Impact on households and critical infrastructures from electricity failure

Two case studies and a survey on public preparedness

Grétar Már Pálsson

Faculty of Civil and Environmental Engineering
University of Iceland

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Grétar Már Pálsson

30 ECTS thesis submitted in partial fulfillment of a
Magister Scientiarum degree in Civil Engineering

Advisors
Dr. Björn Karlsson
Böðvar Tómasson

Faculty Representative
Sveinn Júlíus Björnsson

Faculty of Civil and Environmental Engineering
School of Engineering and Natural Sciences
University of Iceland
Reykjavik, May 2015

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Faculty of Civil and Environmental Engineering
School of Engineering and Natural Sciences
University of Iceland
VR II, Hjarðarhaga 2-6
107, Reykjavik
Iceland

Telephone: 525 4600

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Abstract

This thesis studies the impact from electricity failure in Iceland on households and critical infrastructures. Households and critical infrastructures electricity dependence is discussed along with a theoretical identification of impacts towards these two subjects from electricity failure.

Risk Assessment Plans for Iceland, Norway and Sweden are compared. The main focus of the comparison relates to how the countries focus on electricity, information and communication technologies and the role of the general public in these plans.

Case studies on two recent electricity failure events in Iceland were conducted. Impacts from these events were analysed and evaluated. This process enabled comparison between actual discovered impacts from a real events and those analysed in the beginning of this thesis.

Further, two surveys were conducted. One of them aimed to evaluate the perceived and actual preparedness of the general public, in Iceland, regarding electricity failure and the other aimed to evaluate the confidence that stakeholders have in the general public regarding electricity failure.

Útdráttur

Ritgerð þessi tekur á áhrifum vegna rafmagnsleysis og afleiðingum þeirra á heimili og mikilvæga innviði á Íslandi. Útskýrt er hvernig heimili og mikilvægir innviðir eru háðir rafmagni. Einnig er reynt, út frá fræðilegu sjónarmiði, að bera kennsl á afleiðingar og ógnir sem þessi tvö viðfangsefni kunna að verða fyrir við rafmagnsleysi.

Áhættumöt Íslands, Noregs og Svíþjóðar eru borin saman. Samanburðurinn lítur að því hvernig löndin taka á rafmagni, fjarskipta og upplýsingakerfum og hlutverki almennings í þessum mötum.

Tvær tilviksrannsóknir voru framkvæmdar á nýlegum atburðum varðandi rafmagnsleysi á Íslandi. Áhrif frá þessum atburðum voru greind og metin. Þessar rannsóknir veittu grundvöll til þess að bera saman áhrif frá fræðilegu sjónarmiði við áhrif sem komu í ljós frá raunverulegum atburði.

Ennfremur voru tvær kannanir framkvæmdar. Sú fyrri snéri að því að meta skynjaðan og raunverulegan undirbúning almennings, á Íslandi, gagnvart rafmagnsleysi og sú síðari snéri að mati hagsmunaaðila gagnvart undirbúningi almennings í rafmagnsleysi.

This thesis is dedicated to my parents, Páll Grétarsson and Svanhildur Jónsdóttir, and brother, Sindri Már Pálsson, who have supported me during my education.

Preface

Resilience of the general public as well as of critical infrastructure have both become popular topics in recent years. For a society to be able to function in times of crisis both the public and critical infrastructure have to be able to cope with the consequences as a whole as well as individuals. It is the authors opinion that critical infrastructure needs to become more robust against failure in other infrastructures in order to function. Further, the general public needs to become more self-reliant and less dependent on these critical infrastructures should their functionality fail.

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Abbreviations

ICT:	Information and Communication Technologies
SAR:	Search and Rescue
TETRA:	Terrestrial Trunked Radio
NSR:	Neyðarsamstarf raforkukerfisins (Electricity services, emergency cooperation)
GNSS:	Global Navigation Satellite System
ES:	Emergency services

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First and foremost I would like to thank my advisor Björn Karlsson for his limitless help and enthusiasm and my co-advisor Böðvar Tómasson for his assistance and guidance during the work of this thesis.

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1 Introduction

Electricity and communications are some of the fundamental aspects of modern societies. Ever since the beginning of the 20th century electricity has increasingly become a significant part of everyday life for people in Iceland. From a few lightbulbs in households and on the streets, giving life to the industrial revolution (Gunnarsson, 1995), to becoming the most important factor for daily activities of people and businesses in terms of communications and general operation. The past two decades communication and flow of information has increased drastically. People are constantly connected to each other and have a continuous stream of information which includes anything from general information regarding daily activities to government warnings on natural disasters or devastating weather conditions.

There is no denying that the general public has become increasingly dependent on electricity in their daily lives. People rely on numerous household essentials, from refrigerators and washing machines to televisions and mobile phones. In Iceland the electric power usage of the general public increased from around 400 GWh in 1966 to 2,200 GWh in 2003 while at the same time the population increased from around 194000 to 288000 inhabitants which is an increase in power usage of around 5.5 MWh per capita.

In the last two decades communications have become a large factor of everyday life for the general public. The internet has brought people closer together keeping them in constant communication with each other and informed regarding events and crisis. Regarding communications many risks can be considered; the general user depends on his smartphone to work throughout the day, businesses rely constantly on internet access and communication via email etc. Large companies and official authorities, such as police and rescue services, depend on emergency communication methods such as TETRA.

Communication breakdown can affect people differently depending on their daily habits or where they live. If people living in rural areas were to lose all communications they would probably be worse off than those living in urban areas. Distance from emergency services while being unable to call for aid might have more significant effect on those living rural areas. This is not an unlikely situation in Iceland since many people live in remote areas around the country.

The purpose of this thesis is inspired from the ideology that non-functioning infrastructure, especially during times of crisis, requires a lot of manpower and aid from other infrastructures in order to be repaired or to maintain its function. In these cases the resilience of the general public walk hand in hand with the capability of a society to function. For this reason the best thing for modern societies is to enable people as well as critical infrastructures to become as independent as possible and to inspire them to help themselves, thus enhancing public preparedness and infrastructure resilience.

2 Research goals and methodology

In this chapter the research goals and the methodology for this thesis are discussed.

2.1 Research goals

The goal of this thesis is twofold. On one hand impact from failure in electricity and ICT infrastructure, both in general as well as for 2 different events occurring in Iceland, will be researched. The impact will relate to other critical infrastructures and households. On the other hand an attempt will be made to evaluate the public preparedness in Iceland with respect to failures in electricity and ICT infrastructure. Further Risk Assessment Plans will be analysed considering the previously mentioned topics.

2.2 Methodology

The main focus of this thesis can be described in four parts:

- the importance of electricity and ICT infrastructure will be discussed and analysed in relation to other critical infrastructures and households;
- National Risk Assessment Plans for three countries will be compared;
- two case studies, on electricity failure, will be analysed; and
- an investigation of public preparedness will be performed supported by two surveys.

The importance of critical infrastructure in relation to each other as well as to the general public will be discussed and analysed. The goal is to determine the impact towards critical infrastructures and households should electricity failure occur. This will be accomplished through a description of critical infrastructure in general, focusing on how they are connected, to each other, and dependent on electricity. An attempt will be made to identify impact on critical infrastructures in Iceland directly from electricity failure as well as directly from ICT failure. Further, electricity based equipment in an average household will be analysed. Both analyses of infrastructure and households will contribute to a theoretical impact identification. The impact identification will focus on direct impact from electricity and ICT failure towards critical infrastructures on one hand and towards households (the general public) on the other.

The comparison of National Risk Assessment Plans will include Iceland, Norway and Sweden. An attempt will be made to evaluate the difference in how the countries approach risk from electric failure and ICT breakdown. Further, a discussion is presented on how the countries consider the role, if any, of the general public in hazardous events. This comparison will hopefully give an idea of strength and weaknesses of existing assessments and enhance future assessments.

The case studies focus on two electricity failure events that occurred in Iceland, one in the beginning of 2012 and the other at the end of 2012. The events are different from one another regarding duration of electricity failure and the area affected by it. Robles et al. claim that "threats to critical infrastructures can be classified into 3 categories, natural threats, human-caused, and accidental or technical" (Robles et al., 2008). However, the focus of these case studies will be to evaluate what impact power outages have on other critical infrastructures and households. Impact analysis for the two case studies will be based on media coverage for the two events which includes around 200 articles. Around 50 articles were reviewed for the Brennimelur case study and around 150 for the Westfjords case study. The difference in article quantity is mostly due to the difference in duration of each event. The articles were gathered with the help of Fjölmiðlavaktin, who specialize in gathering articles. The articles can be categorized into three groups; web based media, newspaper articles and live news coverage. An attempt will be made to point out negative impact from electricity failure on households as well as critical infrastructure and how the importance of other infrastructure increases when some of them lack function. Conducting these case studies can give a clear view of what actual threats entail.

Two surveys will be conducted. Firstly a public preparedness survey will be conducted to evaluate the difference between perceived and actual preparedness of the general public. Distribution of the survey will be internet based and sent out to a random group of around 1200 individuals. The participants will be reached out to with the help of the Social Science Department of the University of Iceland. The findings from the theoretical impact identification as well as impact identification from the case studies will contribute to the structure of the survey. Previously conducted surveys in other countries will contribute to the construction as well. Secondly a stakeholder survey will be conducted to evaluate thoughts of government agencies, Search and Rescue, distribution companies, etc. regarding public preparedness as well as their concerns on electricity and ICT infrastructure. The findings from the surveys will hopefully give an overview of public preparedness in Iceland.

3 Infrastructure and households

The aim of Chapter 3 can be described with the following subjects:

- general description of connections between infrastructures and impact towards them from insufficient electricity supply;
- description and analysis of critical infrastructure and the average household in Iceland in relation to electricity dependence; and
- an impact identification on critical infrastructure and households in relation to failures in electricity and ICT infrastructure.

The purpose of this chapter is to identify the impact on infrastructures and household in relation to electricity failure from a theoretical standpoint. Findings from this chapter will then be used: as a comparison for impacts included in the National Risk Assessment Plans, as a comparison for actual impacts discovered in the case studies, and as a contribute to the construction of the surveys.

3.1 General on infrastructure

According to The American Heritage Dictionary the term "infrastructure" is defined as:

> "The basic facilities, services, and installations needed for the functioning of a community or society, such as transportation and communications systems, water and power lines, and public institutions including schools, post offices and prisons" (Harcourt, 2014).

Insufficient function of one critical infrastructure can have a severe consequence on other critical infrastructures. Robles et al. (2008) claim that "if the transportation infrastructure will be damaged, other infrastructure like postal and shipping, emergency services and other infrastructures will also be affected". Robles et al. (2008) linked critical infrastructure together as seen in Figure 3-1.

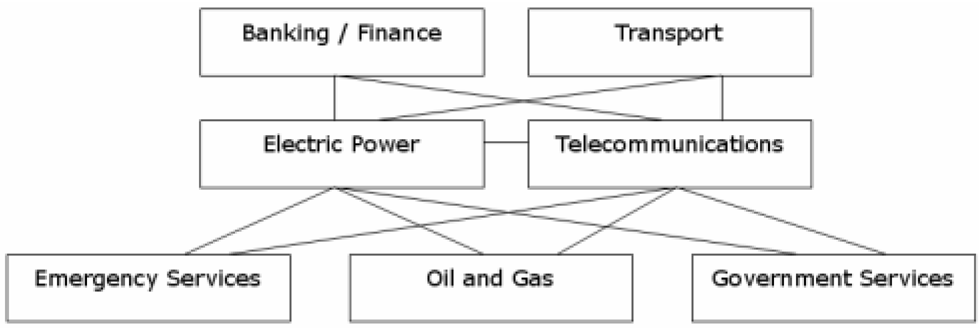


Figure 3-1: Connection between critical infrastructures. Electric power and telecommunications appear to play an important role in the function of these infrastructures. Retrieved from (Robles et al., 2008).

Figure 3-1 clearly demonstrates critical infrastructure dependence on electricity and ICT infrastructure. Although the statement quoted above from Robles et al. concerns transportation infrastructure, the same applies for other critical infrastructures. Emergency services equipped with emergency power would not suffer directly from failure in electricity infrastructure. However, the emergency services still require ICT systems which depend directly on electricity in order to function properly. This concludes that the resilience of emergency response units walks hand in hand with the resilience of electricity.

Bruneau et al. (2003) focused on a framework to assess and enhance the seismic resilience of communities from earthquakes. They point out that the resilience of both physical and social systems can be looked at as four dimensions that are linked together. These dimensions consist of a technical dimension of resilience that refers to the ability of physical systems to perform, an organizational dimension of resilience that refers to organizations capacity to manage critical facilities, a social dimension that consists of measures designed to reduce negative impact from negative consequences on communities when critical services are lost, and an economic dimension that focuses on direct and indirect economic losses. Bruneau et al. (2003) named these dimensions TOSE , or Technical-, Organizational-, Social- and Economic dimension, and linked them to critical infrastructures as seen in Figure 3-2.

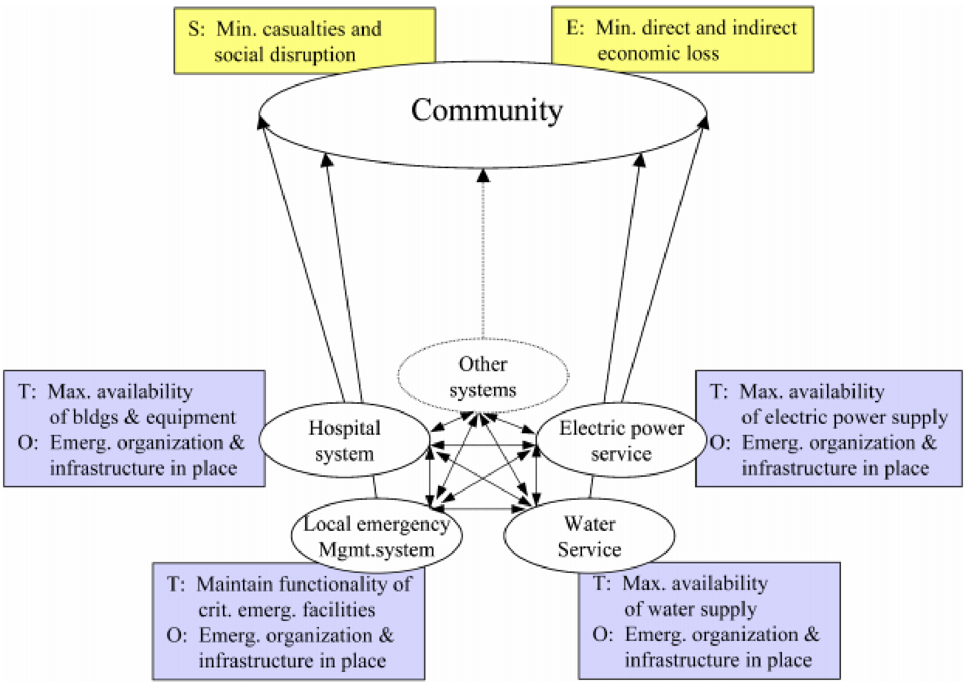


Figure 3-2: Resilience dimensions (TOSE) connected to critical infrastructure. Retrieved from Bruneau et al. (2003).

Figure 3-2 demonstrates how the technical and organizational dimensions relate to reacting to failure in each infrastructure and maintaining their performance. However, the social and economic dimensions relate to social and economic impact towards a community.

