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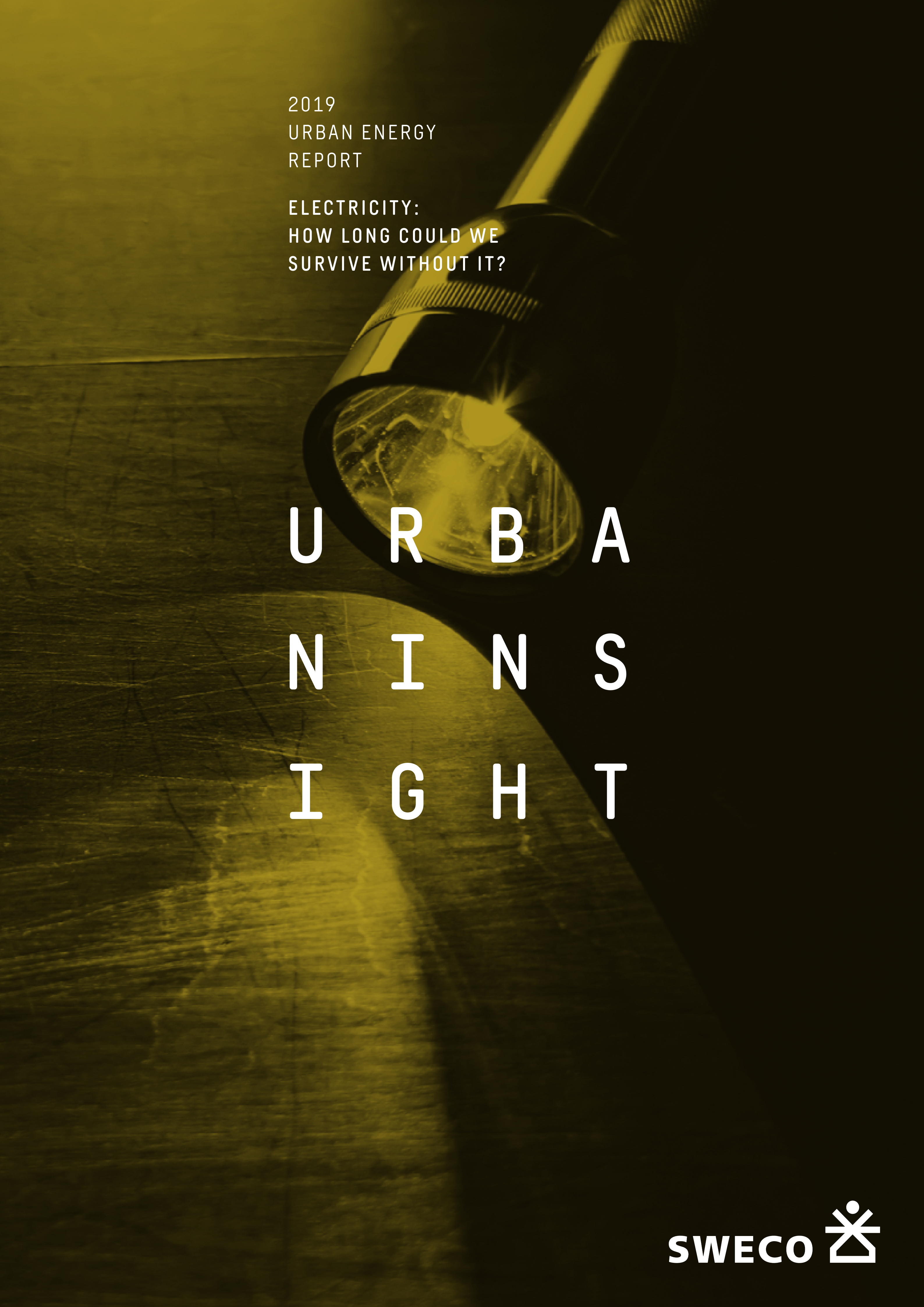

2019
URBAN ENERGY
REPORT

ELECTRICITY:
HOW LONG COULD WE
SURVIVE WITHOUT IT?

# URBAN INSIGHT

SWECO

# ELECTRICITY: HOW LONG COULD WE SURVIVE WITHOUT IT?

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CLIMATE CHANGE IS SET TO INCREASE THE LIKELIHOOD OF SEVERE WEATHER AND THEREBY MORE FREQUENT DAMAGE TO ELECTRICAL SYSTEMS AFFECTING HUNDREDS OF MILLIONS OF PEOPLE.

## CONTENTS

## 1. INTRODUCTION

Power outages occur for many reasons. Power lines can be brought down during storms or by heavy snow, falling trees or even bent branches. Power lines are also susceptible to extreme heat. Power plant operators present a human error risk, and ageing components in electricity infrastructure may also cause power outages. In the most severe cases, power plants may be affected by an accident, for example, fire, where malfunction of a single piece of equipment may result in widespread disruption.[1]

If you wake up to find your home has no power you will soon face some serious problems. You will be unable to flush your toilet, the food in your fridge and freezer will no longer be kept cold and the heating will stop working. Electricity is required to refuel your car, to heat your office and to open electric locks, to name just a few examples.

Power outages pose serious problems in terms of safety, domestic life, transportation, work, heating, nutrition, leisure and healthcare.

### “CITIES ARE DEPENDENT ON ELECTRICITY TO FUNCTION”

Climate change will likely result in more extreme weather, increasing the risk of power outages in the future. How can we become less vulnerable to power failures and mitigate their effects on urban areas?

1) www.fingrid.fi/sivut/ajankohtaista/tiedotteet/2018/virtamuuntajan-tulipalo-olkiluodon-sahkoasemalla/

Electrical networks have changed rapidly in recent decades. Production has become increasingly decentralised due to growing amounts of renewable energy being produced. At the same time, ways of using electricity have changed considerably.

Electricity enables modern life. The prevention of power failures requires the design and construction of safe, secure and functional electrical networks that incorporate a high degree of automation and distribution that is capable of withstanding the likely effects of climate change.

Ill. 1: Today, cyber-attacks on power distribution networks are a real threat that must be considered.

# 2. CASE STUDY: WAKING UP WITHOUT ELECTRICITY

The Strömberg family — Eric, 45, Minnie, 41, Rita, 13, and Edward, 8 — wakes up one wintery Monday morning at the end of February in a snowy city, ready for school and work. Climate change has resulted in unusually intense snowstorms in their town. Straight after turning off his alarm clock, Eric realizes that nothing happens when he tries to turn on the light on his bedside table. He then makes his way to the bathroom in the dark, after which he walks to the kitchen to make some breakfast. Meanwhile, Rita, the daughter, has woken up and shouts from the bathroom as she sees that the toilet is not flushing.

The family gathers for breakfast in the kitchen as they do every morning, but today they need to be creative. The effects of the power cut are beginning to sink in: no coffee, no porridge, no tea nor toast for breakfast. Instead, they eat yoghurt, bread and fruit with cold drinks.

