the infrastructure to be achieved by water works.

In the short term there is a need for improvements in *nonsystemic* security plans to be carried out. For example, there are substantial deficits in sewage treatment plants with regard to their being equipped with systems for uninterrupted power supply, to emergency power generators, and to being supplied with fuel (e.g., diesel) for a longer period of time.

In the area of *fire protection*, there are opportunities to reduce vulnerability, such as by means of the development and utilization of new technologies that, by improving the efficiency in the use of water to fight a fire, reduce the amount of water needed.

FOOD

The food sector comprises the complex supply chain from the production of raw materials to the consumer's purchase of finished products. As a consequence of a power outage, the supply of food will be significantly disturbed. Making food available as it is needed and ensuring its distribution to the public will be primary tasks of the authorities. Not only will the survival of numerous people depend on their success in this endeavor, but also the maintenance of public safety.

Within the first few days, the lack of air conditioning and ventilation will lead to disruptions in the greenhouse production of fruit and vegetables and in the ability to store goods. With regard to animals, the technical functions in the stable that are important for the life and health of animals will initially be maintained by (prescribed) emergency power generators. The failure of further technology in the stable and milking systems will however affect the well being of the animals and possibly result in bovine mastitis in dairy cattle and subsequently lead to their death. As soon as the fuel supply of the emergency power generators is exhausted, which is usually after 24 hours, the animals will suffer from the lack of food, water, and fresh air that cannot be provided manually. Most problematic is the capacity to supply stocks of pigs and chickens numbering several thousand animals. In such circumstances, the animals will often not even survive the first few hours.

Most of the food processing industry will immediately stop working, interrupting the supply to commercial warehouses. Although these warehouses keep very large supplies of food products, they are primarily in the form of frozen foods. Very few of the warehouses will be able to maintain the necessary supply of emergency power for longer than two days. This will cause a massive disruption

in the turnover of goods and thus in the supply of stores. The shelves of the stores will be emptied within a few days.

VULNERABILITY AND COPING CAPACITIES

Confronted by the increased demand, the food trade proves to be the weakest link in the food supply chain. Serious shortages in the supply of food can be expected after just a few days. In pursuing the goal of overcoming the catastrophe, the authorities could for example decide on the following measures:

> On the basis of the Food Provision Act (*Ernährungsvorsorgegesetz*), the rationed release of the stock of the Civilian Emergency Reserve and the Federal Grain Reserve is decided. These reserves will be further processed, where possible, and distributed via establishments known as collective provision institutions (or soup kitchens).
> On the basis of the Transportation Availability Act (*Verkehrsleistungsgesetz*), transportation capacities are made available. Supplementing this, commercial businesses initiate an intensified transregional supply of the region affected.
> In selected food stores, food distribution points are created. These are equipped with emergency generators and taken into consideration in the allocation of fuel. The respective companies coordinate the necessary logistics with the authorities.
> Since a large portion of the population does not have any opportunity to prepare a warm meal, communal kitchens are created, such as by the Federal Agency for Technical Relief, the German Red Cross, and the German army, and warm meals are made available.

Despite the greatest efforts, it is very probable that distribution of food as needed throughout the area affected will be very unsatisfactory. Communication between central offices, warehouses, and stores will be significantly obstructed by the loss of telecommunications connections. The authorities' management of the catastrophe will be significantly limited by the lack of a commonly shared understanding of the situation, drastically obstructing the multistate planning and coordination of measures.

The need for information and action

Starting points for precautionary measures to strengthen the resilience of this sector would above all be the main regional commercial warehouses and possi-

bly selected stores. They could be equipped with robust emergency power generators. If current feed points are available, an option would be to use mobile generatorsbut its functioning would have to be guaranteed for a longer period of time. Another possible option would be for the central warehouses to be supplied by their own locally generated power using regenerative sources of energy, which would create a high degree of autarky.