Studies have been conducted regarding impact from electricity failure on critical infrastructures and the general public. Beatty et al. (2006) investigated the Northeast blackout of August 2003 which resulted in power failure in all five New York City boroughs and lasted for 52 hours the longest. They interviewed people who experienced the blackout and focused on health effect from the event. They found that during the blackout four out of 75 hospitals in the city were temporarily without electricity despite having emergency generators. A 24-hour emergency mental health referral service maintained operation. However, it had to be contacted through the telephone number that was usually devoted to faxing. This was caused by failure in the digital phone system. Other communication troubles occurred. As a result DOHMH (Department of Health and Mental Hygiene) employees were unable to call the employee centre to acquire information regarding if, when and where they should report for work.

Another study covering the same event was conducted, focusing on change in mortality rate during the blackout. Anderson and Bell (2011) found, according to hospital reports, that total mortality rate rose 28% during the blackout resulting in approximately 90 excess deaths. All age groups were affected, however the age group of 65-74 seemed to be most susceptible. The study showed clearly the negative impact that electricity failure can have on health care infrastructure.

Following the New York City blackout a report was conducted pointing out impacts and issues regarding the event. The report included emergency response, communications, transportation and public health, safety and preparedness. Emergency response findings demonstrated inconsistent command and coordination between command centres, lack of emergency dispatch efficiency etc. Faults in communications included loss of service at Verizon central office, overload of the cellular network following the emergency, overload in 911 call volume etc. Troubles in transportation included widespread transportation outages resulting in blockages and complete loss of subways systems, lack of traffic signals at intersections etc. (Alper & Kupferman, 2003).

3.2 Critical infrastructure electricity dependence

In this section critical infrastructure dependence on electricity will be analysed. Including those being of greatest value regarding a functional society and public safety. Critical infrastructures consist of many systems, agencies and services and have over the last decades become increasingly dependent on electricity in order to function. The following sections will describe the infrastructures in Iceland that are considered critical, these infrastructures are:

- ICT – Information and Communication Technology;
- energy production and supply;
- health care and first responders;
- water supply and food;
- transportation; and
- financial systems.

3.2.1 ICT

ICT or Information and Communication Technologies represents a variety of different systems. Phone, internet and radio networks fall under the ICT systems as well as direct communication networks for other infrastructures. All parts of the country, which are inhabited, have connections to these systems. However, some parts are more fragile than others. Cell phone coverage in remote areas can be very limited. All of these systems depend on electricity to function which makes them vulnerable. Cell and smart phone use has increased significantly over the past two decades while normal line phones are used less than before (Þ. Jónasson, 2015). Iceland depends on submarine cables connected to Europe and America for internet usage. The cell phone network depends on transmitters in order to function. These transmitters require a constant source of electricity to function and are equipped with emergency batteries, which normally last around 24 hours (J. Á. Sigurjónsson, 2015). Considerably the most robust system in the ICT category is the landline or phones which draw their power directly from the phone line. The landline also depends on constant source of electricity, however, the operation stations are equipped with oil based backup generators (Þ. Jónasson, 2015).

TETRA-system

The TETRA system is owned by Öryggisfjarskipti ehf. and operated by Neyðarlínan (J. Á. Sigurjónsson, 2015). The majority of its users consists of first responders. Other parties that are dependent on the TETRA-communication are large industries, etc. The system consists out of a central hub, located in Skógarhlíð 14 Reykjavík, and 157 TETRA-transmitters (BTS, Base Transceiver System) located across the country. The BTS's are located in their own facilities or facilities owned by other companies (Gunnarsson, 2013).

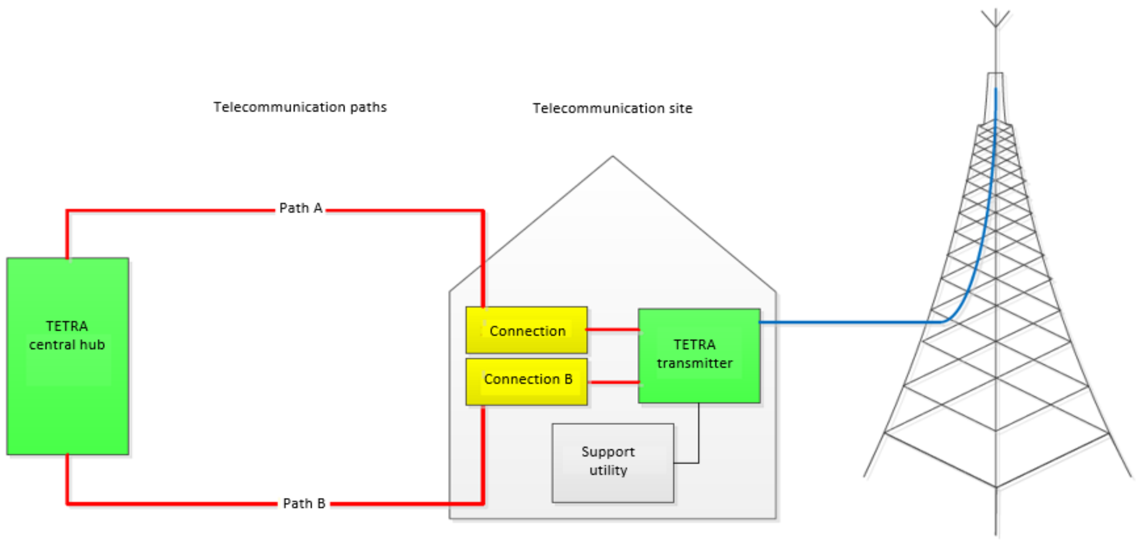


Figure 3-3: A simplified model of the TETRA-system setup. Based on a figure from Gunnarsson (2013).

Figure 3-3 shows a simple model of a TETRA system. Two different telecommunication paths transport communication between the TETRA-central hub and the telecommunication sites that host the TETRA-transmitters. These sites contain emergency power for 48 hours in general, however, some sites have only 24 hours (Gunnarsson, 2013).

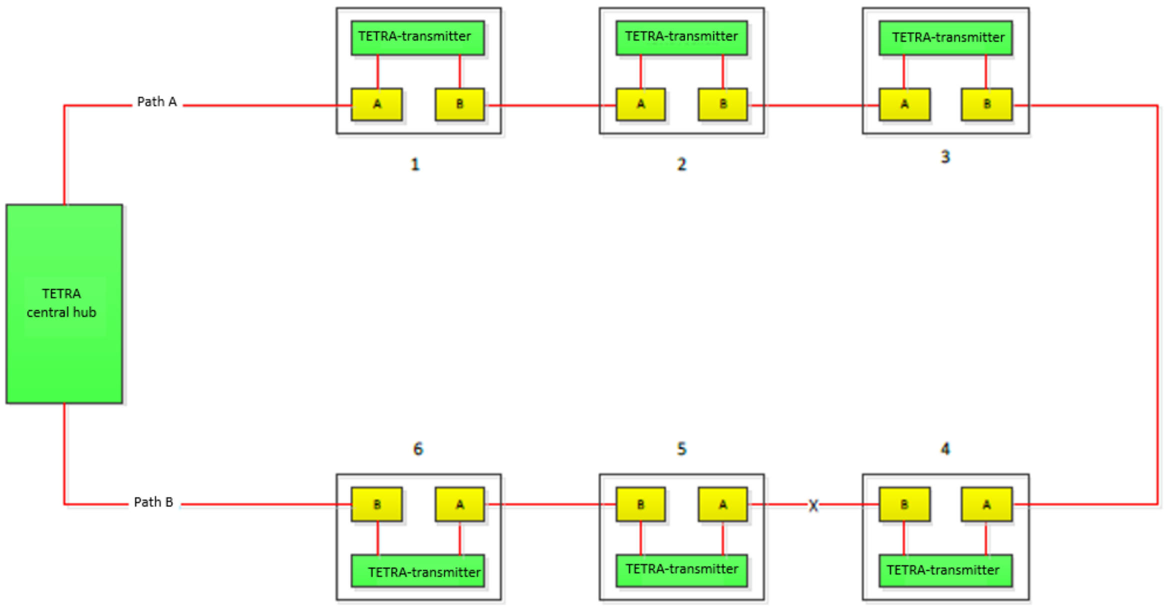


Figure 3-4: TETRA-transmitters connection. Transmitters are connected in a circle creating redundancy when communication paths are severed. Based on a figure from Gunnarsson (2013).

Figure 3-4 shows how TETRA-transmitters are connected forming a circle. With this setup the transmitters have a redundancy when one communication path fails. In case of failure between transmitters 4 and 5 it would result in transmitters 1-4 drawing their power from path A and transmitters 5 and 6 drawing their power from path B. In normal conditions all of the transmitters would draw their power from path A (Gunnarsson, 2013).

The TETRA-system is not without flaws. The system is dependent on electricity making it vulnerable when faced with power failure. The central hub for the network is equipped with a backup power generator that maintains its function of the central system until it runs out of oil. The TETRA-system is dependent on telecommunication sites from other companies that have emergency power of 24 hours. These sites are not defined as safety communication sites that make certain parts of the system weaker. They are therefore less resilient than standards made by TETRA and most of them do not have any backup that lasts as long as equipment operated by TETRA (J. Á. Sigurjónsson, 2015).

3.2.2 Energy

Energy consumption in Iceland is one of the highest in the world when use per capita is considered. Around 20% of the energy used is imported and around 80% is domestic renewable energy. The consumption can be explained by the amount of energy intensive industries such as aluminium smelters. However, in Iceland, the fishing industry and the general user consume a lot of energy compared to other countries. Figure 3-5 shows the energy consumption for the general user in Iceland (Orkusetur, 2011a). The consumption is separated into electric and geothermal energy, produced in Iceland, and oil.

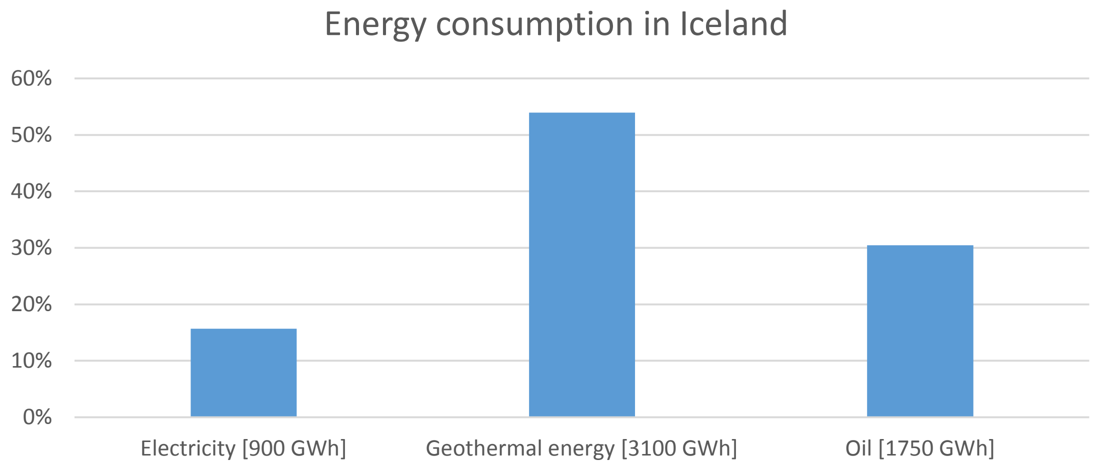


Figure 3-5: Energy usage of the general public in Iceland. Based on a figure from Orkusetur (2011a).

Electricity power sources in Iceland

In Iceland the main source of power is hydropower and geothermal power. In Iceland 99% of all electric energy is produced through renewable energy sources (Landsvirkjun, 2014). Around 73% of the production is hydropower, 27% is geothermal power and only 0.01% comes from diesel based generators (Íslandsbanki, 2012).

Iceland has nearly 100 hydro power plants (Figure 3-6). The largest ones ranging from 48 to 690 MW (Orkustofnun, 2013a). Dams in hydro power plants serve as energy storage making them dependent on precipitation. Threats towards dams also include natural disasters and sabotage which could affect Iceland's energy supply drastically.

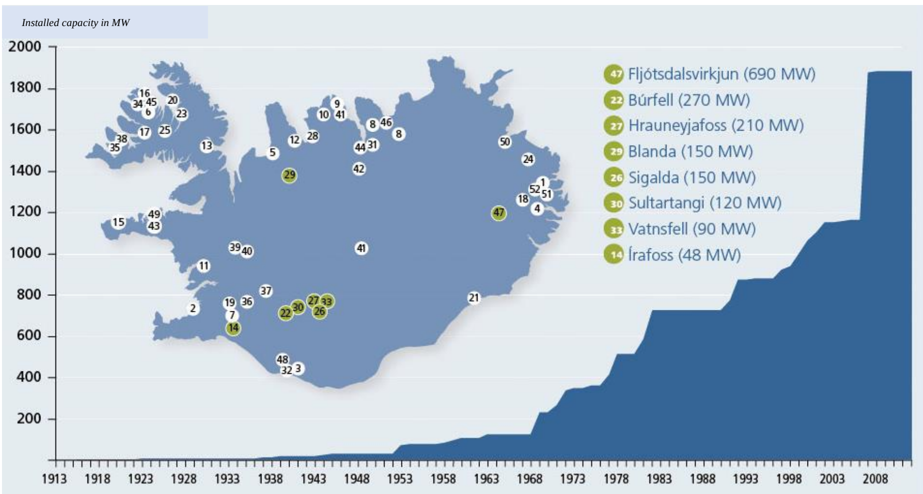


Figure 3-6: Main hydro power plants in Iceland. Numbers represent each power plant and the largest ones are specially listed (green dots), retrieved from Orkustofnun.

The Mid-Atlantic Ridge cuts through Iceland making it part of two tectonic plates. The unique position of the country enables production of electricity from geothermal power plants. The largest geothermal plants in Iceland are Hellisheiðarvirkjun, Nesjavallavirkjun and Reykjanesvirkjun (Figure 3-7).

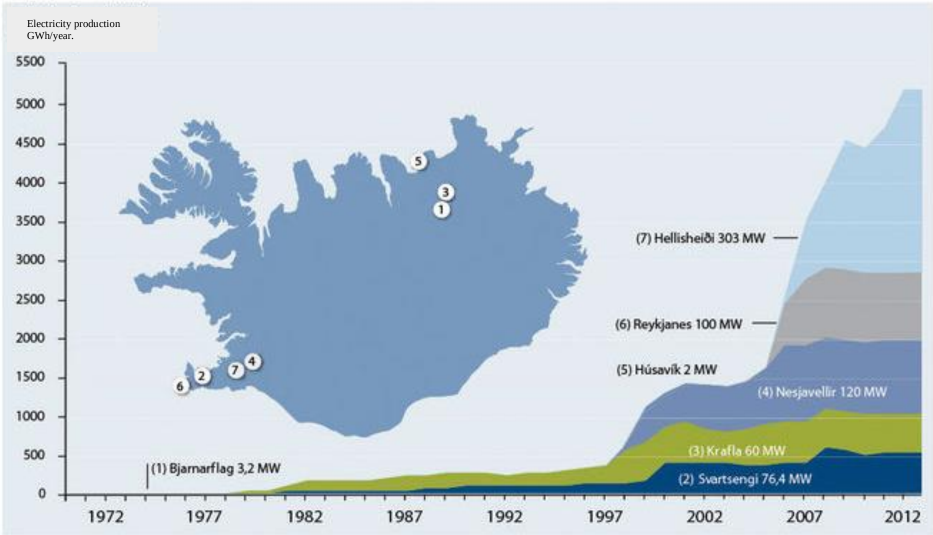


Figure 3-7: Geothermal plants in Iceland. The largest geothermal plants are Hellisheiði nr. 7, Nesjavellir nr. 4 & Reykjanes nr. 6.