Ill. 2: Power outages pose immediate challenges in the home.

The family, surprised by the long power cut, gets dressed and heads to work and school. The children walk to school, Minnie takes the family car to work, and Eric takes the local train from a nearby train station.

It takes Minnie two hours to get to the office. Normally it would take 40 minutes, but today the traffic control system was offline due to the power cut and no streetlights were working anywhere in the city, causing widespread disruption. With no traffic lights operational, police are called in to direct traffic at major intersections. When Minnie arrives at her office car park, the electric gates fail to open. She decides to park her car on the street close to her office and walks to the main entrance.

The snow itself has added to the traffic chaos, with roads not cleared after several snow-ploughs were left stranded without fuel. In addition to the snow, strong winds from the nearby sea adds to the disruption.

Ill. 3–4: Traffic chaos is likely in the event of power outages, especially in winter. Traffic signals, train services and snow clearance can all be hit.

Eric gets to the train station as normal. However, he sees long traffic jams all the way there. He listens to the radio while walking to the station – since the power cut occurred early in the morning his smartphone had time to fully charge during the night. In addition, most radio and phone connections will function for up to three hours after losing power due to batteries in radio signal stations. All stations broadcast the same news story: a massive power cut has paralysed the city.

All trains are at a standstill. Digital signals and information systems are down. Railway staff are on platforms trying to provide information to travellers caught in the chaos. Eric tries to call his children and his wife, but all mobile phone networks are overloaded by emergency calls. At this point Eric decides to walk home.

The children get to school. The classrooms are still warm, but are in darkness. And it is still dark outside. It is announced that school will be closed for the day due to safety reasons and everyone is sent home[2]. A lack of lighting and electronic equipment are not the biggest obstacles to teaching, but a lack of teaching staff is: most teachers failed to make it to school due to traffic jams and accidents.

Meanwhile, Minnie is struggling to get any work done: computers are offline, laptops only work for limited periods without a charge, there is no lighting and neither electronic locks nor elevators are working. Minnie decides to return home to see if the rest of the family has also done so, although she is concerned about how long this will take given all the disruption.

Soon after midday, all family members have made it back home after a difficult morning. It now sinks in just how difficult it is to live and perform everyday tasks without electricity. They have no running water and the drains are making noises. In addition, the ventilation is not working, but on the other hand opening windows is not an option because the heating is also out of order, despite the fact that the house is connected to the local district heating network. Most heating methods require electricity to operate pumps and other auxiliary equipment.

2) www.dailymail.co.uk/wires/ap/article-4101494/Emergency-measures-parts-Serbia-battle-snow-cold.html

Ill. 5 (above left): Severe weather can bring down power lines.

Ill. 6 (above right): Fire, for example in a transformer, can cause power outages.

## CLIMATE CHANGE CHALLENGES TECHNICAL SAFETY

Changes in nature and weather brought on by climate change present new challenges in terms of the technical safety of electricity distribution. On the one hand, solutions are engineered and designed for the built environment that mitigate and control the effects of climate change; while on the other, understanding of the built environment's risk and prevention profile must be improved.

Average temperature rises result in unavoidable changes to plant and animal life. In northern Europe for example, harmful invasive species such as zebra mussels increase in number. Such species can affect water cooling systems by attaching themselves to the surface of pipes. Wind, heavy rain, extreme heat and cold, and flooding are set to become more prevalent throughout Europe.

Severe weather can bring down power lines and cause power failures. Fire can destroy power lines and cause substantial harm to the urban environment.

Mitigation of climate change requires holistic understanding of technical safety and its dimensions in the built environment.

THE THREAT ASSOCIATED WITH CLIMATE CHANGE
On Christmas Day in 2011, cyclone Dagmar left 40,000 people in Norway without mobile coverage or landlines, and more than 40,000 homes in Sweden without power.

On the same day, Finland was hit by Storm Tapani, the worst of its kind for 10 years. Some 300,000 customers were left without power at the height of the storm, with large swaths of the country without power for several days, and some areas for up to three weeks.

Major power cuts are uncommon in industrialised countries, and most incidents are due to the weather. Table 1 shows some of the major blackout events and their causes. It is notable, however, that in developing countries major blackouts are more frequent due to less developed infrastructure and inexperienced users. In developed countries, most power failures typically last a few seconds to a few minutes, and are usually caused by lightning strikes.

**"ACCORDING TO A REPORT BY CLIMATE CENTRAL, WEATHER-RELATED BLACKOUTS DOUBLED BETWEEN 2003 AND 2014 IN THE UNITED STATES. AND HEAVY RAINFALL, STORMS, HEAT WAVES AND DROUGHTS ARE SET TO BECOME EVEN MORE FREQUENT AND SEVERE."[3, 4]**

For example, as a background for a large electric break shown in Table 1, in September 2003, a tree fell on an important power line in Switzerland. The effects rippled down to Southern Italy, causing around €1.2 billion worth of damage. About 56 million people mainly in Italy but also in Switzerland were without power for several hours.[5]

Table 1: Several major blackout events.[6]

| Date | Event | Location | Impact |
|---|---|---|---|
| Jul 1977 | Transmission Failure | New York City | 9 million |
| Aug 1996 | Tree Trimming | West Coast US | 7.5 million |
| Mar 1999 | Lightning | Southern Brazil | 75 million |
| Aug 2003 | Northest Blackout | Northeast US, Ontario | 55 million |
| Sep 2003 | Transmission Failure | Switzerland, Italy, France | 57 million |
| Sep 2011 | Transmission Failure | California–Arizona | 2.7 million |
| Oct 2011 | Snowstorm | Northeast US | 3 million |
| Jun 2012 | Derecho | Midwest, Mid-Atlantic US | 4.2 million |
| Jul 2012 | Transmission Failure | India | 600 million |
| Oct 2012 | Hurricane Sandy | Northeast US | 8.2 million |

3) www.phys.org/news/2016-04-blackouts-europe.html
4) www.assets.climatecentral.org/pdfs/PowerOutages.pdf
5) www.phys.org/news/2016-04-blackouts-europe.html
6) www.core.ac.uk/download/pdf/51067330.pdf

# 3.
# CONSEQUENCES OF POWER FAILURE: HOMES, OFFICES AND SCHOOLS


Chamb milieu
Chamb sud
Chamb sud
Chamb nord
Chamb milieu
Chamb sud

In residential contexts, the effects of extended power cuts on daily life are largely determined by the type and location of the residence. Surviving without electricity in a house in the countryside is much easier than in a flat in the middle of a city. Fireplaces, cellars, outside dry toilets, wells, generators – all necessary components for life without electricity, which tend to be absent in the urban environment.

## "WHILE A SELF-SUSTAINING PERSON LIVING IN THE COUNTRYSIDE MAY SURVIVE FOR SEVERAL WEEKS WITHOUT ELECTRICITY, CITY DWELLERS FACE PROBLEMS ALMOST IMMEDIATELY."