Public–private security partnerships could be examined as a means to strengthening the resilience of this sector. The starting point could for example be a plan in which the attempt is made within the framework of an agreement with commercial businesses to create a disasterproof store for every 10.000 inhabitants and a food warehouse in every state that would be equipped with comprehensive stocks of food, means of communication, and emergency power generators. It would make sense to consider the creation of decentralized power generators at appropriate locations that are capable of islanding and that use regenerative sources of energy. They would be listed in a central database, with whose help the authorities and companies could coordinate deliveries in the case of a catastrophe.

HEALTH CARE SYSTEM

Nearly all institutions providing medical and pharmaceutical care to the public are directly dependent on electricity. The health care system, which is organized in a decentralized manner and based strongly on a division of labor, can only withstand the consequences of a power outage for a short period of time. Even if intensive use was made of regional capacities for providing assistance, within a week, the situation deteriorates to such a degree that we can assume there would be a broad breakdown in the supply of medical and pharmaceutical care.

After just 24 hours the functioning of the health care system will be significantly impaired. While emergency power generators make it possible for hospitals to maintain limited operation, at least some dialysis centers, homes for the aged, and nursing homes will have to be vacated [evacuated] and close some departments. Most doctor's offices and pharmacies cannot continue operation without electricity and will close.

A shortage of pharmaceuticals will develop in the course of the first week since the production and distribution of pharmaceutical products will not be possible in the region affected by the power outage. The stocks of hospitals and of the pharmacies that remain open will become increasingly incomplete. In particular,

pharmaceuticals that are perishable will only be available – if at all – in hospitals. The shortages of insulin, banked blood, and dialysis fluids will have a dramatic impact.

Vulnerability and coping capacities

After just a few days, the decentrally structured sector is swamped in its efforts to cope with the consequences of the power outage. The operational capacity of the health care sector will be reduced not only by the increasing depletion of its internal capacities, but also by the failure of other facets of the critical infrastructure. Deficits in the supply of, for example, water, food, and communication and transportation services will intensify thedecrease in the quantity and quality of medical care.

The emergency services can only be employed to a limited extent for transporting and evacuating people. The impaired communications infrastructure largely cuts them off from emergency calls from the public. The coordination of assignments also becomes more difficult , if not impossible. Problems also result from the dwindling availability of fuel. Preclinical medical care is thus massively obstructed.

There is a threat that the care primarily provided by hospitals will collapse. Some hospitals will initially be able to maintain a limited capacity to provide care, which makes them the core nodes of medical care. They usually have a certain stock of medication and sufficient staff and fuel. The medical staff in outpatient care will support the work of the hospitals. Yet this relatively good status will lead patients to resort to them when other institutions (such as homes for the aged, nursing homes, and dialysis centers) have to close. This will raise the threat that the remaining capacities will collapse. Although the emergency plans of hospitals envisage the release of as many patients as possible, the catastrophic conditions outside the hospitals mean that only those patients can be released that can take care of themselves on their own. The first aid provided by the German army as part of the Civilian–Military Cooperation will provide at most local relief.

At the latest by the end of the first week, a catastrophe can be expected, that is, damage to the health and even the death of a large number of people as well as a situation that cannot be handled by the means and personnel available locally and regionally. The provision of medical and pharmaceutical care is no longer possible without the input of additional medical supplies, infrastructure components, and trained personnel from the outside.

The need for information and action

As anchors in the system providing medical care to the public, hospitals play a pivotal role. Although we can attest them a certain amount of robustness, it will not suffice to compensate for the loss of all the other institutions, in particular of decentralized out-patient care. Hence, it is necessary to ensure a continuous supply of fuel for the existing emergency power generators. Two means to achieve this to a limited extent are the storage of fuel on the grounds and agreements with suppliers (who will probably hardly be able to provide deliveries given the general consequences of a power outage). [Feeding points for an emergency power supply should be part of planning as a matter of principle. Finally, the civil defense authorities should determine that hospitals are entitled to be given priority in the allocation of fuel. A more far-reaching starting point is the creation of as high a degree of energy self-sufficiency and islanding as possible, such as has already been achieved to some extent in the context of steps toward environmental protection and measures to lower the consumption of energy. To ensure the supply of potable water to hospitals, the possibilities for processing and transporting water from emergency wells to hospitals or auxiliary hospitals should be examined more intensely.