Three companies in Iceland produce 97% of all the electric energy for the country. The largest one, Landsvirkjun, produces 71% and relies mostly on hydro power plants. Second largest is Orkuveita Reykjavíkur with 19% of production and the third is HS Orka with 7%, which focus mostly on geothermal energy plants. There are few other producers in the country including Orkusalan (1.5%) and Orkubú Vestfjarða (0.5%) (Orkustofnun, 2013b).

Electricity distribution network in Iceland

Iceland is mostly inhabited near coastal areas leaving the centre of the country, the highlands, uninhabited. This is one of the reasons that the electric distribution network in Iceland circles the country rather than crossing it. Figure 3-8 shows the main distribution network in Iceland, these lines are operated fully or in part by Landsnet. Distribution lines, which reach the general consumer and are not included in the figure, are owned and operated by smaller energy companies.

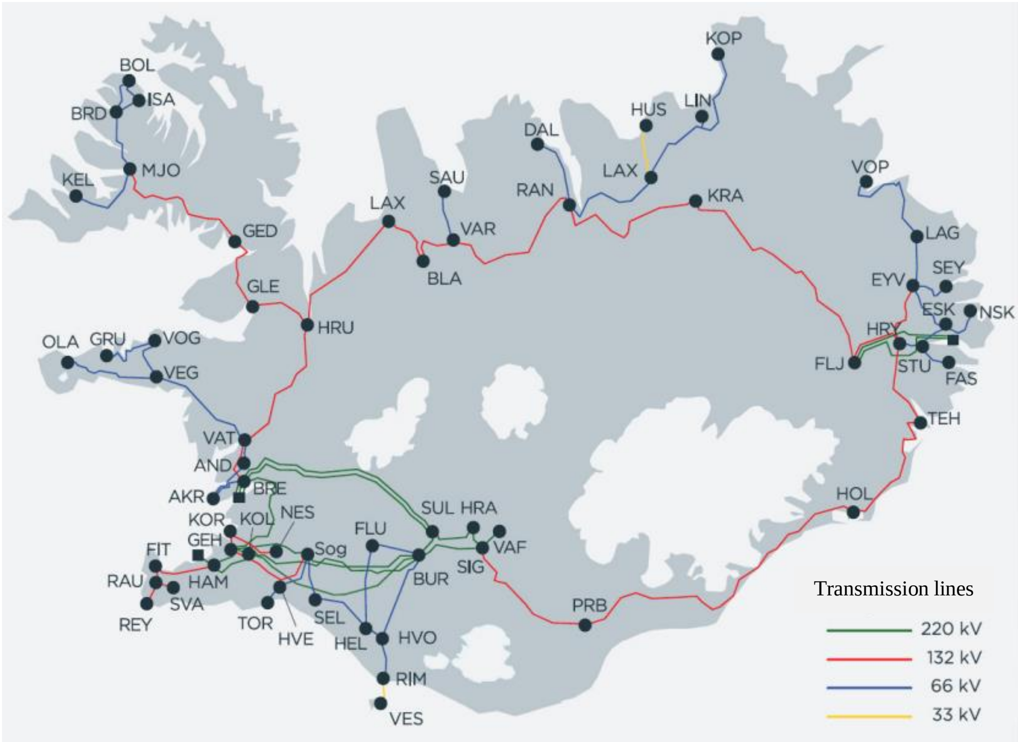


Figure 3-8: Main transmission lines in Iceland. Lines displayed transport electricity from power plants to substations and further throughout the country. Retrieved from Landsnet.

"The main electricity distribution network in Iceland covers all 66 kV transmission lines and higher and also a few 33 kV lines… Furthermore the network covers all the main substations in Iceland" (Landsnet, 2013). As seen in Figure 3-8, transmission lines in the distribution network are in four different voltage groups, 220 kV (green), 132 kV (red), 66 kV (blue) and 33 kV (yellow). The green lines are mainly transmission lines between power plants, energy-intensive industries and substations which then transfer electricity to the red lines. The red lines distribute electricity to different regions of the country where it is transferred to the blue lines. The blue lines distribute the electricity within a certain part or region of the country. The yellow lines have the same purpose as the blue lines except they have lower voltage. The distribution network towards the capital area is fairly strong considering the number of transmission lines that travel towards it from hydro and geothermal plants (Figure 3-8). However, regions solely connected to the red line are much more vulnerable to failure in the distribution network since the red line is only a single line with no backup. Nevertheless, geothermal plants in the North and a hydro power plant in the east do contribute if distribution from the main sources is reduced. Threats towards transmission lines in Iceland include storms, salinity, sabotage, etc.

3.2.3 Health care and first responders

Health care

The health care system in Iceland mainly consists of hospitals and health care centres. There is one main hospital along with a few clinics and healthcare centres servicing the capital area which also serve the rest of the country in terms of specialized procedures. There are also four hospitals servicing other parts of the country located in; Akranes, Ísafjörður, Akureyri and Neskaupstaður. Health care centres are operated in most of the larger towns around the country. Emergency rooms are located in the hospitals mentioned above and open 24/7. Further, nursing homes for the elderly are located in many places around the country.

Figure 3-9: A part of the national hospital in Reykjavík.

Most of lifesaving operations in Iceland have emergency power of some sort that can service them for a short period of time (Almannavarnadeild, 2011). On a daily basis hospitals make complex operations with all sorts of electric equipment, patients are monitored through electric devices and some of them need electric equipment to stay alive while in a hospital. Thus the health care system is highly dependent on electricity to function properly.

First responders

Emergency response units are located in larger towns in Iceland. They are dispatched from the emergency call centre, Neyðarlínan, located in Skógarhlíð 14 Reykjavík. The call centre handles all emergency calls from the public around the country and dispatches fire departments, police, Search and Rescue, ambulances and the Coast Guard.

In Iceland there are nine police jurisdictions in total. According to changes in 2014, on the Police Act of 1996, the Parliament agreed to reduce the jurisdictions from 15 to 9, with a chief of police in each of them (Alþingi, 2014). Apart from general and daily duties of law enforcement the police overseas tasks regarding civil protection on behalf of the Minister of the Interior. Further, the police is the highest form of authority regarding search and rescue mission on land. The Police Commissioner runs a department called the Civil Protection Defence (Almannavarnir) in Iceland, from this point referred to as CPD or civil defence. The CPD is operated according to law no. 82/2008. The goal of the civil defence in Iceland is to prepare, plan and perform measures which aim to prevent and reduce, as much as possible, negative impacts such as injury or health risk towards the general public. Furthermore, to reduce and prevent negative impact from natural disasters, people, plague, war or other reasons (Alþingi, 2008).

Other units classified as first responders are Search and Rescue units in Iceland, from this point referred to as SAR. The SAR in Iceland consists of approximately 5000 volunteers around the country to service regarding storms, search of people and complicated rescue missions etc. These SAR units are very important and a vital part of rescue operations in Iceland.

Law enforcement as well as other first responders are highly dependent on electricity. First and foremost the majority of communication between units and headquarters are through emergency telecommunication. Coordination of these units is therefore highly dependent on communications. Further, the general public needs to be able to communicate with them. Therefore, in case of a blackout, it is not only important that this infrastructure is secured in terms of electricity and communications but also the ability of the general public to communicate to them in case of emergency.

3.2.4 Water supply and food

Water supply

Iceland holds great quantities of fresh water used by the general public. Cold and hot water is distributed through supply lines all over the country from local reservoirs or ground water areas. The cold water is used both for human consumption as well as other use such as washing, showering, etc. The hot geothermal water is used for other daily activities such as showering and house heating. Though some households depend directly on electricity for house heating, the vast majority of the households are heated with geothermal water. The water supply system is dependent on pumps in order to distribute the water throughout the system. These pumps are run on electricity making water distribution vulnerable to power failure.

Food

Food safety and security is most often viewed from a health perspective and consumer safety. However, for this analysis food security relates to enough food supply where both storage and distribution of food is relatively dependent on electricity. A part from goods that can be stored at room temperature for significant amount of time, fresh food and food that depends on cold storage are vulnerable. This applies to households, retailers as well as suppliers.

3.2.5 Transportation

Transportation, on land, air and sea, is a part of critical infrastructure for modern societies. When considering threats towards transportation they can vary greatly between different types of transportation.

Land transportation

In Iceland land transportation mainly consists of vehicles and other road transportations since no trains are operated in Iceland. Risk factors for traffic safety can vary between different parts of the country and season. Factors include narrow bridges, gusts from mountains, too few alternate routes, dangerous parts of the road, natural disasters, etc. (Almannavarnadeild, 2011). Considering power failures regarding land transportation the impact on roads and highways in rural areas could be viewed as minimum since these roads do not depend on traffic lights nor are there any road lights to improve visibility. However, road tunnels are dependent on electricity to maintain operation. Towns, especially the capital area, where traffic can be heavy at a certain time of day, can suffer from the loss of electricity due to possible traffic light malfunction. The lack of traffic lights in urban areas can result in a very slow traffic and even car accidents, risking the health and safety of the general public. The Road Administration in Iceland operates a website, www.vegagerdin.is, where they monitor road conditions all over the country. The general public can visit the site in order to decide which road to take or if they should drive at all. These systems are dependent both on electricity and telecommunications to function properly making them vulnerable in case of power failure.

Air transportation

Air transportation in Iceland has increased significantly in the past decade. International air carriers in Iceland consist mainly of two companies, Icelandair and WOW air, and domestic flights are primarily through Flugfélag Íslands and a few other smaller air carriers. The largest and most specialized part of the healthcare system in Iceland is located in the capital area. Since Iceland is sparsely populated emergency ambulance airlines are highly relied on by health care providers in rural areas. Ambulance flights in Iceland are mainly operated by one airline, Mýflug air, which performs nearly all ambulance flights in Iceland. Mýflug receives between 400-500 ambulance flight requests every year, most of them domestic (Mýflug, 2010). The Icelandic Coast Guard also performs ambulance flights with airplanes and helicopters, however their main focus is to monitor the sea around Iceland; fishing control, pollution control, sea ice control and other research. They also operate in search and rescue missions where SAR units and the police Special Forces need transport. Air traffic is highly dependent on electricity as well as ICT. Insufficient electricity supply for airports can lead to total breakdown of management as well as hazardous landing conditions when ground landing lights lack electricity. Breakdown in ICT could cripple air traffic control as well as aircraft communication and navigation systems would malfunction.

Sea transportation

Iceland is highly dependent on sea operation, both as industry and transportation of food and other goods. Electricity failure could not be considered as critical when it comes to sea transport, however, failure in ICT could have drastic effect. This failure could result in ships being unable to call for aid and failure in their navigation systems.

3.2.6 Financial systems

Iceland's financial system is highly dependent on electricity and ICT, both for international trading as well as everyday transactions from the general public. In Iceland the vast majority of the population relies on debit or credit cards in order to purchase items. Failure in electricity and ICT systems would affect every individual or company and could lead to people being unable to purchase items as well as increased management in stores would be required in order to control cash flow.

3.3 Critical infrastructure connectivity

In this section electricity dependence of critical infrastructure will be considered. This enhances our ability to determine threats that may occur towards critical infrastructures during electricity and ICT failure.

Understanding of interdependency between critical infrastructures is crucial in the case of hazardous events. Pederson et al. (2006) argue that "In chaotic environments such as emergency response to catastrophic events, decision makers should understand the dynamics underlying the infrastructures. Failure to understand those dynamics will result in ineffective response and poor coordination between decision makers and agencies responsible for rescue, recovery, and restoration". Further, they made a simple schematic to demonstrate the complexity of interdependency between critical infrastructures, see Figure 3-10. They demonstrate the importance of electricity and ICT for other critical infrastructures to function. In Figure 3-10 the solid lines crossing sectors and connecting nodes, represent internal dependencies, while the dashed lines represent dependencies that also exist between different infrastructures. According to the figure, water and ICT infrastructure are interdependent on electricity through sewer pumping and telephone services respectively. Further the interdependence between ICT infrastructures to emergency services is demonstrated making emergency services dependent on electricity. Although the figure demonstrates these connections it could be argued that the interdependencies work both ways. By looking at a scenario where energy supply would fail in a remote area, methods of transportation become crucial in order to resolve the situation. Further, energy distribution and manufacturing is dependent on ICT systems for monitoring, operating etc.

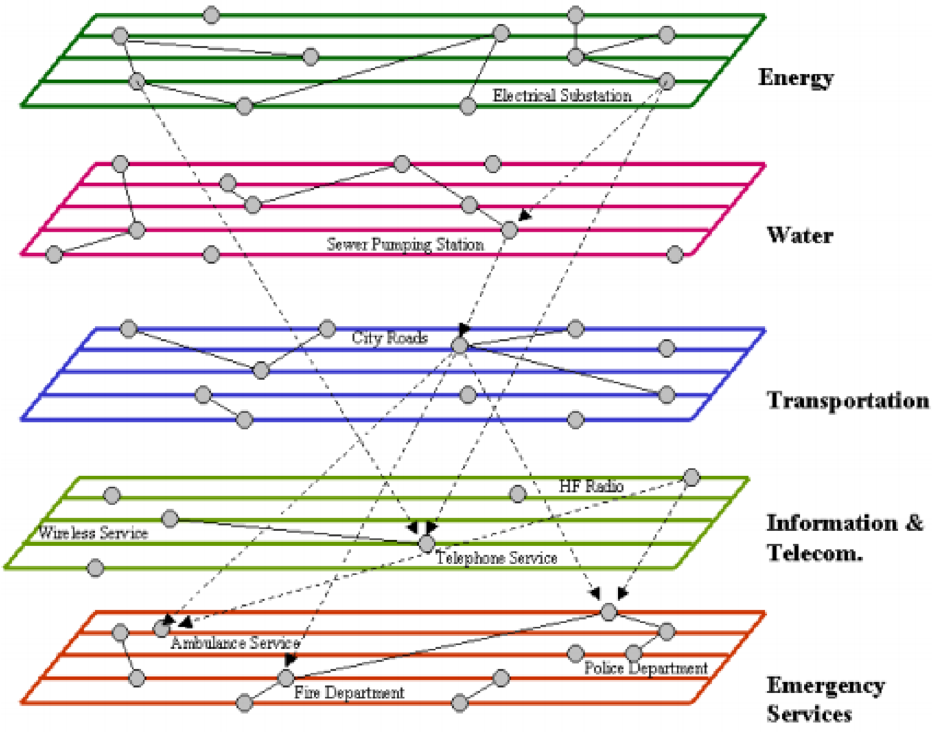


Figure 3-10: Critical infrastructures interdependencies. Solid lines crossing sectors and connecting nodes represent internal dependencies. Dashed lines represent dependencies that exist between different infrastructures (interdependencies). Retrieved from Pederson et al. (2006).

The Federal Communications Commission (The FCC) describes interdependencies between infrastructures in greater detail with a similar approach referring to a diagram made by the National of Regulatory Utility Commissioners, see Figure 2-11. They show that „there is a great deal of interdependency between the Communication Sector and a number of the functionaries within the utility community" (FCC, 2011). Where utility refers to electric power, oil, gas and water. They further point out that the dominant dependency for the Communication Sector is electricity… weather it is a switching centre, radio relay site, cell site, other remote site, or any other facility (FCC, 2011).