Ill. 7: Power cuts paralyse activity in the home, in schools and offices. For example, air conditioning systems shut down.

During a power outage, electronic devices cease to function. Depending on local weather conditions, if heating or cooling is off, power breaks can cause severe problems for the inhabitants, especially for elderly people and children.

## "ANYTHING MORE COMPLICATED THAN A ROWING BOAT DOES NOT FUNCTION WITHOUT ELECTRICITY."

Pasi Haravuori, Power distribution specialist, Sweco Finland

Ill. 8: During longer power cuts, electronic devices such as tablets and smartphones eventually run out of power.

A basic requirement of life, water, will cease to flow to high-rise buildings at the point power is lost because pumps are dependent on electricity. On lower floors, water availability will worsen as water towers run out of water. Waste water will also start to flow back to apartments.

Apart from open fires, buildings' heating systems are dependent on electricity. Buildings heated by oil, district heating, or geothermal heating systems will be at risk because all these systems need pumps to circulate hot water. When the distribution of heat stops, it is extremely important to preserve the leftover heat stored in structures by keeping doors, hatches and ventilation shafts closed. During the coldest months of the year, frozen water pipes pose the risk of severe structural damage.

Fridges and freezers – and their contents – are especially susceptible to power cuts. Humans endure heat much better than many devices or things, however people have a limited tolerance of extreme heat and urban environments increase the negative effects of heatwaves. Heat gathers between buildings in so called "heat islands", and asphalted surfaces intensify heat further[7, 8]. According to a study made by health experts around the world, heat is set to cause growing numbers of premature deaths in Europe[9, 10]. Loss of cooling not only causes spoiled groceries, it can even be life threatening to many people.

Initially, the only noticeable effect of a loss of ventilation in a building is stuffiness. However, the loss of ventilation in locations where explosive or flammable materials are stored presents a major safety risk. In addition to safety concerns, economic impacts are also potentially serious with, for example, stoppages in production and raw materials being contaminated due to the lack of correct relative air pressure between spaces.

Centennials, or Generation Z, do not know the world without the Internet[11]. They carry out some daily tasks through virtual assistants. When arriving at the front door, they might ask a virtual assistant to turn on the lights or close the garage door behind them.[12, 13] Electric-powered software has established itself into every aspect of everyday life virtually unnoticed.

Power cuts may cause severe disruptions to everyday life. Even to functions that one might not think are reliant on electricity. By careful design even the most exceptional events can be taken into account, and by doing this the sustainable and safe urban environment can be achieved.

7) www.epa.gov/heat-islands/learn-about-heat-islands
8) www.tandfonline.com/doi/abs/10.1016/j.hazards.2004.12.002
9) www.thelancet.com/journals/lanplh/article/PIIS2542-5196(17)30082-7/fulltext?elsca1=tlpr
10) www.who.int/news-room/fact-sheets/detail/climate-change-and-health
11) www.whatis.techtarget.com/definition/Generation-Z
12) www.cnet.com/how-to/the-complete-list-of-siri-commands/
13) www.support.apple.com/en-us/HT208280

## ENERGY SELF-SUFFICIENT BUILDINGS

Zero-net-energy buildings, (ZNE), are self-sufficient in energy[14]. Specifically, a ZNE building must have its own energy production capacity and be able to supply the grid. Net-zero is reached with, for example, solar panels, and excess capacity is sold in summer months and the same amount is purchased from the grid in winter.[15]

During power outages, solar panels are, however, of limited use if the sun is not shining. Local and small scale "off-grid" combined heat and power production works both as a cutter for peak powers and in an emergency situation as a provider for essential power and heat requirements. When 100 per cent biogas is used as a fuel, the whole production is renewable energy according to the energy efficiency directive[16, 17].


Ill. 9: Smart housing refers to a variety of automated services in the home. Power outages render such services inoperable, potentially, for example, leaving residents locked in or out of their homes.

14) www.abb.com/cawp/seitp202/229b08404998932ec125826500253e2b.aspx
15) www.ara.fi/download/noname/%7BE7FE1AD9-4529-4CC5-8063-8D7D078C15E8%7D/24217
16) www.gasum.com/kaasusta/biokaasu/biokaasu/
17) www.eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:315:0001:0056:FI:PDF


Ill. 10: Electrical locks, like any other smart device in the home, must also be hack-resistant.

## HOLISTIC SAFETY MANAGEMENT – THE IMPORTANCE OF PERSONAL SAFETY

Digitalisation has changed our homes: we now have more automated devices than ever before; and many of them are connected to the Internet and may even have artificial intelligence to support functionality. Digitalisation brings us more information about things that are important to us, but this brings with it greater safety requirements.[18]

Not only do designers need to consider how devices work, but also what happens if they malfunction. In terms of power outages, planned rundown or prepared malfunctioning are the most important from the safety perspective.

What happens with electrical locks for example? Locks may remain locked or unlocked in the event of a power cut. In the home, you do not want your front door to be unlocked, vulnerable to any passerby, but at the same time, you want to be able to enter your property. Retail outlets and other business premises will also want to ensure that their properties are protected.

Electrical locks, like any other smart device in the home, must also be hack-resistant. Who would have imagined that a toy doll could be used to open electrical locks in people's homes? But this is precisely what happened in 2017 with Cayla Doll.[19]

18) www.citrix.com/content/dam/citrix/en_us/documents/analyst-report/ponemon-security-study-compliance-challenges.pdf
19) www.cyberscout.com/education/blog/germany-bans-my-friend-cayla-doll-due-to-privacy-concerns

# 4. CONSEQUENCES OF POWER FAILURE: GROCERY STORES AND HOSPITALS

Grocery stores cannot function without electricity. The most acute problems for stores of any size facing power cuts are related to cooling and heating of food products and payment activities that are increasingly electronic. In the case of extended power cuts, problems will spread to storage management and ordering, and thereby supply chains. Grocery store chains' logistics are reliant on automation, which will be paralysed during power outages[20].

### GROCERY STORE ON GOTLAND PREPARES FOR RECURRING POWER OUTAGES

Stora Coop in Visby, one of the biggest food stores on the Swedish island of Gotland, decided to connect its cash register system to backup power when its new store was built in 2014. This decision, combined with active choices of energy-efficient installations, such as freezers with doors, made it possible for the store to remain open even during recurring power outages in 2017. The store has introduced a system that allows staff in the event of a power failure to guide customers using torches. These decisions have made the store one of the few retail outlets on Gotland that have been able to stay open in the face of interruptions, while other stores have had to employ guards to prevent looting.

Hypermarkets are able to remain open for around four hours in the event of a loss of power by using back-ups such as diesel generators. Cashier systems in smaller stores may be backed up by battery systems, in which case, customers are able to complete their purchases after a power loss. Such systems are, however, relatively rare.