Increased stockpiling of medical supplies could constitute a significant contribution to strengthening their resilience. Further exceptions in the German Medicines Act (*Arzneimittelgesetz*) might also be considered for emergencies and catastrophes. The goal would have to be practical regulations for a prolonged emergency and for supplying the public. Finally, it appears to be essential for manufacturers, wholesalers, and pharmacies to be included in the disaster response. The precondition would be that these actors would have to take precautionary measures to maintain production and distribution in the case of a prolonger power outage. The (legal) form in which this could be implemented would have to be examined.

FINANCIAL SERVICES

Even in a widespread and prolonged power outage, individual segments of the financial services system will prove to be relatively robust. According to estimates of experts, the data traffic and payment transactions between banks, the clearing houses, and the exchanges are guaranteed for a long time by emergency power sources and could also be moved to an unaffected area. The same is true of data storage and other critical business processes. The measures planned in the exchanges for an emergency are adequate from a technical, staffing, and

organizational perspective to ensure operation essentially throughout the entire length of the power outage.

Vulnerability and coping capacities

Less robust are the paths of communication between the banks, clearing houses, and trading centers on the one hand and the persons and companies seeking financial services on the other. Because of the failure of the telephone network and the Internet, it will be impossible after just a short period of time to carry out any financial transactions. Many of the banks that stay open after the power outage begins will close after several days. Since automatic teller machines (cash points) also do not function, there is a threat that the supply of cash to the public will collapse. It can be assumed that this and the failure of the means for making electronic payments in stores and banks will with time lead to resentment and some aggressive altercations since the public cannot find any possibilities for making payments.

The Achilles heel of the sector proves to be the lack of possibilities for making payments electronically and the public's dwindling supply of cash. This enhances the public's uncertainty. People fear that they will not be able to obtain food and other essential goods. It thus becomes increasingly important for customers to be informed and for there to be appropriate communication about risks, which should be made in consultation with the civil defense authorities.

The need for information and action

The German Central Bank is faced with the task, in cooperation with other organizations and emergency workers in civil defense, to ensure at least the rudimentary supply of cash to the public. Banks must be a part of this. A comprehensive organizational and logistics plan for the delivery and distribution of the cash would be necessary. An extended safety plan would also have to be developed since it is questionable whether the private security providers could adequately safeguard the intensive delivery of cash.

CASE STUDY »PRISONS«

Emergency power generators will enable prisons to initially maintain the primary functions of their operation. These functions are primarily the safekeeping of prisoners and their provision with essentials (lighting, ventilation, heating). The first phase of the power outage is the most chaotic. Particularly problematic is a

power outage that takes place in the daytime since a large number of prisoners are outside their cells. All security devices, facilities for building services, computer facilities, and the means of communication will no longer be available. This makes it necessary to keep the prisoners in their cells continuously. In addition to the resulting psychic stress, the prisoners may exhibit health problems from the worsening hygienic conditions, insufficient supply of food, and lack of heating.

The staff at prisons will also increasingly be under pressure and overtired. Furthermore, because of the traffic problems, some of the staff will arrive at work late or not come at all. Overall this will raise the danger of disobedience and unrest. The impact of the power outage on other sectors means that police and other support workers will presumably not be able to provide relief. Ensuring the supply of fuel to the emergency power generators is the highest priority. This is essential to make it possible for the prison to continue (reduced) operation and to ensure adequate control of the prisoners. Even if this succeeds, a situation will develop that can hardly be contained, especially as a result of problems in providing for needs, such as hygiene and medical care. The situation will be aggravated if the number of prisoners grows as a result of increased criminal activity and arrests in the region affected.

Vulnerability and coping capacities

The fuel reserves at the prisons will probably suffice for a few days. To ensure the emergency power supply, it is absolutely necessary for mobile power generators to be made available and for additional amounts of fuel to be delivered. It is almost imperative for the prisoners to be transferred to other prisons outside the affected region (and whose capacities have not been exceeded) if the emergency power supply is endangered.