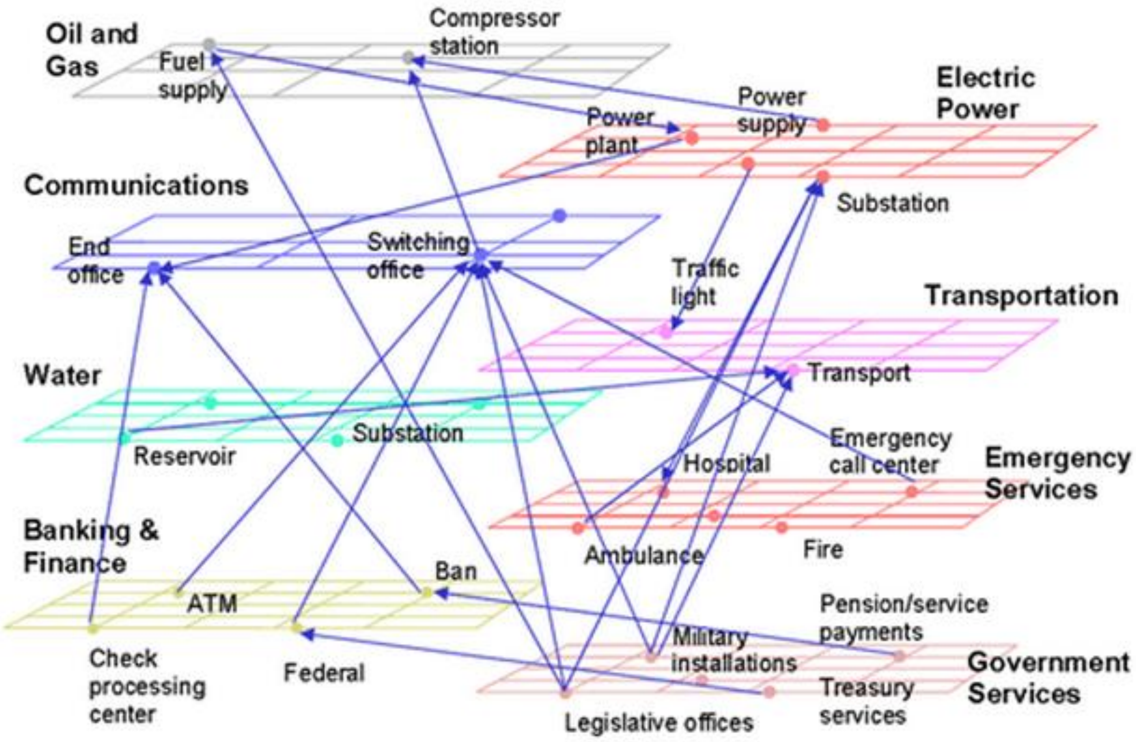


Figure 3-11: Critical infrastructures interdependencies. Blue lines show how critical infrastructures depend on each other to function. Retrieved from the Federal Communication Commission (2011).

As Figures 3-10 and 3-11 show, the interdependencies between critical infrastructures are highly complex. Understanding these connections is crucial in evaluating the impact caused by one or more of them malfunctioning. Therefore key personnel as well as the general public need to be aware of these connections. The key aspect is to realise that infrastructures such as first responders rely on ICT in order to coordinate and communicate. ICT is dependent on electricity thus first responders are dependent on electricity. Though emergency services depend on electricity through communications it does not neglect the fact that they are not also directly dependent on electricity. Both key personnel and the general public have to be able to function during electricity failure, with alternative heating sources or cooking methods, and ICT failure, with emergency communications or old fashion hardwired phones that draws power directly from the telephone line.

3.3.1 Impact on critical infrastructure from electricity and ICT failure

A deep understanding of the consequences from electric and ICT failure on other infrastructures is highly important. In Figures 3-12 and 3-13 an attempt will be made to account for impacts, from electricity failure and communication breakdown respectively, on other infrastructures. Impacts focused on in this section will not include causes of electricity or ICT failures such as sabotage, bad weather etc. Rather the assumption is made that these system have failed and no longer contribute to the other infrastructures.

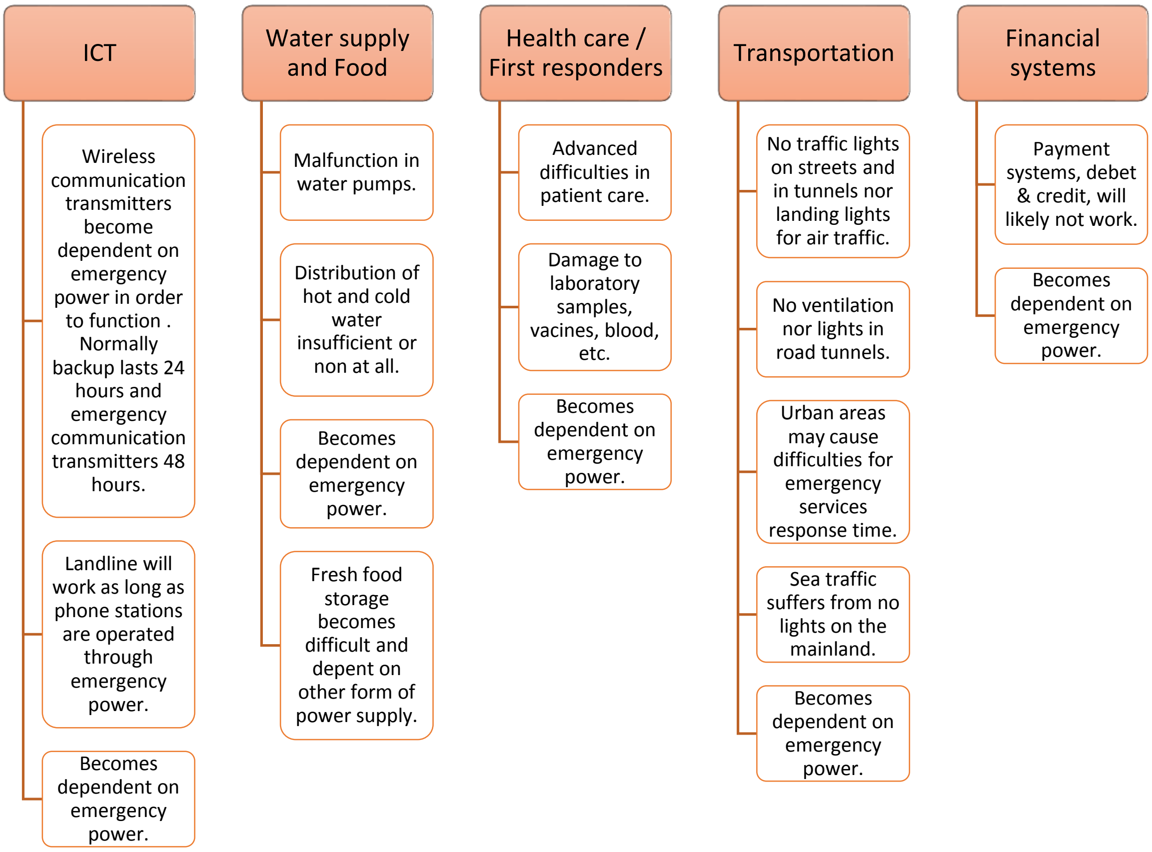


Figure 3-12: Theoretical direct negative impact from electricity failure on other critical infrastructure; ICT, Water supply and Food, Health care/First responders, Transportation and Financial systems.

As Figure 3-12 demonstrates the impacts from electricity failure on critical infrastructure are widespread. Though the figure does not include every aspect of failure that would appear in these infrastructures, it demonstrates the importance of a functioning electricity distribution in a modern society.

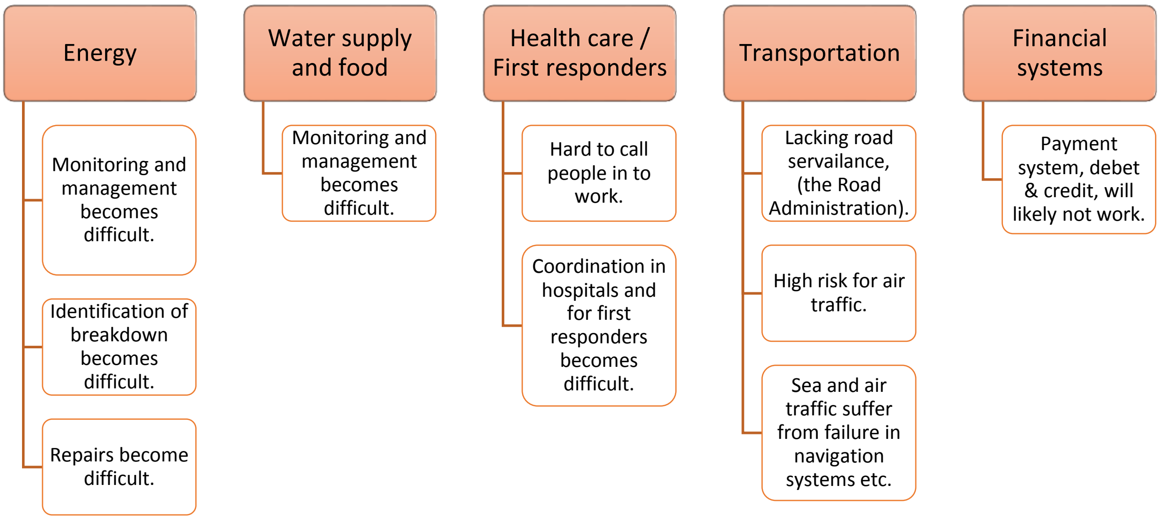


Figure 3-13: Theoretical direct negative impact from ICT failure on other critical infrastructures; Energy, Water supply and Food, Health care/First responders, Transportation and Financial systems.

Impact from ICT failure on critical infrastructure (Figure 3-13) seems to be less serious than from electric failure (Figure 3-12). However, scenarios where impacts from electricity and ICT failure collide the threat towards the general public and the importance of keeping critical infrastructure functioning increases drastically.

3.4 Households electricity dependence

In this section electricity dependent equipment in an average modern household will be identified. The purpose is to analyse which impacts towards households could possibly appear during electricity and ICT failure and to rationalise which of them are most important.

3.4.1 The average household in Iceland

According to Orkusetur (2011b) the average household in Iceland consumes around 5 MWh of electric energy apart from house heating. They point out that studies on energy consumption for an average household in the Nordic countries suggest that the consumption can be broken down into certain aspects (Figure 3-14).

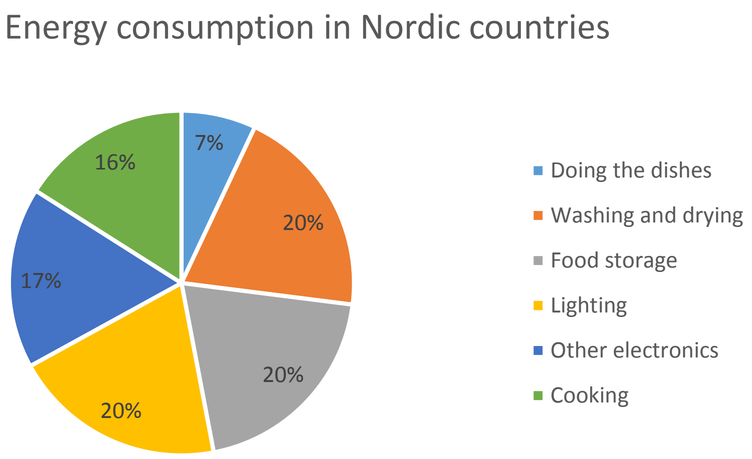


Figure 3-14: Energy consumption in the Nordic countries. The average household is broken into certain aspects that are dependent on electricity. Based on a figure from Orkusetur (2011b).

Every aspect listed in Figure 3-14 depends directly on electricity from the household in order to function. However, households are dependent on more than just internal equipment to function properly. Being able to heat a household, make a phone call, turn on a TV, etc. relies on functional infrastructures or so called utilities. In their studies Karaca et al. (2013) included water, electricity, gas, information, waste and sewage removal in their utility category. Apart from gas, Iceland dependence on these utilities is very high. Some government related programs encourage citizens to learn how to shut off their utilities (Ready, 2013b). The utilities are extremely dependent on electricity in order to function. For example, washing clothes requires the washing machine to receive electricity from the house and also to receive water from the water distribution system. Failure in the electricity infrastructure could eventually lead to the malfunction of these utilities as well as in all aspects mentioned in Figure 3-14.

In this section an attempt will be made to categorise this equipment into primary and secondary equipment and its importance for households. The primary equipment covers equipment which is dependent on a household's electricity to function such as lights, washing machine, etc. (Table 3-1). The secondary equipment covers equipment or utilities which require external functionality such as water distribution, phones, etc. (Table 3-2).

Table 3-1: Household equipment considered as primary equipment and its importance.

Primary	Not important	Important	Very important
Cell/smartphones			X
Computer		X	
Dish washer	X		
Dryer	X		
Electric cars		X	
Freezer		X	
Internet			X
Lights		X	
Radio			X
Refrigerator		X	
Security alarm			X
Stove		X	
Telephone			X
Television		X	
Vacuum cleaner	X		
Washing machine	X		

As seen in Table 3-1, various equipment is present in households that make up for everyday living and is dependent on functioning electricity. Some of them are considered more important than others. The equipment that was considered most important was mostly related to ICT. This evaluation is based on the importance of information distribution during times of crisis and the importance of the general public to be able to reach out to emergency services in case of emergency.

Table 3-2: Household equipment considered as secondary equipment and its importance.

Secondary	Not important	Important	Very important
Water supply/house heating			X
Drainage			X
Internet			X
Telephone			X
Cell/smartphones			X
Dish washer / washing machine	X		

Table 3-2 covers equipment that is dependent on more than power from the household to function. The table includes equipment in relation to water distribution and ICT infrastructure. Every item, except the dish washer, is considered very important since water distribution and ICT have a significant part to play for human survival during times of crisis.

3.4.2 Impact on households from electricity and ICT failure

In this section an attempt will be made to point out how failure in electricity and ICT infrastructure effects households. Figure 3-14 demonstrates the possible impacts that were considered in relation to each critical infrastructure after electricity failure occurs.

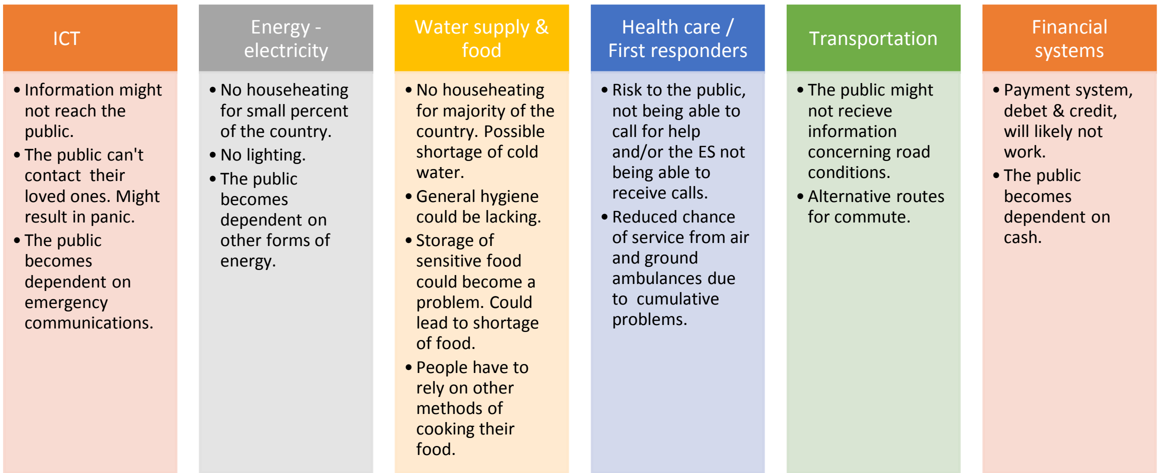


Figure 3-15: Main impact on the general public from electricity and ICT failure. The impacts are categorised by the following infrastructure; ICT, Energy, Water supply & Food, Health care/First responders, Transportation and Financial systems.