Electricity is especially vital in hospitals: in the absence of power, surgeries are at risk, respirators shut down, and hygiene is threatened. Waste management may also be affected if dependent on pressure piping, which requires electricity to function.

Hospitals are typically backed up by diesel generator systems that provide electrical power during brief blackouts. Diesel generators work as long as they are fuelled, but the availability of fuel can not necessarily be assured in emergency situations. Furthermore, even if a hospital is operational, it is likely that people will have difficulty in getting to hospitals for medical treatment due to widespread traffic disruption.

Ill. 11: A wide variety of activities would cease immediately in the absence of back-up generators.

20) www.nordic.businessinsider.com/south-korea-robots-2018-winter-olympics-2017-12/

EXAMPLE OF COST CALCULATION:
WHAT WOULD A POWER OUTAGE COST FOR COMPANIES, ORGANISATIONS AND INSTITUTIONS?

| | |
|---|---|
| A 1,000-employee office without power for one hour: | EUR 67,000 |
| A hypermarket without power for one hour: | EUR 6,000 |
| A shopping mall without power for one hour: | EUR 100,000 |
| An industrial production line without power for one hour: | EUR 100 / employee |
| A farm without power for one hour: | EUR 15 |

AN INCREASING NUMBER OF ELECTRIC CARS COULD POSE A THREAT TO POWER SUPPLY
Electrical network dimensioning is set to face exceptional pressure as the number of electric vehicles and energy stores reliant on the network increases. While the overall amount of energy used may not increase rapidly, momentary peaks in demand may threaten supply. It is therefore extremely important to design residential networks correctly. In addition, different digitalised solutions for managing power consumption evenly for multiple consumer points will be extremely important. This is especially the case with car parks, where the number of electric vehicles may increase significantly in the next five to 10 years.

If all these vehicles need to charge their batteries at full power, this will place considerable demands on the power network. However, this can be addressed by careful design and consulting. If these issues are taken into account at the earlier stages of a project in dimensioning and utilising dynamic power distribution, additional costs may be limited or negligible. In completely new projects, such aspects tend to be taken into consideration, but they risk being overlooked with the renovation of old sites with the installation of the latest charging infrastructure.

Ill. 12: Electric cars are becoming increasingly common in European cities. However, in the absence of intelligent control systems, large numbers of electric vehicles connected to the grid simultaneously may cause local power outages.

# 5. CONSEQUENCES OF POWER FAILURE: POWER AND PRODUCTION PLANTS

Production facilities, such as power stations producing electricity and heat, wastewater treatment plants and industrial plants face multiple challenges during power outages. Production losses can result in substantial financial costs, and pose a threat to safety. For example, production plants handling chemicals requiring high temperatures and pressures are an imminent threat to the environment and personal safety when power is lost as equipment fails.

From a technical safety perspective, production plants can be approached from two different angles. First, how to ensure that the production will not be affected by power outages. Second, how to keep facilities safe to ensure no additional damage following a power cut.

Will fire protection systems work without electricity, and do operators know enough about process status in the absence of electrically powered instrumentation? Distribution failure should be included in risk management reviews for production plants as is the case for hospitals and shopping centres. For example, explosion risk must be minimised in the event of a loss of power.

### ENERGY AND WATER SUPPLY

Nordic cities typically obtain electricity and heat from centralised combined heat and power plants (CHP), which are usually located near cities.

**"IF A BROAD DISTRIBUTION NETWORK FAILURE OCCURS IN A NETWORK OUTSIDE A CITY, IT IS POSSIBLE THAT CHP PLANTS REMAIN ON A CITY'S NETWORK DURING THE OUTAGE, AND ENERGY SUPPLY IS MAINTAINED."**

It is likely, however, that protection mechanisms of power plants automatically disconnect plants from power networks. If a CHP plant continues to operate during a power cut it may still deliver heat and electricity to consumers.

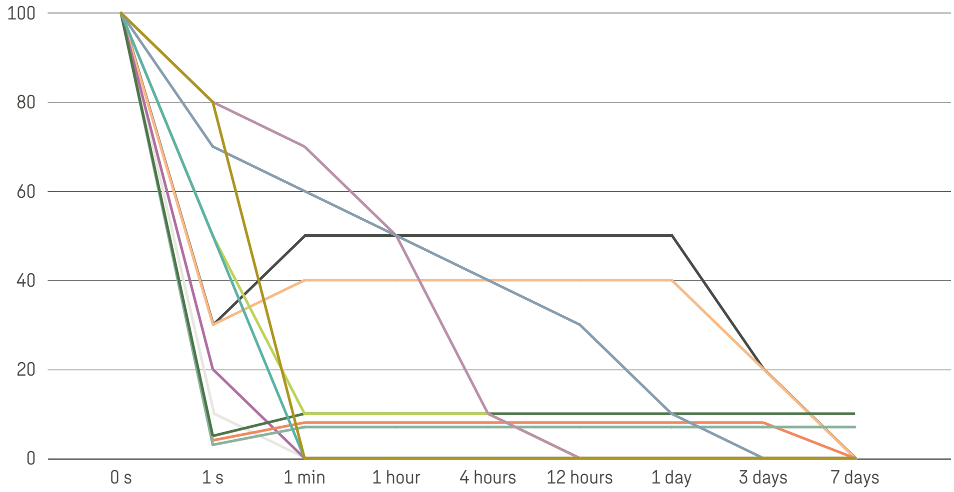
Decentralised energy production, solar and wind power for example, is typically characterised by local energy production solutions. Wind power production is, however, extremely sensitive to physical disturbances such as storms.

Water supply also needs electricity. The supply of fresh water to consumers, and waste water management from the sewers to purification plants require pumping. Typically, water management systems in cities are controlled using automation systems.

To keep water pressure constant, there is a need for electrically powered pumps and water towers. These are used to balance water pressure and consumption peaks. Without pumped water, water towers empty in anything from one hour to a few days. On average, water towers hold sufficient capacity for about 14 hours.[21]

Ill. 13: Usability of facilities and services during power outages while taking into account possible back-up power.

PERCENTAGE OF USABILITY




Y-axis is Percentage of Usability (For example half of the facility is running or by half the nominal power)

- Warm water
- Sewage
- Water supply
- Shops
- Hypermarkets
- Hospitals
- Food production
- Industrial production
- Traffic light control
- Railway control
- Aviation control
- Petrol stations

## THE IMPORTANCE OF HOLISTIC RISK ASSESSMENT

Holistic risk assessment is always needed when building industrial production plants. Risks change over time, which means that assessments must be updated during the life cycle of plants. Risk assessment consists of evaluating all critical functions and processes and proposing solutions to optimise safety.

The safety of automation is even more critical in industrial production plants than in smart buildings. Every part of the process should be designed such that in case of a malfunction, the production plant will run down safely or the process will stay in a safe, stable state. One example is the possibility to restrict the increase of pressure or heat. Plants can be prepared for power outages with reserve power so that the critical process equipment can continue to operate.