Even if the emergency power continues to function, security and health issues will raise questions within a few days about the ability to keep a prison open [operatiting]. For this reason and because of the danger of prison escapes, a decision must be made about evacuating the prison, and the necessary arrangements must be made. This could be affected by massive coordination problems resulting from the failure of landline and mobile phones. It is further doubtful whether sufficient and appropriate transportation capacity, including the necessary security personnel, is available.

The need for information and action

Explicit legal regulations of the emergency power supply of prisons cannot be found. Whether at the level of administrative rules or as a consequence of the state laws governing disaster protection and emergency assistance, it was impossible to clarify with certainty if there are relevant stipulations. It is also unclear if a prolonged power outage is part of the emergency plans of prisons or of the alarm and action plans of the lower-level disaster protection authorities, and if appropriate exercises take place with external support organizations. The need for further information and legal clarification will result in]unusual measures that may become necessary, such as the decision not to house day-release prisoners or to selectively release certain groups of prisoners (prison furlough).

The sector-based perspective in the analysis of consequences has made apparent how limited the coping capacities are. The significant interdependence of the sectors also further reduces their perseverance and limits the options of the relief systems. In the following, this assessment will be further substantiated, and several conclusions will be drawn that span several sectors.

BEHAVIOR

Collapse of the power supply will raise questions about everyday actions and will mean that customary means of communication are largely unusable. The dangers and uncertainties tied to this will make people feel insecure and destroy their conviction that their living conditions can be controlled. This will be aggravated by the fact that the people affected will be unprepared for the power outage, the length of which will be unknown. Feelings of helplessness and stress will develop if supplies are interrupted, information is unavailable, and public order begins to break down.

The consequences of this fear and uncertainty for human behavior are by no means uniform. It can rather be expected that there will be a wide spectrum of different and even contradictory reactions. Some individuals and groups will drop behind the established norms of social life. They will become more reckless, aggressive, and prone to violence. The willingness to help others may decline. On the other hand, reactions and forms of behavior such as cooperation, empathy, and helpfulness will be seen that give those affected the feeling of being able to cope with the catastrophe.

The *members of the relief organizations* will experience the consequences of the power outage as extreme stress, imposing high physical and psychic burdens. Missing resources and inadequate local coordination as well as diverse organizational cultures could cause abnormal behavior when facing danger, impede efficient communication and cooperation between the emergency workers, or intensify the conflicts between the helpers.

The behavior of groups and individuals in a catastrophe has not yet been adequately studied. For example, there are no analyses of the public's protective, flight, or supportive behavior or of stress accumulation in protracted hazardous situations]. At the same time, there are a number of largely questionable assumptions, especially regarding the expected, primarily unsocial, apathetic behaviour in the public or the outbreak of a panic. This means that further clarification is necessary, especially regarding the possible potential of the public to provide assistance. Differentiated research steps on the example of a power outage could provide a contribution to the analysis of threatening anddeviating behavior of humans (that has hardly been a topic in the study of catastrophes) and of its causes. The behavior of the helpers should also be an object of study. Above all, there is a need for infomation and research on communication and cooperation between organizations. Intensified socioscientific and interdisciplinary analysis should shed light on the supporting and inhibiting factors of communication.

LEGAL ASPECTS OF COPING WITH A CATASTROPHE

The direct consequences and the chains of consequences resulting from a power outage lead to a situation in which a person's life, physical integrity, and safety are profoundly endangered and there is severe material damage. This turns into a dangerous and damaging situation in which resources must be mobilized from within and beyond the region affected so that the country can fulfill its obligations to provide security. The legislature and the authorities must create the necessary legal and regulatory preconditions.

For example, various laws covering precautionary measures provide the foundation for activating different coping capacities to support regional ones. These would for example include the following options:

> Military forces will be mobilized in the framework of Civilian–Military Cooperation. This will make manpower available to support, e.g., the police, the civil defense authorities, and health care institutions, as well as material resources. Hospitals and assembly points could for example be equipped with

cots and tents, canteens established, or army vehicles used for transportation and evacuation.