Figure 3-14 demonstrates that failure caused by electricity and ICT results in households being effected by every critical infrastructure. Though the level of threat from these impacts varies, it is very important that authorities, infrastructure personnel as well as the general public are aware of these consequences in order to reduce the negative impact when crisis occur.

3.5 Summary

In this chapter the functionality between critical infrastructures was discovered to be highly complex. A deep understanding of these systems is crucial to reveal impacts, from non-functioning infrastructures, on households and other critical infrastructures. Further, it is important for key personnel as well as the general public to understand this relationship by being aware of the consequences that they may face during failure of electricity and ICT and managing them best to their abilities. In this chapter the impact identification revealed that each critical infrastructure suffers when electricity or ICT fails. A variety of impacts can occur leading to different levels of threat. For example being unable to use a credit card to purchase items is less harmful than a family losing the ability to heat up their house. The impact identification for households demonstrated that failure caused by electricity and ICT results in households being effected by every critical infrastructure. The impact identification does not substitute for expert opinion regarding each infrastructure and should be investigated further both individually and in relation to one another.

4 National Risk Assessment Plans

The aim of Chapter 4 can be described with the following subjects:

- analysis on how authorities in Iceland, Norway and Sweden consider impact from electricity and ICT failure, along with their view towards the role of the general public during crisis; and
- a comparison of the previously mentioned subjects between the three countries.

In 2009 a decision was made to construct a framework on disaster prevention within the European Union. Member States were invited to develop national approaches and procedures to risk management including risk analysis, covering the potential major natural disasters etc. (Puigarnau, 2011). This included Sweden as an EU member, and Iceland and Norway also delivered their own. The purpose of this chapter is to analyse Risk Assessment Plans for each of the countries in order to identify the main difference in their approach. The comparison will focus on how each country approaches their assessment and their concerns regarding electricity failure along with telecommunication breakdown. Furthermore there will be an attempt to identify what part or duty, if any, the general public is supposed to deliver during crisis.

4.1 Iceland

The Icelandic risk assessment (Almannavarnadeild, 2011) is divided into natural hazards, environment and health, health care, fire safety, dangerous chemicals, buildings, and infrastructure and social security. Each part contains various events such as storms, volcanic eruptions etc. The events are then described in general where known and possible risks are mentioned. Further, each event contains a specific scenario where previous incidents are mentioned along with likelihood, mitigation methods etc. In the Icelandic risk assessment the risk for every region is considered independently. This is performed through special reports by each jurisdiction in Iceland and the key findings are published in the national assessment. A summary from the regional reports can be seen in Appendix A.

4.1.1 Electricity

Power failure can have a significant or paralysing effect on societies. In general lifesaving operations are equipped with electricity backup such as batteries or power generators. Backup power is often present in critical services such as police and fire departments and especially in hospitals. However, other operations generally lack backup power which can lead to negative impacts on various industries, production, hot and cold water supply and other critical infrastructures (Almannavarnadeild, 2011). The specific scenario, presented in the Icelandic national risk assessment for electricity, covers an undefined area that suffers electricity failure. The scenario does not address the magnitude, duration etc. of an event but only that such an event would occur. Impact from this event is considered to have widespread effect and not analysed further.

In case of power failure an emergency collaboration (NSR) has been set up. It is a collaboration platform for processing companies, transport companies, distribution companies, energy intensive companies and official parties in Iceland in case of emergencies regarding, production, transportation or distribution of electric energy (l. no. 65/2003). Many of the larger distribution companies have established emergency management where risk is evaluated officially. This includes inspection of electricity production, distribution safety through transmission lines and substations, etc.

The risk assessment points out that a coordinated nationwide plan for the whole country is needed (Almannavarnadeild, 2011). Furthermore it points out that climate change, resulting in more frequent thunderstorms, can increase negative effect on the distribution system. Thus, preparations for these events are important regarding distribution lines and constructions. Volcanic activity is also said to be a possible factor for power failure, however it is only considered for one region. Lastly it is noted that greater supply of emergency power is required.

4.1.2 ICT

Information and communication technologies have become a significant part of everyone's daily life. Awareness of the need of securing systems relying on these technologies has been growing. Safety regarding radars, air communications, radio distribution networks etc. have got to be ensured. Emergency response units are highly dependent on TETRA which could lead to great lack of communication and coordination should it fail (Almannavarnadeild, 2011).

Failures in these systems that could be harmful to the society have been pointed out. The failures cover damaged submarine cables connecting Iceland to Europe and America, a long duration of electric power failure, malfunction in fibre optic cables etc. The same applies for failures in other communication systems such as TETRA. Serious failures in these systems are considered to cause a significant impact on safety, economy, transportation and the common good. The specific scenario for ICT is a rather broad view of communication breakdown both domestic and to other countries and cyber threats (Almannavarnadeild, 2011).

4.1.3 Role of the public

In Iceland, the national risk assessment (Almannavarnadeild, 2011) hardly addresses the role of the general public. However, the assessment looks at dangers that could affect the general public and how key personnel, government etc. have a responsibility to reduce negative impact towards them. It points out that the resilience of people has to increase in the future by raising awareness. Further, the public needs to be educated on natural hazards and insurance. No discussion is made regarding the role of the general public in times of crisis; whether the general public should be self-reliant for a certain time period during a crisis, if they should rely on evacuation, or should get themselves out of dangerous situations.

4.2 Norway

In Norway the Risk Assessment Plan mainly consists of two parts. One covers natural events and the other major accidents. Each part covers a variety of cases, such as extreme weather, etc. Each case is described in four parts, with a background where previous events are inspected such as previous hurricanes etc. and other events regarding each case. Risk from those events is both observed and speculated with expert consulting. Prevention and emergency preparedness for these events, both what has been done and what has to be done, is analysed. Lastly a specific scenario is presented where an event that is considered very extreme, but at the same time realistic, is described an analysed. In these scenarios they assess probability of the event and its consequences, which are broken into life and health, nature and the environment, economy, societal stability, and capacity to govern and territorial control. Further, they make an uncertainty assessment which is often based on their knowledge of the scenario, if it has happened before, etc.

4.2.1 Electricity

Power failure is not singled out as a specific event such as “extreme weather” but rather as a by-product from certain events. Norway recognises events that can lead to electric failure, such as great storms and flying objects that would damage the distribution network, a lack of precipitation that would lead to insufficient water supply for hydro power plants and “space weather” such as solar storms. The results would be limited or no power supply leading to power rationing to keep critical functions of society operational (DSB, 2013).

For a specific “worst case” scenarios they address electricity in two ways. One being a great storm near Oslo where the impact includes damage to power distribution and the other specifically associated with electricity covering long-term power rationing. In the second scenario areas affected have no supply of power. Crucial societal function such as hospitals are given priority to electricity usage while other consumers receive limited power. In terms of detail they cover the power rationing, to the general consumer, which they conclude is 4 hours 2 times a day. Further, they speculate that the power rationing “will lead to social unrest and reactions such as anger and aggression” (DSB, 2013). For a 100-year solar storm they estimate “hundreds of thousand inhabitants will be affected by a loss of power for up to ten hours, and subsequently an unstable power supply for the entire day that the storm lasts” (DSB, 2013). They also argue that this impact will mostly affect vulnerable groups like the elderly. However, they estimate that this type of event will not lead to a critical situation and evacuation will not be necessary (DSB, 2013).

4.2.2 ICT

There are no specific events for ICT failure in the Norwegian risk assessment and their attention on ICT is less than on electricity. In terms of risk from the main events ICT is neglected or mentioned in terms of possible risk from electric failure along with other critical infrastructure (DSB, 2013).

“Worst case” scenarios are not created specifically for ICT failure in Norway. For a long-term power rationing scenario they indicate that ICT systems will be hit hard along with all networks that transmit electronic information and other critical function that depend on electricity supply (DSB, 2013). For a rockslide with advance warning they assume “between 1,000 and 10,000 people will experience disruption in their everyday lives… and problems with communication via ordinary ICT systems” (DSB, 2013). Further they indicate that commuters travelling to the area will be effected by power supply disruption (DSB, 2013). Lastly they address ICT systems for a 100-year solar storm scenario where “disturbances in high-frequency (HF) communications… will affect both air traffic and military users of such communication bands” (DSB, 2013). Further, they assume that “over a 100,000 people will be unable to use ordinary electronic communications or public Internet-based services" (DSB, 2013). As a consequence of these failures they address the reduced ability of emergency services, disruption in satellite signals which would impact financial transactions, control systems telecommunications etc. (DSB, 2013).

4.2.3 Role of the public

Public action is not particularly considered apart from social unrest and possible aggression from people during crisis. However, the general public is assumed to avoid crowds during pandemics and is considered being a source of information concerning forest fires (DSB, 2013).

4.3 Sweden

Sweden's national risk assessment (MSB, 2012) uses scenario analysis. Firstly they demonstrate what the scenarios include such as school shooting, failure in large damn, etc. Secondly they describe the thematic background including similar events that have happened in the past. Thirdly an impact-, likelihood-, and uncertainty assessment is performed for the scenario. The Swedish plan has a specific view towards risk assessments since they do not consider general events, such as "bad weather", but only specific scenarios (MSB, 2012).

4.3.1 Electricity

Sweden considers electricity failure as a by-product of other scenarios. One is a "prolonged heat wave" that includes a possible direct impact on electrical wires and cables and an indirect impact on the electricity supply from limited precipitation. They point out high level of uncertainty regarding the effects from this scenario (MSB, 2012). The other scenario relates to "failure of a large dam on a river" where the impact from the flood on transmission lines is considered along with disruption in the electricity supply (MSB, 2012). Further, in these scenarios they include a detailed analysis of causes that lead to failure and the impact from such failures. The report further recognizes a few threats regarding electric power failure such as landslides, storms, solar storms etc. Furthermore the importance of electricity in terms of infrastructures and emergencies is mentioned. They point out that electricity is an important factor in medicine supply in terms of transportation and storage. The distribution and storage along with the production of food is also considered to be threatened from power failure. Lastly they point out that payment systems are at risk from electric failure.

Sweden has had incidents in the past regarding banks getting wrong payments because of bad communication. The report also recognizes the importance of the payment system to work in order to enable people to acquire important goods for their daily life (MSB, 2012). Sweden does not consider a special case for electric power failure as a whole but rather series of incidents which electric failure leads to such as; disruptions in electronic communications, disruptions in payment systems and disruptions in energy supplies. When it comes to disruptions in energy supplies Sweden seems to be keen on emergency power sources such as oil. They demand oil companies and other large parties to have a backup stockpile of oil that is sufficient to handle all normal use for 90 days. They acknowledge the fact that functioning electricity, distribution network, would fall under the disruption of energy supply. Sweden also looks at scenarios such as the impact from downtime of several nuclear reactors while at the same time water levels in hydro power plants are low. Their connection to the neighbouring countries also increases energy safety if something would go wrong. However in case of failure in the regional main network neighbouring countries could be effected as well (MSB, 2012).

4.3.2 ICT

Causes leading to ICT failure events and their impacts are mentioned in few of the scenarios. A specific scenario on a disruption in the GNSS (Global Navigation Satellite System) covers impact from telecommunications on emergency units and others depending on it. In another scenario, failure in ICT is considered as a secondary effect from a prolonged heat wave where problems in the ICT is mentioned to occur. However the uncertainty is high regarding impacts from heat waves. Another scenario that addresses communications is when a large dam fails. This could lead to water crushing communication infrastructure (MSB, 2012).

4.3.3 Role of the public

No mention is made in the Swedish national risk assessment (MSB, 2012) of roles regarding the general public.

4.4 Comparison

There are certain similarities regarding how the impact from electric power and communication failure is evaluated in the three countries. The countries evaluate potential threats causing power and ICT failure similarly. The likelihood of electric failure, or a scenario leading to one, was considered as moderate to high risk varying between the countries. ICT failure varied from very low to high risk. The low evaluation corresponds to Sweden's GNSS scenario. Scenarios, for electricity and ICT, in the Icelandic risk assessment are vaguely described and include possible mitigation methods and identification of key personnel. On the other hand, scenarios in the Norwegian and Swedish risk assessments focus more on analysing consequences and impacts from such events on infrastructure and the general public. In terms of an overall view and knowledge of the current situation of infrastructures and causes leading to hazardous events the Icelandic assessment surpasses the others. However, the Icelandic assessment is inferior regarding analysis on possible scenarios and impacts that could occur from electricity failure in which Norway gives the most comprehensive analysis. Further, the Icelandic risk assessment has poorly described specific scenarios that focus on either electricity or ICT failure where Sweden has the most detailed description in terms of ICT. When it comes to the general public one can conclude that emphasis on public preparedness or resilience is non-existent in all cases. The comparison of the risk assessment for Iceland, Norway and Sweden led to the following differences shown in Table 4-1 on page 28. Further, the comparison is more visually demonstrated in Table 4-2 on page 29. It is also worth pointing out that there was no reason to compare findings from this comparison to what was put forth in Chapter 3. Impacts covered in the risk assessment were from a broad viewpoint and thus not comparable to those in Chapter 3.

Table 4-1: Comparison of the National Risk Assessment Plans for Iceland, Norway and Sweden. The table demonstrates difference between electricity and ICT, and if the general public has some role to play in large events.

Iceland	Norway	Sweden
	Methodology	
• Dedicated chapters on events, infrastructure etc. • Least detailed dedicated scenarios.	• Dedicated chapters on most events. • Most specific scenarios analysis.	• No dedicated chapters for events. • Mildly less detailed scenario analysis than Norway.
	Electricity	
• Dedicated chapter. • Dedicated scenarios with a broad perspective. • Focus more on cause then impact. • More focus on key personnel.	• No dedicated chapter. • Dedicated and detailed scenario analyses. • Focus both on impact and cause. • Estimated numbers on public effected by events.	• No dedicated chapter. • By-product from "damn failure" scenario.
	ICT – Information and Communication Technologies	
• Dedicated chapter / section on electricity. • Looked at from a broad perspective.	• No dedicated chapter. • Is mentioned in a detailed scenario on power.	• No dedicated chapter. • Mentioned in other scenarios. • Dedicated scenario for GNSS.
	Role of the general public	
• No dedicated chapter. • The public is referred to as something that needs to be protected. • No mention on public resilience.	• No dedicated chapter. • Expectation regarding public gathering during pandemics. • Source of information from forest fires. • No direct mention of public resilience.	• No dedicated chapter. • No mention of public resilience.

Table 4-2 demonstrates the comparison between each country by subject more visually. "X" represents that the topic is present in the assessment and rather good, the "+" represents that the topic is present to some extent and the "-" represents the topic is addressed but rather poorly. Blank spots then represent that the topic is not addressed at all.

Table 4-2: Visual comparison of the Risk Assessment Plans between Iceland, Norway and Sweden.