Risk assessment is crucial. If potential issues are not identified, risk related to them cannot be minimised.

21) www.defmin.fi/files/3070/sahkoriippuvuus_modernissa_yhteiskunnassa_verkkojulkaisu.pdf

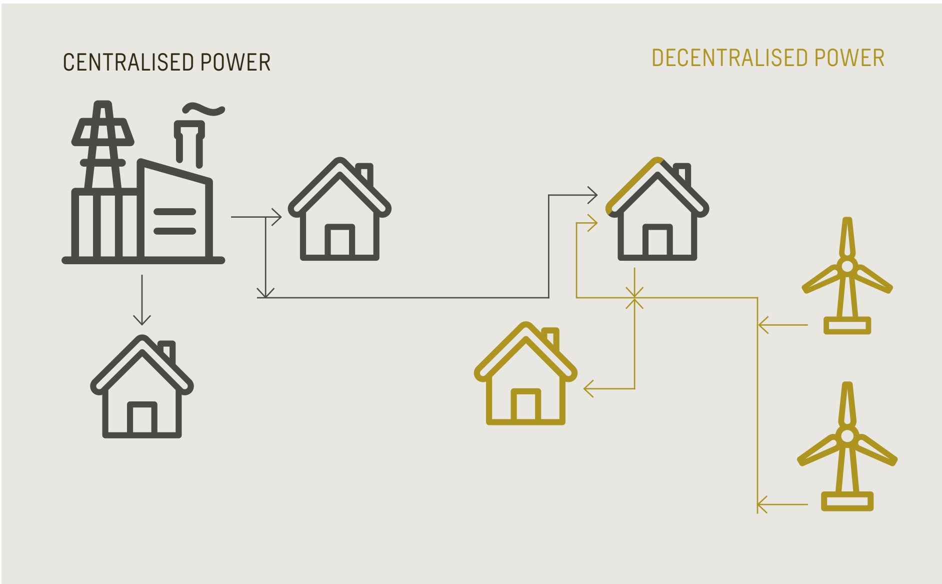
# 6. CHALLENGES ON THE NATIONAL LEVEL

ON
OFF

Previously, the basic principle of electric networks and energy production was that energy flows from production plants to consumers. Production was determined by the needs of consumers. In addition, using and controlling the network was straightforward (design, protection, control) when power effectively flowed in one direction.

Nowadays, mostly due to renewable energy and local, decentralised energy production, power also flows from consumers to electricity networks, even though networks were not originally designed for this. This may create dangers, which can be prevented by intelligent design. Dangers may be especially acute if power is cut from a wide area and maintenance personnel do not have information about local energy production. In such cases, the network may contain residual voltage.

Ill. 14: Differences between centralised and decentralised energy networks. Local producers are connected to net-works, an aspect that should be con-sidered in network design.




Ill. 15 (left): An LNG facility at the Port of Rotterdam.

Ill. 16 (right): Solar panels offer a viable alternative to fossil fuels.

## "IN TERMS OF TRANSPORT, A LARGE-SCALE BLACKOUT RAISES THREE KEY ISSUES: TRAFFIC CONTROL, FUEL DISTRIBUTION, AND THE USE OF THE ROAD NETWORK."

In the event of a power outage, air traffic control would continue to operate on back-up power for a sufficient amount of time to direct aircraft to other airports. Train services and vehicle traffic would by hit relatively quickly following a power cut due to control systems, (train networks, traffic lights etc.), being electrically powered and typically lacking back-up power. Sea traffic control centres have been equipped with UPS devices lasting for two hours but problems with mobile and data transmission would occur much sooner.

The fuel distribution network would stop functioning for aircraft and vehicle traffic, which would cause widespread disruption as soon as fuel reserves run dry. Electrically powered trains would cease operating immediately.

Water would flood streets due to inefficient, or a total lack of pumping. In winter, snow ploughing would also be hit, causing further disruption.

Ill. 17: A car drives through flood water in Baarn, the Netherlands.

CYBER ATTACKS ON NETWORK INFRASTRUCTURE: DISRUPTING THE NETWORK

Cyber attacks on network infrastructure have been well documented, and the types of attacks are constantly changing. Recently, cyber terrorists have started mounting so-called “Botnet” attacks that use high-wattage devices on the grid. These kinds of attacks switch large numbers of devices on and off simultaneously, which destabilises the network and may result in large-scale power outages.[22]

HOW TO COMMUNICATE NATIONWIDE IN EMERGENCY SITUATIONS?
Communication plays a key role during severe emergency situations. Authorities need to communicate quickly and efficiently about disruption when there is still a chance to do so. Radio is one of the most important communication platforms for authorities to inform citizens. In most European countries, national broadcasting companies have a regulatory requirement to uphold crisis communication under all circumstances[23]. Commercial media companies in many countries also have access to communication equipment in case of emergency. Organisations offering broadcasting infrastructure usually have transmission networks that run on back-up power. Such back-ups provide power only if fuel supply is secured.

Ill. 18: A firefighter communicates using the radio network.

22) www.arxiv.org/pdf/1808.03826.pdf
23) www.vnk.fi/documents/10616/622950/J1507_Valtionhallinnon+viestint%C3%A4+kriisitilanteissa+ja+poikkeusoloissa.pdf/953946f4-6b44-46a8-bf8a-ac144828b4ab?version=1.0

Communication is extremely challenging during widespread power disruption. Telecommunications and information networks typically function for up to three hours on back-up power, after which time communication is primarily handled via an official authority communication network, which has a reserve capacity of roughly six hours. It should be noted that emergency services' contact numbers are likely to be overloaded fast in the event of a crisis situation, making it difficult to contact the authorities.

While consumers will notice power outages immediately, they may not be aware of changes in the quality of electricity. Today, equipment connected to the grid is more sensitive – arguably demanding – in terms of power demand than ever before. On the other hand, there are large amounts of equipment in the network that disturb the network quality. The quality of electricity will be even more important in the future with sensitive sensors and such in normal apartment.

Table 2: Key aspects of smart grids of the future.[24]

| Technology | Open environment | Intelligence |
|---|---|---|
| Network structure | Harmonisation | Information systems |
| Fault management | Standardisation | Data systems |
| Quality of electricity distribution | Legislation | Telecommunication systems |
| Decentralised production | | Protection systems |
| Energy storage | | |
| Power electronics | | |

EUROPEAN COUNTRIES PREPARING FOR POWER OUTAGES

In 2013, partly after the long interruptions by storms, the Finnish Parliament passed the new Electricity Market law, which requires distribution operators to enhance the reliability of distribution networks. The goal is a weather proof network. According to the law the network must be designed, built and maintained in a way that storms or snow may not inflict blackouts more than 6 hours in urban areas. In other areas the maximum length for the blackout is 36 hours.