> On the basis of the act ensuring postal and telecommunications services (*Post- und Telekommunikationssicherstellungsgesetz*) and a corresponding decree by the Federal Ministry of Economy, it is possible for certain, to give largely public, agencies privileged access to telecommunications and postal services.
> To ensure the food supply, according to the precautionary food supply act (*Ernährungsvorsorgegesetz*) and the corresponding state regulations, it is possible to draw on the civilian emergency reserve and the federal grain reserve.
> After the emergency is confirmed by the federal government, the region affected by the crisis could be provided support in the form of transportation capacity by private companies on the basis of the transportation act (*Verkehrsleistungsgesetz*). The The Federal Office for Cargo Transportation would make this transportation capacity available to those requesting support.

The Federal Ministry of Economy can release, on the basis of the oil provisioning actthe fuel reserve in order to ensure the provision with fuel. Fuel can be made available and distributed via the railway network using diesel-powered engines or with tank trucks.

These measures, together with further state laws and regulations as well as the implementation instructions of the authorities, have created the necessary prerequisites for mobilizing capacities for coping – including capacities from outside the region affected – in a comprehensive yet differentiated manner for both specific and multisectoral necessitiesAt the same time, this range of legal material appears overly complex and poorly coordinated. For example [instance], the legal foundation for disaster management in the health care sector can be found in at least eleven federal and state laws and ten administrative regulations] and directions. This multitude of instruments must be employed by the actors responsible at the different levels in a coordinated and objective manner at the right point in time. This can only be achieved successfully if competent experts work in the crisis teams who share a common understanding of the legal foundations and if anticipatory measures have been taken regulating the optimal application of the laws and regulations. These prerequisites may well not yet have been created completely.

PRIVATE SECURITY PARTNERS

The task of well-coordinated emergency and crisis management is made even more complex by the fact that the relevant nongovernmental actors must be included. These include many companies in addition to the energy supply companies, such as those in the sectors of information and communications, food, and security. The multitude and heterogeneity of these companies makes these tasks significantly more complicated. One just has to realize, for example, that there are 5200 providers and 5900 disposal companies in the water sector and 3000 service providers in the information technology and telecommunications sector. They operate partly locally and partly in more than one region, and the competence and capacity of each with regard to crisis management vary extremely. The multitude and heterogeneity of the potential security partners of the authorities lead to the assumption that there is a need for further optimization in selecting private security partners at the county and state levels and in integrating them into the disaster prevention and response efforts.

NETWORKED DISASTER RESPONSE: COMMUNICATION AND COORDINATION

Modern information and communications technology are virtually indispensable to obtain a commonly shared view of the situation and to coordinate the multiple regional and supraregional crisis management teams and emergency control centers. Yet because of the power outage it will hardly be possible to have recourse to the different facets of the public communications infrastructure. Furthermore, the coping capacities that are available and the authorities' own communications network are not designed for a prolonged power outage.

> The communication of the authorities and organizations responsible for security tasks will take place via the nonpublic radio network designed for their use (BOS). A digital network is to be introduced nationwide by 2012. In terms of energy dependence, the modernization of this network means, however, increases vulnerability in a power outage. While the analog relay stations had an emergency power supply for four to eight hours, the base stations in the new system have a battery-based supply that is only designed for two hours.
> The army employs the digital TETRAPOL radio, which supports mobile speech and data communications. It is not directly compatible with the BOS network. Since deployment of the army is only to be expected after a few days, the BOS network will no longer be functioning.
> The local crisis management teams would also have the option to fall back on

mobile radio stations that are independent of the power grid. The telecommunications companies as well as the Federal Agency for Technical Relief and the army have emergency standby equipment with which they can establish speech and data services and supply it with power from emergency generators. The capacity of such power generators of the technical relief agency are however limited. This service is intended primarily for communication between crisis management teams and emergency control centers. It is unknown what capacity is at the disposal of the telecommunications companies.