		Topics								
		Dedicated chapter on infrastructure	Dedicated chapter on events	Dedicated scenarios	Detailed scenario description	Detailed impact description	Cause of failure in scenarios	Viewed as a derivative	Protecting the public	Duties of the public
Methodology	Iceland	X	X	X	-	-				
	Norway		X	X	X	X	X			
	Sweden			X	X	X	+			
Electricity	Iceland	X	X	X	-	-				
	Norway			X	X	+	X	X		
	Sweden					-	+	X		
ICT	Iceland	X	X	X	-	-				
	Norway					+	+	X		
	Sweden		X	X	X	X	X			
Role of the general public	Iceland								X	-
	Norway								X	-
	Sweden								X	

The table shows that almost nothing is mentioned regarding the general public. Impacts that could occur from power failure are rather poorly addressed.

4.5 Summary

In this chapter National Risk Assessment Plans for Iceland, Norway and Sweden were compared. All of the risk assessments provide detailed descriptions for causes that lead to electricity or ICT failure. However, impact identification from these failures on other critical infrastructures and households is poorly conducted, especially in Iceland. Focus on the general public, their duties and preparedness, is lacking and almost non-existent in all countries.

5 Two case studies

The aim of Chapter 5 can be described with the following subjects:

- description of two electricity failure events that occurred in Iceland recently;
- media analysis focusing on impact towards critical infrastructures and the general public;
- summary of impact towards critical infrastructure and households; and
- threats from impacts and resilience of infrastructure and the general public will be evaluated.

The purpose of this chapter is to analyse impact from an actual electricity failure event in Iceland. These analyses are performed in order to enhance the understanding of such impact towards critical infrastructures and households. Further, it will enable a comparison of a theoretical and an actual impact identification.

5.1 Brennimelur

This case study will focus on a power failure event that occurred in Brennimelur in 2012 and the impact it had on critical infrastructure as well as the general public.

5.1.1 Electricity distribution around Brennimelur

The electricity distribution network in Iceland is mostly in the hands of Landsnet. The company was founded in 2005 due to the electric energy law that the parliament implemented in 2003. The purpose of Landsnet is to distribute electric energy while operating and maintaining the electric power network.

Substations

According to Landsnet (2012), substations are structures and equipment which are used to feed electricity into the distribution network or to draw the electricity out of it. The main components are power transformers, circuit breakers, delivery switches, ground sheets, measuring transformers (i. mælaspennar), protective equipment, reactive equipment (launaflsbúnaður) and aid equipment. Substations are considered vulnerable to sabotage, bad weather and other external causes.

The substation at Brennimelur is one of the most important supply centres in the distribution network. There are three 220 kV transmission lines connected to the substation, Brennimelslína 1 and Sultartangalína 1 and 3. These lines distribute electricity straight from large hydro power plants in the country. Further, the substation transports electricity on to the country’s distribution network (132 kV) and to the region nearby (66 kV). It is also connected to two energy intensive industries, Norðurál and Elkem. Another substation nearby at Norðurál started operating in 2014. It increases the quality of electricity coming from Landsnet into the aluminium smelter operated by Norðurál. There are two transmission lines leading from the substation into Norðurál. Both are capable of delivering 500 MW in case either one of them fails. However the lines do not operate at full capacity in general (E. Sigurðsson & Magnússon, 2015). Norðurál also installed a device called crowbar which helps them to deal with disturbance in the electricity network and has positive effects on Landsnets distribution network.

5.1.2 Event description

On Tuesday the 10th of January 2012 an incident occurred in one of Landsnet‘s substation called Brennimelur and is located in the West part of Iceland on the north side of Hvalfjörður. Figure 5-1 shows the location where the incident originated. The cause of this incident was mainly due to abnormal weather conditions. The incident caused interference in Landsnet’s network at Brennimelur, Vatnshamrar, Hvolsvöllur and Rimakot. This led to loss of electricity in different places around the country were the longest duration was in the aluminium smelter (Norðurál) and Járnblendifélag Íslands (Elkem) in Grundartangi. The aluminium smelter suffered electric failure for almost three and a half hours and limited supply of electricity nine hours later. Elkem suffered loss of electricity for nearly 12 hours.

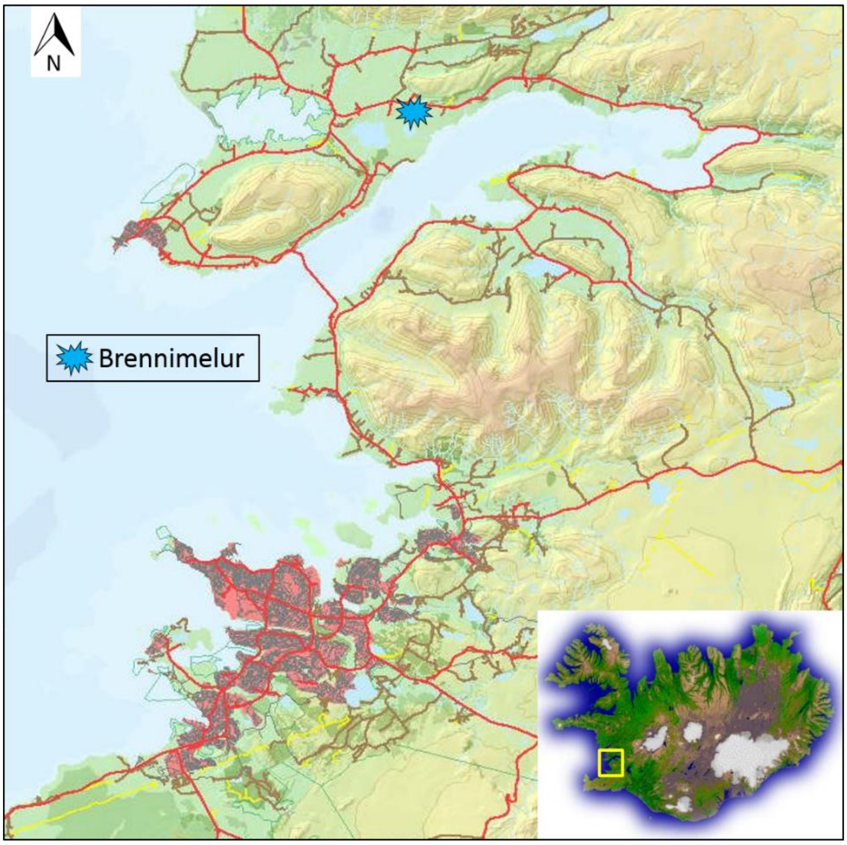


Figure 5-1: The location of Brennimelur, the teal coloured mark, where the power failure originated. The yellow box on the overview map of Iceland shows the location of the enlarged figure.

Weather conditions

The area is close to the sea making salt pollution in the atmosphere quite frequent. When the incident occurred the salt pollution meter varied from around 20 to 208 with an extreme high value of 425,8 (Figure 5-2). The extreme high data point should not be taken too seriously since that measurement occurred after the initial event and could be some form of malfunction or another abnormality. Considering the fact that normal conditions of the salt pollution meter ranges from 25-50 suggests the conditions were really bad.

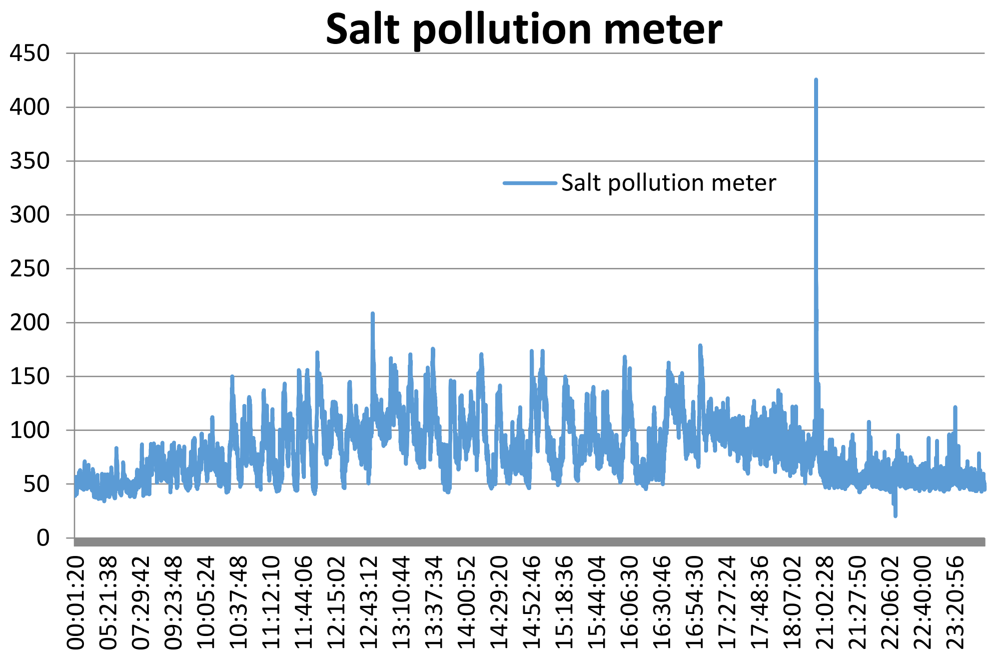


Figure 5-2: Salt pollution meter for the Brennimelur area. In normal conditions the salt pollution meter ranges from 25-50, salty weather from 50 to 100, heavy salty weather when around 100 and over and very heavy salty weather when the meter shows 100-200. Retrieved from Landsnet.

> "Later in the day on the 10th of January the atmosphere travelled over Grænlandssund to Iceland leading to decrease in heat and humidity flowing into the atmosphere. After that precipitation decreased. Humidity then decreased in many locations from 80-90% to 50-60%, still it was cloudy in the west and north part of Iceland. Possible explanation for the drop in humidity is the reduction in hail rather than the air, travelling into the West part of Iceland, being dryer. With fewer hails the salt did not wash off the capacitors of the transmission lines and led to a serious power failure in the substation in Brennimelur around 6pm" (Petersen & Sveinbjörnsson, 2015).

Salinity has been a problem regarding electricity distribution in the past. On the 14th of January 2001 power failures occurred in six different places. The same year, on the 10th to the 13th of November, there were 24 interruptions in the network operated by Landsvirkjun, including eleven on Vesturlína. Also, many power failures occurred on the country's main transmission line and in two other places (Landsvirkjun, 2001). In 2002 there were 241 interruptions in the electric grid operated by Orkubú Vestfjarða. The primary cause of spontaneous interruptions in that year were traced to salinity, dirt and snow (Vestfjarða, 2004). The 27th of January 2008 capacitor 1 in Brennimelur malfunctioned which led to loss of 300 MW to Norðurál. The main cause of the malfunction was salinity on capacitors in Brennimelur (Landsvirkjun, 2008).

Communication

During the event Landsnet was dependent on the emergency communication TETRA in order to resolve the situation. Interruptions occurred on normal communications during the event which increased the need of emergency communication usage. Since the duration of the event was rather short the TETRA system performed well, as expected (J. Á. Sigurjónsson, 2015). It is worth mentioning that the event did not last long enough for emergency power of communication transmitters to start getting low since the TETRA system has emergency power for 48 hours.

Affected areas

There were nine main locations in Landsnet's electric distribution grid that suffered loss of power during the incidents. Two quadrants of the country also suffered loss of power, Austurland (0.53 hours) and Vestfirðir (1.28 hours), along with two aluminium smelters, Norðurál and Elkem. Appendix B describes the locations in more detail, their importance in social terms and the transmission lines that service them. Down time of electric power for Austurland, Vestfirðir and the aluminium smelters, as well as for the nine main locations, is further analysed in Appendix B.

5.1.3 Media coverage analysis

In this section analysis will be performed on media coverage for the event. The purpose is to identify impact, which occurred during the event, on critical infrastructures and households. During the interruption in Brennimelur the effect from the power failure on households was primarily in the form of no electricity for a rather short period of time. Therefore it does not come as a surprise that there were no scenarios which made people feel threatened in any way.

According to the media "television transmitting and a part of one company's phone network stopped working" (Fréttablaðið, 2012); (Hjaltadóttir, 2012). Interruptions of this kind may lead to doubts on the reliability of ICT, since the event does not even last close to 24 hours and causes significant malfunction in ICT. For a short or extended period of time this could prevent people's ability to receive information on the hazardous event, its magnitude and impact on others. They might also be unable to call for help in case of emergencies, caused by unrelated issues, such as health problems or accidents. Furthermore the importance of the TETRA-network, though not mentioned in media reports, was discovered. Landsnet depended greatly on this form of communication in order to resolve the situation.

The electric failure affected other infrastructure as well, most important of which being the hot water supply that stopped working entirely in one part of the country (Guðmundsson, 2012); (Malmquist, 2012c); (G. Sigurðsson, 2012). This is also pointed out in the annual report from Orkuveita Reykjavíkur in 2012. Furthermore the Brennimelur event is mentioned to have caused malfunction in many pumps for hot water and sewer systems, leading to shortage of hot water distribution in many places in southern Iceland (Reykjavíkur, 2012). Because Iceland is highly dependent on geothermal water for house heating the lack of its distribution can have a significant impact on households. Also, the lack of function in the sewer system might lead to health problems if the time period would be extended. For this event the impact cannot be considered as significant but rather as inconvenience regarding daily activities such as showering or cleaning. However, if this kind of malfunction to the distribution would extend to a longer period of time people could experience their room temperature dropping very low, depending on season and weather.

A couple of factors were discovered regarding impact on transportation from the event. The electric failure affected the road tunnel Hvalfjarðargöng, which is a part of the main road in Iceland, leading to its closure for some time (Guðmundsson, 2012); (G. Sigurðsson, 2012). Closed road tunnels from power failure results first and foremost in interruption of traffic for the general public and the transportation of goods. If the tunnels had been closed for a longer duration it could have led to a more significant impact on people's lives, such as commuting to work, receiving essentials, etc. Also, sudden electric failure in the road tunnel, during heavy traffic, could cause a major automobile accident inside the tunnel which in this case is under the sea. This could result in lives lost and a major rescue operation. Drivers that forget to turn their car lights on might increase the risk of such accidents. It is worth mentioning that after this event Spölur, owner and operator of the tunnels, has installed emergency power. Another threat connected to power failure in tunnels is the accumulation of toxins should the ventilation system stop functioning. The other discovered factor, which could have happened, concerns the distribution of information from the Road Administration. The road agency reminded people to call and check the road conditions during the event (Malmquist, 2012c). A scenario could arise where important information about road conditions could not reach the general public. Considering bad weather on top of that could lead to increased strain on rescue units, fire department etc. which might be involved in resolving the original situation.

Further, an impact was detected which was not caused by the lack of functioning electricity supply. As mentioned in the case study for Brennimelur the substation caught on fire which was handled by the fire department in Akranes (G. Sigurðsson, 2012). This demonstrates that electric power failure event can have various effects. In this case increased strain on other critical infrastructures, the fire department, was in the form of them helping to restore the electricity infrastructure.

5.1.4 Household and infrastructure impact summary

The analysis shows clearly that power failure for brief period of time can have a significant impact on the function of infrastructures in modern societies. A power failure of this duration seems not to impact people's lives significantly and could be considered as an unnecessary inconvenience. The level of concern rises after revealing the impact from the event on infrastructures. Since infrastructures have both direct and indirect effect on daily lives of the general public, strengthening and enhancing security of these infrastructures is of the utmost importance for civilian security and maintaining daily routines. A summary of the impacts that occurred in Brennimelur is demonstrated in Table 5-1 on the following page.