Distribution operators must fulfil the demands gradually within 15 years from the inception of the law. By the end of 2019 reliability of delivery must reach at least half of the customers. By the end of 2028 all consumers must be reached.

24) www.vtt.fi/inf/pdf/tiedotteet/2006/T2361.pdf

## EUROPEAN COUNTRIES PREPARING FOR POWER OUTAGES

Many European countries have prepared information for their citizens about how to cope in the event of a power cut. However, much of this material is available only online, making it hard to access in the event of a loss of power. In Sweden, a printed leaflet providing advice on what to do in the event of a power cut has been sent to every home in the country.

| | |
|---|---|
| Sweden: | Leaflet sent to every household and a website for instructions about what to do in a crisis[25] |
| Finland: | Website providing instructions on what to do in the event of a widespread electrical blackout[26] |
| Poland: | National SMS system for threat / crisis communication[27] |
| Norway: | Similar website documentation as Sweden and Finland[28] |
| Belgium: | Crisis and threat information and preparation instructions[29] |

## ELECTRICAL NETWORK CODES

Network codes are associated with the aim of the EU's third energy package that entered into force in 2009 concerning the European internal electricity market[30]. Key actors in the preparation of network codes are the European Commission, energy regulators and European transmission system operators.

These network codes are European regulations. They are legislation directly in force in EU member states. As European legislation, the network codes are ahead of national legislation in the hierarchy. The member states are responsible for implementing the network codes to strengthen the security of supply and preparing for power outages.

The network codes are divided into three groups: connections, operations and the market codes.

It is the duty of the member states to implement the network codes, and to ensure the harmonisation of national legislation with the network codes.

In addition to the above, there are international standards that guide and harmonize the use of power grid and set requirements for network-connected devices.

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25) www.dinsakerhet.se/kris-och-krig/broschyren-om-krisen-eller-kriget-kommer/english-engelska/
26) www.defmin.fi/files/1275/Pahasti_poikki_nettiversio.pdf
27) www.rcb.gov.pl/alertrcb/
28) www.dsb.no/globalassets/dokumenter/egenberedskap/brosjyrer-og-plakater-uten-logo/dsb_beredskap_brosjyre_originalutvikling_02_print_utenlogo_nbb.pdf
29) www.risico-info.be/en
30) www.europa.eu/rapid/press-release_MEMO-09-176_en.htm?locale=en

## GROUND CABLING REDUCES THE NUMBER OF BLACKOUTS

Due to the Finnish Electricity Market Law, it is basically the only chance for distribution operators, to fulfil the requirements of distribution downtime, to utilize cabling in the ground more widely. Table 3 presents the percentage of ground cabling in relation to overall network length. Calculated costs for Finnish inhabitants when investing in underground cables, to reach the demands of the Electricity Market Law, is approximately EUR 8.6 billion[31], amounting to approximately EUR 1,500 / capita and EUR 2,218 / tax payer[32]. These costs are met by increasing distribution charges, which has sparked considerable public debate in recent years[33]. The effect of ground cabling from 2011 to 2029 is illustrated in ill. 20.

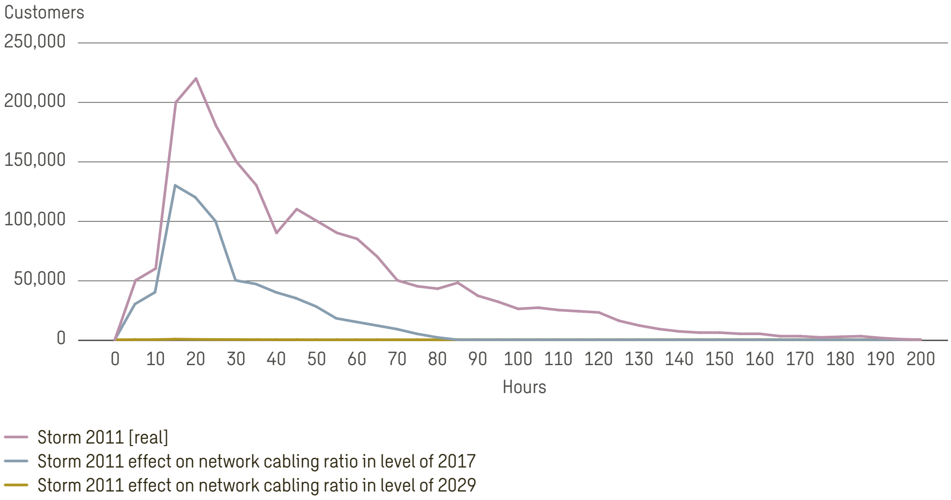
Table 3: Amount of electrical network per capita and cabling ratio[33]. Considerable differences exist between European countries.

| Country | Electrical network length per capita [m] | Percentage of underground cable in networks [%] |
|---|---|---|
| Czech Republic | 20 | 40 |
| Estonia | 49 | 21 |
| Finland | 67 | 26 |
| Germany | 20 | 83 |
| Great Britain | 12 | 66 |
| Iceland | 273 | 33 |
| Lithuania | 80 | 10 |
| Norway | 55 | 46 |
| Poland | 19 | 28 |
| Sweden | 49 | 65 |
| The Netherlands | 14 | 82 |

Ill. 19: Ground cabling is common to reduce blackouts.

31) www.tekniikanmaailma.fi/digilehti/?numero=17/2018
32) www.veronmaksajat.fi/luvut/Tilastot/Verotuotot/Maksetut-tuloverot/
33) www.ceer.eu/documents/104400/-/-/0f8a1aca-9139-9bd4-e1f5-cdbdf10c4609

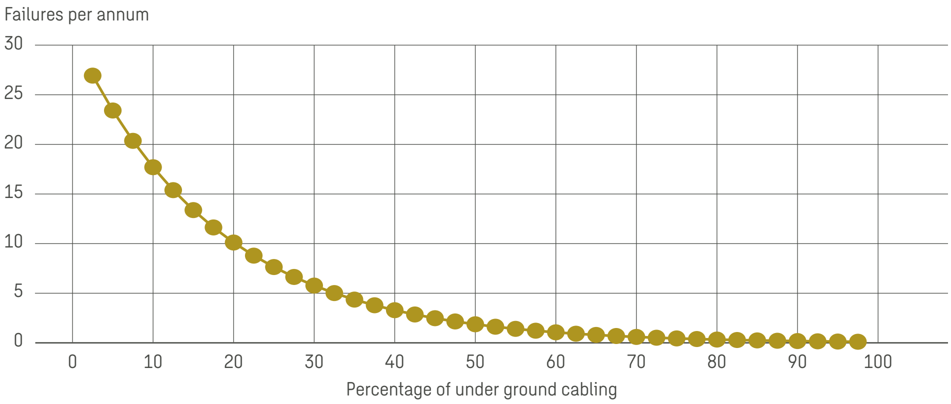
Ill. 20: Effect of ground cabling regarding 2011 storms.[34] Number of failures seen by customers of one distribution network operation.