> Further options in a power outage are the creation of provisional networks of field cables, the support of amateur radio users according to §2 Para 2 of the Amateur Radio Act, and recourse to satellite communications. Communication by means of field cables depends on mobile power generators that have to be refueled within a short period of time. The energy requirements of amateur radio equipment are in contrast very small. Satellite phone systems and satellite-based Internet connections offer sufficientcommmunication paths if the necessary terrestrial elements (e.g., the ground stations) can be supplied with power.

The authorities thus do have the possibility of locally reestablishing individual facets of the infrastructure. One option is to supply emergency power to the ground stations of the mobile radio system and the mobile-services switching center at least on an hourly basis. As soon as a chain can be created with further mobile-services switching centers, connections between participants would be within reach as well as with regions not affected by the power outage. It is doubtful, however, whether this system could provide permanent means of communication and connections with further mobile-services switching centers within and outside the region affected by the power outage.

For these reasons, it should be assumed that it will not be possible to create a commonly shared view of the situation despite intensive efforts to reestablish the communications infrastructure. With regard to the technical options that can be implemented, their range and time frame are limited.The communication that can be created by using them is problematic in nature, and coordination of the emergency services and measures that can thus be provided is inadequate. For all of these reasons, the disaster response of the authorities will be extremely deficient.

COMMUNICATION WITH THE PUBLIC DURING THE CRISIS

The outages in the information technology and telecommunications sector destroy most of the basis for two-way communication with the public during a crisis. Since the remaining or restored means of communication will be used by the authorities for the immediate purpose of overcoming damage and coping with the catastrophe, communication with the public must in large measure resort to local battery-powered warning systems, radio reports, and loud speaker vans. Since radio stations are suitable for broadcasting warning messages and information transmitted via the federal satellite-based warning system (SatWaS), the authorities will attempt to supply selected stations with emergency power as a means of communication during the crisis. Established meeting points, such as a mayor's office, a fire station, or a municipal hall, can – as experience has shown – develop into nodes for the distribution of information. Loud speaker announcements made by emergency vehicles or patrols operated by the emergency forces constitute further options for meeting the public's need for information.

It is obvious, however, that such a fragmented (one-way form of) communication can hardly meet the expectations of a continuous and target group-specific emergency communication. It will be extremely difficult to convey credibility and create confidence if electricity-based forms of communications fail to such a degree as described here. It is still largely unclear how such emergency communication can be organized without electricity. There is thus need for conceptual and practicable considerations

THE SUPPLY OF FUEL AND EMERGENCY POWER

The availability of the resource fuel is of primary importance for disaster management. It is essential, for example, that the following be supplied:

> Emergency vehicles of the relief organizations and the support organizations
> Diesel-powered engines for clearing abandoned trains and for the purpose of transportation as well as buses for public transportation to maintain some minimum service
> Emergency power generators that maintain the functioning of sensitive infrastructure components (such as emergency control centers, fire stations, mobile radio stations)

The existing coping capacities in the form of fuel reserves generally constitute the required preconditions to provide the actors of the crisis management with the necessary mobility despite unvafourable circumstances as for example the shutdown of service stations. The legally prescribed oil reserves, for example, mean that substantial amounts of fuel reserves are available that could meet the needs even during a prolonged power outage. Since gasoline and diesel are primarily stored in tanks above ground, it is possible to use the force of gravity to fill tank trucks or train tank cars if electricity in not available.

Despite this potential, it is questionable whether these capacities and resources can be activated and utilized in a power outage. Considering the impairment of the different components of the traffic infrastructure, it is likely that transport planes cannot be used quickly and comprehensively enough to prevent shortages of fuel, in particular in the urban centers. Finally, the coordination and distribution of fuel supplies according to an official allocation is an extremely complex task, even if one succeeded in obtaining enough tank trucks from the petroleum and logistic companies on the basis of the Transportation Availability Act. Since an extensive region is affected, it can be expected that there will be both problems in the determination of who is responsible and logistic challenges. The poor possibilities to communicate will aggravate the problem so situations may arise in which erroneous or insufficient supplies will be delivered.