Table 5-1: Impact on infrastructures from the Brennimelur case study. Direct and possible effect on the general public is also included.

Infrastructure	Impact	Effect on public
Energy – electricity	A large impact on the electric distribution system separating it into independent areas out of reach from the main source. A lot of manpower required to resolve the situation. Large impact on energy intense industry, close to devastating.	None or interrupted lighting. Lack of house heating in some cases, for electric dependent households.
ICT – information and communication technologies	Failure in television transmitting from certain distribution companies.	Lack of information to general public regarding the progression of the event. Other consequences would be lack of general entertainment but would not be considered as threats.
Water supply and sewer	Breakdown in water pumps from electric failure.	No significant impact regarding the event itself. Possible consequences would be minor inconvenience unless for a prolonged period of time. Further, the function of sewer systems is critical for dense societies to function and maintain a viable level of a healthy community.
Transportation	Most clear impact was the closing of the road tunnel in Hvalfjörður. The other one was more of concern regarding information flow from the Road Administration.	Sudden failure of lights in tunnels could lead to accidents and prolonged down time of ventilation would lead to dangerous level of toxins in the air. Redirection of traffic through less maintained roads could increase the number of accidents causing increased stress on other infrastructures, first responders etc.
First responders	In the case study the particular incident occurred where the cooperation of a fire department was needed in order for maintenance in the substation to continue.	No direct consequences except if a possible scenario was to happen where the fire department’s man power would be needed elsewhere.

5.2 The Westfjords

This case study focuses on power failure that occurred around new-year in 2012/2013 and the impact it had on critical infrastructures as well as the general public. The incident happened because of a great storm that impacted the North-West part of Iceland called Vestfirðir (e. Westfjords). The location of Westfjords can be seen in Figure 5-3.

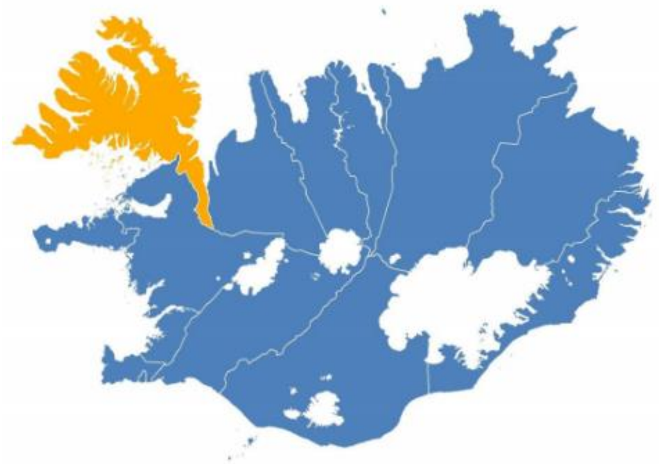


Figure 5-3: Geographic position of the Westfjords. Retrieved from Almannavarnir.

The Westfjords are a rather isolated part of the country and fairly irregular in shape. Towns are located in some of the fjords the largest being Ísafjörður with around 2600 inhabitants. There is a ring road in the Westfjords that makes most of the towns connected to 2 roads rather than one. However in the winter time these roads are fragile when it comes to heavy snow and storms and can isolate people, or even towns, from essential services like health care etc. There are also other factors that threaten the safety of the people living in the Westfjords such as electricity and internet connection. The Westfjords are connected to the main distribution network for Iceland through a single 132 kV transmission line. Apart from that they rely on hydro power plants for electricity. They are also connected to the internet through a single cable, which is being worked on to double the safety.

5.2.1 Westfjords electricity distribution network

In this chapter the power distribution network in the Westfjords will be described. Readers can reference the explanations in Figure 5-4.

Source of power for the power distribution network in the Westfjords consists of:

- electric power distribution from Landsnet through a 132 kV transmission line called Mjólkárlína 1, the red line from Geiradalur to Mjólká;
- twelve hydro power plants, blue circles located throughout the Westfjords; and
- thirteen diesel generators, red squares located throughout the Westfjords.

The 132 kV red line is owned and operated by Landsnet and the blue lines are operated by both Landsnet and Orkubú Vestfjarða. Orkubú Vestfjarða is then solely responsible for other lines shown in Figure 5-4.

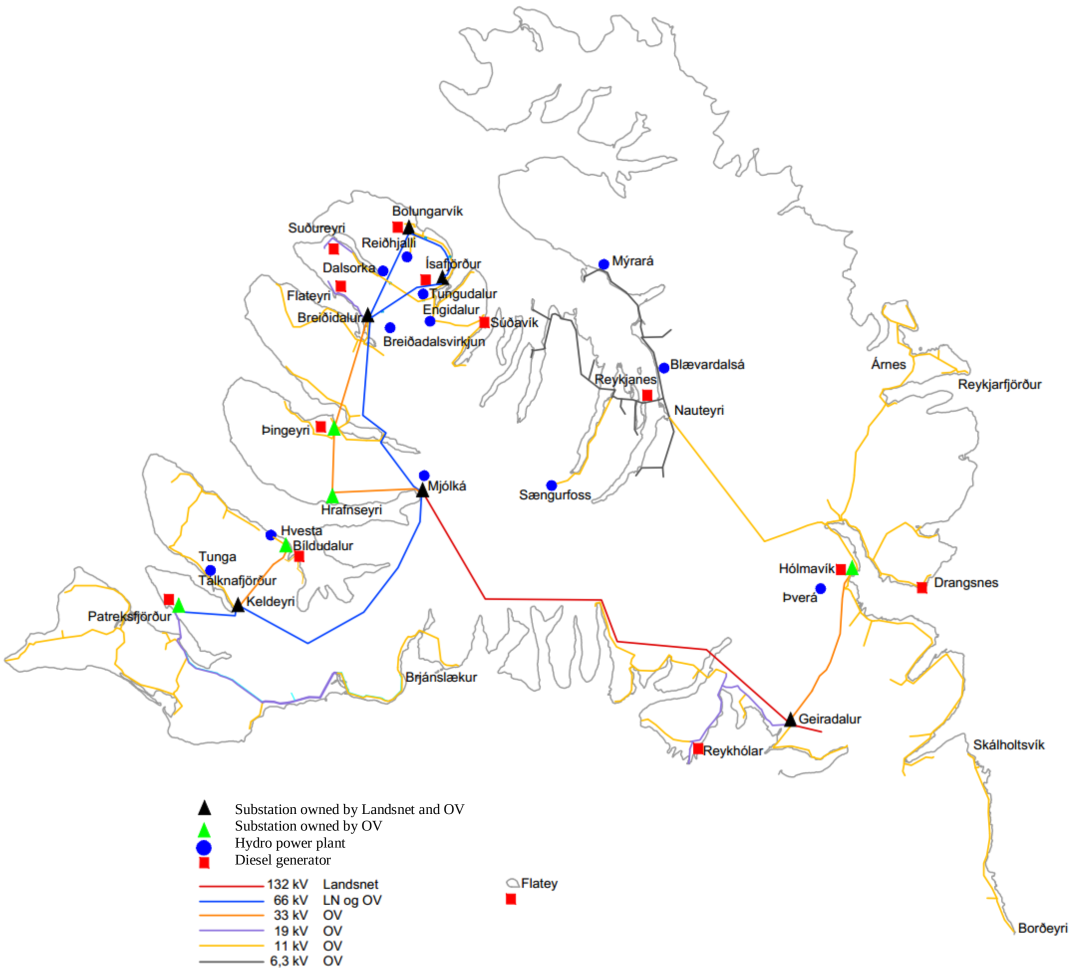


Figure 5-4: The power distribution network in the Westfjords. Retrieved from Orkubú Vestfjarða.

Power sources in the Westfjords

As mentioned earlier there are twelve hydro power plants in the Westfjords, eight of them are owned and operated by Orkubú Vestfjarða, the others are privately owned but still connected to the network (Vestfjarða, 2011).

Mjólkárvirkun (e. hydro power plant in Milk River)

Construction of the power plant in Milk River started in 1956 and was operational in 1958. The power plant was connected to the national distribution network in 1980 through Vesturlína. Until that year it had been the main source of power for the Westfjords, now it generates power directly into Landsnets distribution system. Since the power plant was constructed two more have been built, Mjólká II and Mjólká III. These two power plants combined generate 10,6 MW in total making them the “single” largest power plant in the Westfjords (Vestfjarða, 2012). The power plant has played a key role in the past when the Westfjords have lost connection to the main distribution grid in Iceland. However, during this event the power plant failed to operate.

Emergency power

There were over two dozen diesel generators in the Westfjords at the time of the event that are owned by the electric distribution company. The generators should be able to sustain urban areas in the region as long as there is oil to burn and they are functioning. However, during the event a few of them malfunctioned and some ran out of oil. Furthermore some of them were located in places that were hard to reach or dangerous to stay in for operators due to risk of avalanches.

5.2.2 Event description

Weather conditions

In the Westfjords event weather conditions differed a lot from Brennimelur. Though salinity contributed to malfunctions in the electric distribution network the main impact was from the storm itself. Winds were very strong and reached over 40 m/s in many places with heavy snow fall in most areas and avalanches. All these factors lead to the collapse of the electric distribution network at that time. The weather and risk of avalanches did not only concern the distribution system but also blocked roads leading to isolation of many places in the Westfjords.

Effected areas

The event affected the Westfjords as a whole, some areas more than others. Impact from the power failure on the people in the Westfjords depended greatly on where they were located. People living in towns were a lot better off since emergency power was present and kept electric distribution going at some level. The power failure started on December the 28th at 23:00 with minor interruptions. Throughout the night and morning of December the 29th failure of four main distribution lines in Westfjords occurred. On the same day at 18:45 all four main distribution lines from Mjólkárvirkjun were out of service. At that time all emergency power generators had been started. These generators are located in Ísafjörður (population: 2602), Bolungarvík (866), Þingeyri (267), Flateyri (214), Súgandafjörður, Súðavík (145), Hólmavík (380), Reykhólar (121), Reykjanes, Patreksfjörður (636) and Bíldudalur (168). In 2013 the number of people living in the Westfjords were around 7000 and around 700 people were estimated to be living in rural areas. Final repairs were made on January the 1st and on that evening at 19:30 Ársneshreppur finally had functioning electricity having been without electricity for three and a half days. Communication during the event was terrible. Both normal and emergency communications stopped working during the event. This effected the general public as well as first responders and key personnel working on resolving the situation.

5.2.3 Media coverage analysis

In this section analysis will be performed on media coverage for the event. The purpose is to identify impacts, which occurred during the event, on critical infrastructures and households. During the interruption in the Westfjords the effect from the power failure was far greater on households as well as infrastructure than in the Brennimelur event.

Impact on household

Barði Sveinsson, a farmer in Innri-Múli, experienced the power failure on the 29th of December. When the blackout occurred all roads leading to his home were impassable (Malmquist, 2012a). This scenario could be frightening to anyone, being out of contact with everyone you know and unable to call for help in case of emergencies. Furthermore other alternatives of transportation were unavailable due to the bad weather at the time. Other people with a similar experience of the event expressed more concerns. One of them was Jóhanna Kristjánsdóttir, a farmer in Svansvík in Ísafjarðardjúp. She described that loss of communication was the worst in her opinion. She felt very insecure, not being able to monitor the situation and that people could not contact her. She also mentioned that in these situations the neighbours on the countryside try to communicate in order to check if everyone is all right (Broddason). This statement stresses the importance of communication in order for the public to reach first responders and to control panic.

Eyþór Jóvinsson, a store owner in Ísafjörður, went to buy batteries in a store which was lit up with candles (Valþórsson, 2012). Though candlelit stores sound romantic and appealing it does not always make them the most functional. There was nothing mentioned regarding payment for the batteries however if the scenario would be expanded to a larger city and for a longer period of time the method regarding payment could easily be questioned. That would not be the first time stores had to deal with electricity problems regarding payment and they probably could write every purchase down to a large extent. On the other hand the general public might not be ready with a stock of cash in order to buy food and other goods.

The people living in Ísafjörður were generally not pleased with the service from the electricity distributor and found lack of information on progress concerning the event staggering (Einarsson, 2012b). It could be a quite troubling factor to have no information about what is happening, how long the situation will last or how to behave during the event. The lack of information was caused from chaos that occurred within the distribution company and their failure to allocate the information rather than the communication breakdown.

The event in the Westfjords caused serious problems for a lot of people when it came to living conditions inside their homes. In remote places houses are often heated with electricity or oil but not with hot water like 90% of houses in Iceland (Orkusetur, 2005). However households in the Westfjords either depend on electricity or geothermal water for househeating. Ágústa Sveinsdóttir, a resident in Norðurfjörður, said she could not deny that she was starting to get cold. She had to put on lot of clothes and walk around the house to keep warm. She also made hot drinks using her Primus gas stove (Malmquist, 2013). Others had similar stories to tell like Gunnsteinn Gíslason and his wife Margrét Jónsdóttir who live in Bergistanga in Árneshreppur. Their living room temperature dropped down to 7°C. They focused on staying in the smallest room of their house, using a gas stove for heating and slept fully clothed to prevent hypothermia. They killed time by listening to their battery powered radio and mentioned that general hygiene diminishes quickly when you are not able to shower. Like many rural areas they were not equipped with diesel generators for heating which would have come in handy. Elísa Ösp Valgeirsdóttir, the principal of Finnbogastaðaskóli, did not enjoy the luxury of diesel generator for heating like the previously mentioned couple. She, her husband and their three kids sought refuge at her brother's home, who lived nearby, during nights. They also experienced a lot of cold and felt that the darkness was overwhelming since the sun hardly shows itself at this time of year in this part of the country (Helgason, 2013). Some people were better equipped to deal with the situation like Bjarnheiður Júlía Fossdal, a farmer in Melar. She explains that the diesel generators saved her and many others nearby. She also mentioned that a special deal had to be made with the power distribution company for her to own the machine (Helgason, 2013). A drop in inside temperature over a long period of time can have severe effect on people's health and living conditions especially if they are ill equipped. For people living in remote places or outside of towns the affects become more significant than they would in the eyes of people living in a town or city. Because the event in the Westfjords was a combination of electric failure, communication breakdown and horrible weather, the impact from one of these factors all of a sudden turns into situations that are considered dangerous or in some cases life threatening.

To weigh up the downside of these events there was at least one individual that thought of the event as very romantic and was certain that the number of new-borns would be high nine months from the event. It is very likely that this individual did not have to deal with the impact on the same level as some of the people described above.

Impact on infrastructure

The greatest impact on the electric distribution system was mostly caused by the bad weather, resulting in transmission lines being covered in snow, broken masts and salinity (Malmquist, 2012b). The number of broken masts in one of the transmission lines, called Ólafsfjarðarlína, was 67 (Pétursdóttir, 2013).

Emergency power required during the event was far from reliable. Some diesel generators had to be relied on to function without an operator since they were stationed in exposed areas where avalanche risk was high (Einarsson, 2012c). Areas in the region were isolated and used emergency power separately and the urban areas were a lot better off than the rural areas (Halldórsson, 2012a).