Two third of all faults in power distribution networks are due to weather related accidents. Ground cabling decreases this number as illustrated ill. 20. Due to the high number of weather related accidents, as shown in ill. 23, the number of failures seen by customers decreased substantially to the point where the share of ground cabling reaches 50 per cent, see ill. 21. After this cabling rate, the amount of failures decreases relatively modestly as the influence of cabling for low density population areas is relatively small. In such cases, the majority of customers are individual property owners, summer cottages etc.

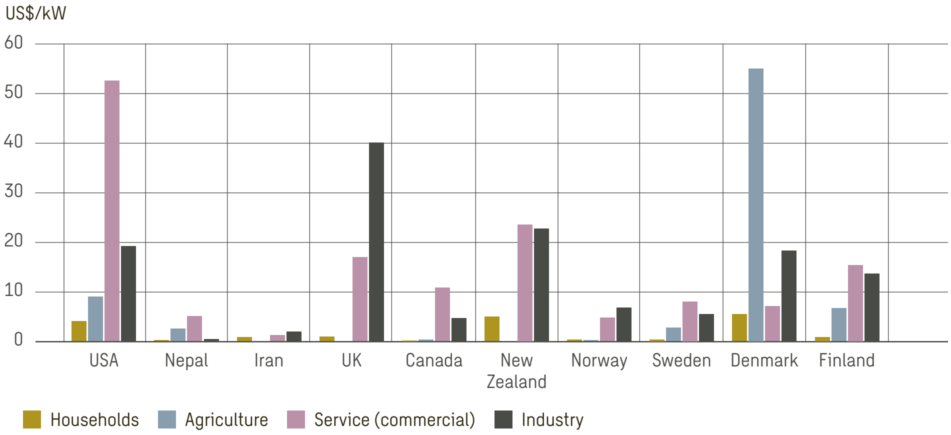
The effectiveness of improvements to the electric network is proportional to the number of customers who experience power outages. Ill. 22 shows costs by business sector when the energy supply is cut. When the number of customers without electricity is reduced, (for example by ground cabling), losses diminish. It is more feasible to reduce costs by improving distribution reliability than to find new approaches within the sectors to reduce electricity dependence.

Ill. 21: The graph shows how failure frequency decreases as the amount of underground cabling increases.[35]



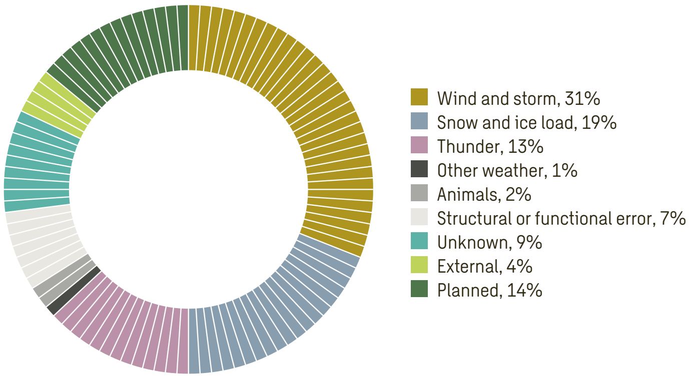

34) www.tekniikanmaailma.fi/digilehti/?numero=17/2018
35) www.ieeexplore.ieee.org/abstract/document/7028930

Ill. 22: Economic losses of one-hour interruption in electricity distribution in US$/kW, comparing different business sectors: households, agriculture, service (commercial), industry.[36]




Electricity distribution network are critical infrastructure. As such, they provide potentially high-value targets for cyber-attacks. Attacks against critical infrastructure may cause substantial harm to society. By increasing the level of automation and automated control, vulnerable targets are introduced to the distribution network.

Ill. 23: Causes of interruptions in Finland.[37]




## HOLISTIC SAFETY REQUIRES A SAFETY PARTNER

Safety in the urban environment is the result of several different factors. These various technical safety details must function together to achieve a fully safe built environment fit for everyday living.

Holistic safety in the urban environment requires systematic safety management. This comes from close co-operation between different stakeholders in society. To create an environment of overarching safety, extensive expertise from technical safety and all fields of the urban environment is necessary.

36) www.ktm.elinar.fi/ktm_jur/ktmjur.nsf/all/6AFAFB826AEF5800C22570E600371215/$file/74642004.pdf
37) www.energia.fi/files/607/Keskeytystilasto_2014.pdf

# 7.
# CONCLUSIONS AND RECOMMENDATIONS

Urban environments are highly dependent on electricity, and hence vulnerable to power outages. The Strömberg family may never have realised how much their daily routine depends on electricity: cooking, lighting, heating, flushing the toilet, driving to work and so on. Today, the majority of our infrastructure functions with smart devices and building services are even more dependent on the supply of electricity. In the absence of electrical power, everyday life feels unsafe on many levels.

Ill. 24: What do we lose when we lose power?[38]


Contemporary power systems face multiple and varying challenges. Climate change is likely to present unexpected challenges in terms of the natural environment and weather conditions, which means there is a need to be more technically prepared for more extreme weather events. In addition, increased digitalisation has made it harder for society to predict and therefore mitigate all outcomes. Furthermore, the issue of cyber security needs to be given special consideration in the context of today's urban environment.

How can vulnerability to power failures be reduced; and the resilience of electrical systems in Europe be enhanced? When the power is gone, it´s gone. The preparation you could do is to have some canned food, water and a flashlight in storage. On a national level the key lies in technical safety and making power distribution networks more functional. Technical safety is not only related to power distribution networks and power plants; it requires a holistic approach encompassing the environment, cities and industry. For instance, technical safety should be taken into consideration when designing traffic control systems, electrical locks, building services, heating, cooling, water management and so on.

38) www.currents.plos.org/disasters/index.html%3Fp=10801.html

Technical safety is often overlooked. Our sense of safety tends only to be triggered when technical safety fails. Technical safety is traditionally handled individually in different sub-areas but by managing technical safety effectively, all sub-sections can be made to work together seamlessly. Well managed, overall safety cannot be the responsibility of a single individual, entity or organization.

Technical safety incorporates two main aspects. First, in this case in power plants and energy distribution networks: what can be done to prevent emergency situations in the first place? Second: what can be done to minimize disruption to society when faced with a power outage? In an emergency situation, everything needs to be done to keep society safe; however, the ultimate aim should be to build resilient electrical systems for the long-term.

Extreme weather – the main cause of power outages – is set to influence grid infrastructure of the future to a far greater extent than is currently the case. Resilience and mitigation of climate change can be ensured, for example, with underground cabling and energy storage. Ground cabling is an effective way to reduce weather damage.