Overall it is clear that extensive preparations have been made to ensure the availability of logistics services to supply fuel in the case of an emergency. Yet under the specific conditions of a power outage, the prompt and well coordinated activation and distribution of fuel reserves will be a critical factor in coping with the consequences.

A starting point for increasing the resilience of the sector would consist in an improvement in the resources available at the scene. It could for example be planned that selected service stations would be equipped with emergency power generators and continuously supplied with fuel. Under the premise that these stations are primarily available for the purposes of the authorities and the relief organizations, this would reduce the time pressure on supplying the fuel and ensure the mobility and capacity of the emergency groups to respond for a certain amount of time. To continuously operate emergency power generators, it would also be essential for the necessary fuel to be resupplied on schedule to the selected relevant locations critical for security.

ROBUST POWER SUPPLY AFTER A POWER OUTAGE: ISLANDING AS AN OPTION

The sustainability of numerous infrastructure elements is curtailed by the limited capacities of the batteries and the limited fuel storage of the plants to provide an uninterrupted supply of electricity and grid independence. In view of the immense need and growing competition for fuel, even a nationwide extension of the capacities of stationary and mobile emergency power generators would at the most result in an improved sustainability of critical components of the infrastructure in individual localities for a limited amount of time.

A more far-reaching perspective for a sustainable improvement in the robustness of the (emergency) power supply would be offered by the idea of utilizing islanding. By utilizing decentralized networked power generators, regionally limited islands of power could continue to produce electricity following a power outage. Even a local development and extension of such islands limited to the public institutions that are very important for coping with an emergency – especially on the basis of regenerative energy – could lead to a strengthened resilience of the power supply and thus of the critical components of the infrastructure. For this reason, the suggestion is made that the technical and economic viability be examined in a model project.

RAISING THE SOCIETY'S AWARENESS AND INFORMING THE PUBLIC

There is a substantial deficit in the degree to which the public is aware of the consequences of a prolonged power outage. The power supply, although a critical component of our infrastructure, is not a topic for the public.The public does not pay attention to the possibility of a power outage or to the consequences of an interruption of the power supply. Any personal experience of a power outage is usually quickly forgotten.

Disasters such as power outages are usually associated with extreme weather events and terrorism. Since the occurrence of natural events is perceived as being inevitable, and since terrorism is met with a type of fatalism, the individual assumes that he or she cannot make preparations for meeting these presumed sole causes. Consequently, there has not been any noteworthy preparation by the public for a power outage, and in this sense the capacity for coping with its consequences is inadequate. Considering the limited awareness for the risk of a power outage and the dangers posed by one, we should consider how we can use information and counseling to arouse and maintain the public's interest in order

to be able to appeal to the public in the appropriate manner in a crisis situation. A scientifically grounded strategy for communicating with the public about the risks posed by a power outage should at least be prepared before there is one. In this strategy, the citizens should not be viewed as passive victims of a catastrophe but as competent and active actors.

CONCLUSION

Analysis of the consequences of a prolonged and widespread power outage has shown that even after a few days it is no longer possible to ensure that goods and services that are vitally necessary to the public are supplied as needed throughout the area affected. The public security is endangered, and the government can no longer meet its legally anchored obligation to protect the life and well-being of its citizens. The probability of a prolonged power outage affecting the area of several states may be minimal. Yet if one were to occur, the consequences that it would trigger would amount to a national catastrophe. Even the mobilization of all internal and external organizations and resources would not make the catastrophe manageable, but at most lessen its impact.

Further efforts must be made at all levels to improve the resilience of the sectors of the critical infrastructure over the short and medium term and to further optimize the capacities of the national system of disaster management. As a classic example of the cascading effects of damage, a power outage should therefore continue to have high priority on the agenda of those responsible in politics and society. One reason is to increase the[awareness of the economic sphere and the public for this topic. The TAB report presented here should make a contribution to this effort.

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