Energy storage can improve the resilience of electrical systems by reducing dependence on national network infrastructure and centralised power plants. With energy storage facilities equidistant from power plants and consumers, the risk of shorter power outages can be reduced.

In addition, society must be prepared to alter production and consumption patterns with, for example, decentralised production. Centralised and decentralised production are necessary in terms of optimizing distribution. With a decentralised approach, the loss of one production facility does not cripple an entire grid. However, with centralised production, large production facilities must be designed to be highly reliable with the help of advanced safety measures.

Decentralised production and energy storage are useful tools to manage the supply of electricity from renewable energy sources, in the event of power outages, and differences in energy consumption. Even though the point of view is commonly economic, these tools can be used in an emergency to generate reserve power.

The number of production facilities connected to national power networks is increasing. This increases their vulnerability to cyber-attack. On national and local levels, every country should conduct risk assessments based on the security of supply, focusing on potential vulnerabilities, both physical and non-physical, of the energy supply and take action accordingly.

Naturally, not only technical safety management but also local and national wide decision making is part of the solution to ensure power distribution in urban areas.

# 8.
# ABOUT THE AUTHORS

ERKKI HÄRÖ is a power distribution specialist and electrification team leader at Sweco in Helsinki, Finland. He holds a D.Sc. in Electrical Engineering from Tampere University of Technology. Since joining Sweco in 2016, he has been working on industrial electrification projects and renewable energy. In his work on power distribution, Erkki is especially interested in planning a safe, functional and cost-efficient power distribution entity. Erkki's projects involve feasibility studies, pre-engineering and detail engineering duties. His customers mostly comprise of production industry and renewable energy companies.

SANNA-MARIA JÄRVENSIVU is Sweco's technical safety expert, working on holistic safety management and risk assessments. She holds an M.Sc. in Automation Engineering and her career begun with functional safety in industry. Since joining Sweco in 2014, Sanna-Maria has focused on holistic safety management and understanding of technical safety from industry to urban environment in a wider perspective. Urban environment has become increasingly similar to industrial applications, as automation and digitalisation of the urban environment increases. Sanna-Maria also participates in international standardisation of technical safety and risk assessment, and is developing practices to increase safety in the process industry.

JUSSI ALILEHTO specialises in complex energy and HVAC-systems and their automation. He has been working with building service systems for nearly 20 years although his B.Eng. is in Media Engineering. His previous experience in building automation contracting has lead him to work on projects spanning conceptual design of urban area to fine tuning a heat pump setup. Jussi is a leading consultant in life cycle services, and he frequently emphasises the importance of attention to detail when creating safe, long-term solutions.

PASI HARAVUORI is a senior advisor in electrification and automation at Sweco in Helsinki, Finland. Since joining Sweco in 2001, Pasi has worked on electrification projects in the process industry and distribution segments. Pasi is interested in how electricity distribution and safety systems can become a functional and natural part of the everyday life in industry and cities. Pasi holds an M.Sc. in Energy Technology and has broad experience of electrification and automation. Pasi is currently department manager for Sweco Industry, Finland. By working with new technology and smart innovation models, Sweco is planning better, smarter industry and cities of the future.

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# 9. REFERENCES

**REFERENCES:**

– www.fingrid.fi/sivut/ajankohtaista/tiedotteet/2018/virtamuuntajan-tulipalo-olkiluodon-sahkoasemalla/
– www.dailymail.co.uk/wires/ap/article-4101494/Emergency-measures-parts-Serbia-battle-snow-cold.html
– www.phys.org/news/2016-04-blackouts-europe.html
– www.assets.climatecentral.org/pdfs/PowerOutages.pdf
– www.core.ac.uk/download/pdf/51067330.pdf
– www.epa.gov/heat-islands/learn-about-heat-islands
– www.tandfonline.com/doi/abs/10.1016/j.hazards.2004.12.002
– www.thelancet.com/journals/lanplh/article/PIIS2542-5196(17)30082-7/fulltext?elsca1=tlpr
– www.who.int/news-room/fact-sheets/detail/climate-change-and-health
– www.whatis.techtarget.com/definition/Generation-Z
– www.cnet.com/how-to/the-complete-list-of-siri-commands/
– www.support.apple.com/en-us/HT208280
– www.abb.com/cawp/seitp202/229b08404998932ec125826500253e2b.aspx
– www.ara.fi/download/noname/%7BE7FE1AD9-4529-4CC5-8063-8D7D078C15E8%7D/24217
– www.gasum.com/kaasusta/biokaasu/biokaasu/
– www.eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:315:0001:0056:FI:PDF
– www.citrix.com/content/dam/citrix/en_us/documents/analyst-report/ponemon-security-study-compliance-challenges.pdf
– www.cyberscout.com/education/blog/germany-bans-my-friend-cayla-doll-due-to-privacy-concerns
– www.nordic.businessinsider.com/south-korea-robots-2018-winter-olympics-2017-12/
– www.defmin.fi/files/3070/sahkoriippuvuus_modernissa_yhteiskunnassa_verkkojulkaisu.pdf
– www.arxiv.org/pdf/1808.03826.pdf
– www.vnk.fi/documents/10616/622950/J1507_Valtionhallinnon+viestint%C3%A4+kriisitilanteissa+ja+poikkeusoloissa.pdf/953946f4-6b44-46a8-bf8a-ac144828b4ab?version=1.0
– www.vtt.fi/inf/pdf/tiedotteet/2006/T2361.pdf
– www.dinsakerhet.se/kris-och-krig/broschyren-om-krisen-eller-kriget-kommer/english-engelska/
– www.defmin.fi/files/1275/Pahasti_poikki_nettiversio.pdf
– rcb.gov.pl/alertrcb/
– www.dsb.no/globalassets/dokumenter/egenberedskap/brosjyrer-og-plakater-uten-logo/dsb_beredskap_brosjyre_originalutvikling_02_print_utenlogo_nbb.pdf
– www.risico-info.be/en
– www.europa.eu/rapid/press-release_MEMO-09-176_en.htm?locale=en
– www.tekniikanmaailma.fi/digilehti/?numero=17/2018
– www.ieeexplore.ieee.org/abstract/document/7028930
– www.veronmaksajat.fi/luvut/Tilastot/Verotuotot/Maksetut-tuloverot/
– www.tekniikkatalous.fi/tekniikka/energia/caruna-nostaa-sahkonsiirtomaksua-omakotiasujalle-liki-100-vuodessa-6721899
– www.ceer.eu/documents/104400/-/-/0f8a1aca-9139-9bd4-e1f5-cdbdf10c4609
– www.vtt.fi/inf/pdf/tiedotteet/2006/T2361.pdf
– www.ktm.elinar.fi/ktm_jur/ktmjur.nsf/all/6AFAFB826AEF5800C22570E600371215/$file/74642004.pdf
– www.energia.fi/files/607/Keskeytystilasto_2014.pdf
– www.currents.plos.org/disasters/index.html%3Fp=10801.html