Telecommunication was very fragile during the event and connection to a lot of telecommunication transmitters was lost along with a few GSM-transmitters due to bad weather (Halldórsson, 2012b); (Häsler, Malmquist, & Einarsson, 2012). A meeting was called with the telecommunication companies in order to figure out how to react regarding a long lasting electric failure (Häsler et al., 2012). This raises the question of the preparedness and capabilities of Iceland's infrastructure to deal with these events. Electricity was directed in order to charge the communication transmitters (Häsler, 2012). During the event tens of transmitters stopped working because of electric failure, the TETRA network which services the police, first responders and SAR did not function properly and at some point the communications could only be performed locally (Malmquist, 2012d). As much as 29 telecommunication transmitters were out of power during the event and were therefore shut down. The GSM-network was used to warn people about potential avalanches and evacuation, it did function in urban areas where emergency power was present (Harðarson, 2013). In threatening scenarios as formed during the event the importance of communication systems is crucial. Because of the regions geographic condition and its history of bad weather and heavy snow, the importance of good communication is critical. The fact that the police department, first responders and Search and Rescue units had to deal with issues regarding their emergency communication devices raises concerns. Further it was mentioned that telecommunications almost completely failed throughout all of the Westfjords (Valþórsson, 2013). It is of the upmost importance that critical infrastructure such as lifesaving operations are fully functional. These functions need to be equipped to maintain their role when serious events occur. Another consideration came up regarding communication system which was regarding landline connection. Many important centres in the landline network were operated on emergency power (Valþórsson & Gunnarsson, 2012). Should these centres fail completely in terms of power the final frontier of public communications would fall, old touch-tone telephones would therefore stop working.

Transportation was crippled during the event which was not caused by electric failure but bad weather. However, the importance of other infrastructure is crucial when one or several of them fail. Trucks with groceries and other goods were unable to reach their destination due to heavy snow and avalanche risk. Further, another truck was dispatched from the other side of the country in order to deliver oil for the diesel generators (Einarsson & Jónasson, 2012). Another threat regarding transportation similar to the Brennimelur case study was due to electric failure and malfunction in the transmitters owned and operated by the Icelandic Road Association (K. Sigurjónsson, 2012). This could lead to wrong information from the agency regarding road conditions that might impact the general public while trying to reach their destination and resulting in them calling for help. That situation would increase stress on Search and Rescue, police etc. which were fully occupied during the event.

Search and Rescue units were dispatched to investigate the impact on transmission lines (Malmquist & Einarsson, 2012). Due to bad weather and heavy snow conditions the Search and Rescue units were needed in order to get parts of the telecommunication network up and running (P. Jónasson, 2012). They also accompanied workers for the diesel generators because of avalanche risk (Einarsson, 2012a). Apart from assisting workers regarding repairs on transmission lines, the Search and Rescue units also assisted hospitals employees to get to and from work. Since Iceland does not operate a military that services the country in time of crisis, the importance of volunteer work performed by SAR during those crisis cannot be overstated. Other infrastructure related to SAR had a role to play in the event. First and foremost of which was the Coast Guard which deployed workers from the telecommunication companies in remote places to refill energy supplies in certain transmitters.

5.2.4 Household and infrastructure impact summary

The Westfjord's event led to a significant impact on the general public and on critical infrastructures. The analysis clearly demonstrates the vulnerability of the public and infrastructures. The case study further reveals how factors such as weather, time of year, etc. can decrease the capabilities of those trying to resolve a large electricity failure. A summary of the impacts occurring in the Westfjords event can be seen in Tables 5-2 and 5-3 on the following pages.

Table 5-2: Impact on household from failure in infrastructure from the Westfjords case study. Further, impact towards individuals from impact on households is demonstrated.

Infrastructure	Impact on homes	Effect on public / individuals
Energy – electricity	Failure in lighting, house heating and communications.	Though the absent of lighting for a few days can't be considered as a threat to people, it can however impact the mood of some people. Further, it can cause trouble to people who have home grown products or have a lot of plant life in their household.
ICT – information and communication technologies	Failure of emergency and normal telecommunications. Landline was operational but required people to have older phones that draw their power directly from the phone line.	Most significant impact on individuals was the disability in being able to contact emergency services. Other impacts included people not being able to contact their loved ones, generating disturbance in their peace of mind. Lack of information flow to the public. Some people had to depend on battery powered radios to be informed about the development of the incident.
Water supply and sewer	Failure in hot water distribution and the access to drinking water, possibly.	In terms of house heating, the impact corresponds to the electric factor mentioned above. The lack of water distribution long-term has negative effects on the health aspects on a society. Depending on the season the access to drinking water can vary. Combining frozen water and the lack equipment to heat it could turn into a difficult situation regarding consumption of fresh water.
Transportation	Impact was not a result of electric failure, however avalanche risk and heavy snow blocked off roads.	Isolates people from emergency services and other daily services. Making people incapable to reach for help or help to come to them. Making people depend on food and other equipment present in their homes.
Financial system	Store in Ísafjörður serviced goods over the counter over candle light.	In a certain point of view the electric failure happened at a good time, when people have already stocked up on food and goods. However prolonged exposure to electric failure causes people to be dependent on cash to pay for food/goods. This is a concern since credit / debit car use in Iceland is very high.

Table 5-3: Impact on infrastructure from the Westfjords case study. Further, the effect caused by the impact on infrastructures function is demonstrated.

Infrastructure	Impact on infrastructure	Effect on function
Energy – electricity	Impact on energy infrastructure was not due to electric failure but bad weather destroying parts of the distribution system and restricting access to repair it.	Insufficient or no electricity distribution to homes and other infrastructure.
ICT – information and communication technologies	Impact was both due to lack of electricity and bad weather.	Failure both locally and "globally". Dependent on emergency power which depleted in some cases. Unable to maintain function after 24-48 hours of reserve power.
Water supply and sewer	Lack of electricity to keep pumps working.	Limited or no water distribution towards households. Comes dependent on emergency power.
Transportation	Direct impact on road monitoring system operated by the Road Administration. Other impacts were weather and season based.	Lack of important information. Alternative routes were needed.
Financial system	No concrete evidence of failure.	No evidence of lack of function.
Health care	Depended on emergency power.	No evidence on lack of function except for their reliance on SAR to transport workers to and from the hospital.
First responders	Impact in form of communication breakdown.	Coordination becomes more difficult. Loss of communication towards the Civil Protection Agency. People trying to reach them were unable to.

5.3 Impact evaluation

In this section evaluation of the impact from the previously mentioned case studies will be performed. One in form of threat evaluation from certain impacts that were accounted for in the studies, another regarding resilience of infrastructure during the events and the last one focusing on the resilience of the public. Beneath each evaluation table justifications for each evaluation is given. Further, impact found in the case studies are compared to those put forth in chapter 3.

5.3.1 Threat evaluation

In this section the main impact that was identified in the case studies is represented with evaluation of threat towards the public and/or infrastructure (Table 5-4). The evaluation is based on the case studies directly but not for electric failure in general. Since the other factors, like time of year, location, etc., contribute towards the results of this kind of evaluation the following findings cannot be universally considered however they can be used as references for further studies. For this threat evaluation factors such as credible or likely to happen will not contribute to the evaluation since the incidents already occurred. Instead the following factors will be considered for the evaluation in Table 5-4:

- impact on critical infrastructures;
- impact on normal living conditions;
- impact on the ability to reach safety or help (first responders, hospitals, etc.); and
- connection between impacts during an event.

Table 5-4: Threat evaluation from the main impacts discovered from the case studies. Threat is displayed with colours green, light green, yellow, orange and red. Green corresponds very low level of threat while red corresponds to very high levels of threat.

		Threat level				
		green	light green	yellow	orange	red
Impact	*Lack of electricity*					■
	House heating					■
	Cell phone network				■	
	Emergency communications					■
	Lighting	■				
	Alternative transportation routes		■			
	Blocking of transportation routes					■
	Closed tunnels			■		
	Information flow			■		
	Isolation					■
	Fresh water distribution			■		
	Lack of information			■		
	Landline				■	

Lack of electricity scores a “very high” threat because of its overall broad impact. *House heating* scores a “very high” threat because the impact led to people’s homes dropping in temperature, which is especially bad considering the time of year the event occurs, and that very few households seemed to be prepared with alternative heating. Failure in *cell phone network* gets a “rather high” threat rating since it limits people‘s ability to call for aid while at the same time landlines were still functioning but with interruptions. Failure in *emergency communications* gets the “very high“ rating since not only would that be one of the last ways for the public to reach emergency services, should they have emergency communications, but further it limits these services to coordinate during the event. *Lighting* gets the rating of “very little” threat especially since there were no direct consequences other than some emotional unrest. *Alternative transportation routes* gets a “rather little“ threat rating since the risk involved would be to travel less maintained routes and people had to be more alert regarding road conditions. *Blocking of transportation* on the other hand gets a threat rating of “very high” since people living in isolated places could be unable to reach for help, especially when communications are down, and transportation of food, goods, etc. could become problematic. *Closed tunnels* get a rating of “medium” which is evaluated on two things, one the alternative road scenario and a more critical one being sudden failure of lighting and air vents in the tunnels. This could possibly lead to more crashes and a worst case scenario a long-term exposure to toxins, death. *Information flow* gets the rating of “medium” threat, information flow was mostly important during the Westfjord incident but was somewhat lacking. Threats from lack information were considered as emotional and leading to bad judgement on what to do during the event which resulted in the previously mentioned evaluation. *Isolation* gets the “very high” rating since it corresponds both to isolation towards communications and commute (blocking of roads) which both got very high levels of threat. *Lack of information* gets a “medium” rating since the lack of information towards the public can have significant impact on the public in terms of moral as well as decision making during the event. A worse rating than medium was considered inappropriate since this impact would likely not risk the health of the public. *Landline* gets evaluation of “rather high” since during the event it did not stop functioning entirely however being the most robust system in the ICT category and arguably the most relied on in terms of durability during crisis it should be considered a high threat.

5.3.2 Infrastructure resilience evaluation

Evaluation of infrastructure resilience can be seen in Table 5-5. For this evaluation performance of the infrastructures was taken into account, their capability to withstand electric failure as well general operation capability during the event unrelated to electricity. Table 5-5 can be seen on the following page. The resilience evaluation will mostly rely on the following factors:

- operational capabilities that focus on how the main system as well as its backup functioned during the events; and
- restoring capabilities that focus on how well the infrastructures were able to restore their systems.

Table 5-5: Resilience evaluation for critical infrastructures. Resilience is displayed with colours green, light green, yellow, orange and red. Green corresponds very good resilience while red corresponds to very bad resilience.

Infrastrcucture	Resilience level				
Electricity					■
ICT					■
Transportation					■
Water supply				■	
Financial systems	■				
Health care	■				
First responders		■			
Distribution companies				■	
Food		■			

The *electricity* infrastructure got a resilience evaluation of "very bad". Failure was caused by bad weather and salinity in both cases. Further, the Brennimelur case the electric distribution network was effected in some way throughout the whole country.The Westfjords case emergency power failed during the event and operating those facilities was dangerous because of avalanche risk. The distribution between the area effected and the main distribution network was completely severed. The *ICT* infrastructure suffered failure in cell phone and emergency communication along with interruptions in the landline. This results in an evaluation of "bad". *Transportation* infrastructure during the event gets evaluation of "very bad" since roads were closed or too dangerous to drive from avalanche risk blocking distribution of goods. Further sea and air transportations were down. *Water supply* was mentioned to have suffered interruptions during Brennimelur event and even more so during the Westfjords event resulting in a "rather bad" evaluation. Both *financial systems* and *health care* score a "very good" rating since there were no direct evidence of failure in these infrastructures. This rating should not be taken too seriously or look at these infrastructures as safe. *First responders* get a rating of "rather good" which is justified by the fact that during the Westfjords event the police lost communications during the event. In terms of manpower and capability the police, SAR, etc. of doing their job they would score "very good" but since communications failed it must be considered as part of their infrastructure. *Distribution companies* get a rating of "rather bad" because of their dependencies on SAR in order to reach areas where systems failed and during the Westfjords event emergency power they are responsible for stopped functioning during the event. Considered the chaos during the event the companies did not get a "really bad" rating. *Food* infrastructure relates mainly to distribution for this case, it gets the rating of "rather good" since it did occur that food distribution was blocked due to snow and avalanche risk.

5.3.3 Household resilience evaluation

The public cannot be categorized like the infrastructures in Table 5-5. Most of the public during the Westfjord event had emergency power for large part of the event. However the analysis show really well that the public is quite resourceful and self-reliant. The people who suffered the most live in areas that are considered dangerous in terms of electric, communication and transportation safety. This could contribute to the fact that the public in the area were perhaps more prepared or resourceful than other parts of the country would be, especially urban areas. Furthermore there were no cases of the public suffering from food shortage which is not surprising since the event occurred during Christmas when people are normally stocked up on food. Since the event did not last too long, though almost four days is far too long compared to standards set on electricity by modern societies, people who suffered the most were starting to get cold, lacked emergency communication as well as alternative heating sources. Another factor that diminishes the preparedness of the public is their incompetence to get to and from work and needing the help of SAR to do so, it is the author's opinion that the resilience of the public should be categorized as medium.

5.3.4 Comparing to the theoretical impact

Comparing the results of actual events to what was identified in Chapter 3 there are a few differences regarding which infrastructures and which impacts occurred. Figure 5-5 demonstrates infrastructures considered in Chapter 3 and those the case studies. The red circles indicate those infrastructures that were affected by the actual events and the green circles represent those who were not affected in the case studies or very little but were at the same time covered in Chapter 3. The blue circle represents an infrastructure that was not included especially in the theoretical identification however, it is a part of the energy infrastructure but was included especially because of its lack of resilience.

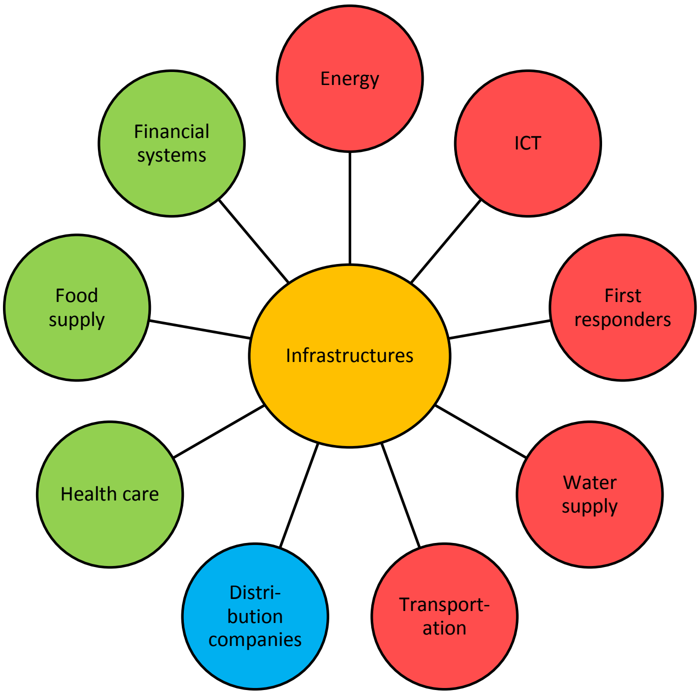


Figure 5-5: Infrastructures from the theoretical identification as well as the case studies.

Impacts on households turned out to relate to failure in electricity and ICT to a large extent even though in one case study bad weather resulted in numerous impacts. Further, impacts due to other reasons such as blocked roads becomes much more severe when additional impact from no electricity and ICT occurs. Comparing impacts on households from the case studies to those put forth in Chapter 3 revealed three new impacts which had not been accounted for. Figure 5-6 demonstrates impacts towards households from the theoretical identification as well as those discovered in the case studies. The red circles represent impact which was included in the theoretical identification and appeared in the case studies. The green circles represent impacts which were accounted for originally but did not appear in the case studies and the blue circles represent impacts which were not accounted for originally but did appear in the case studies.

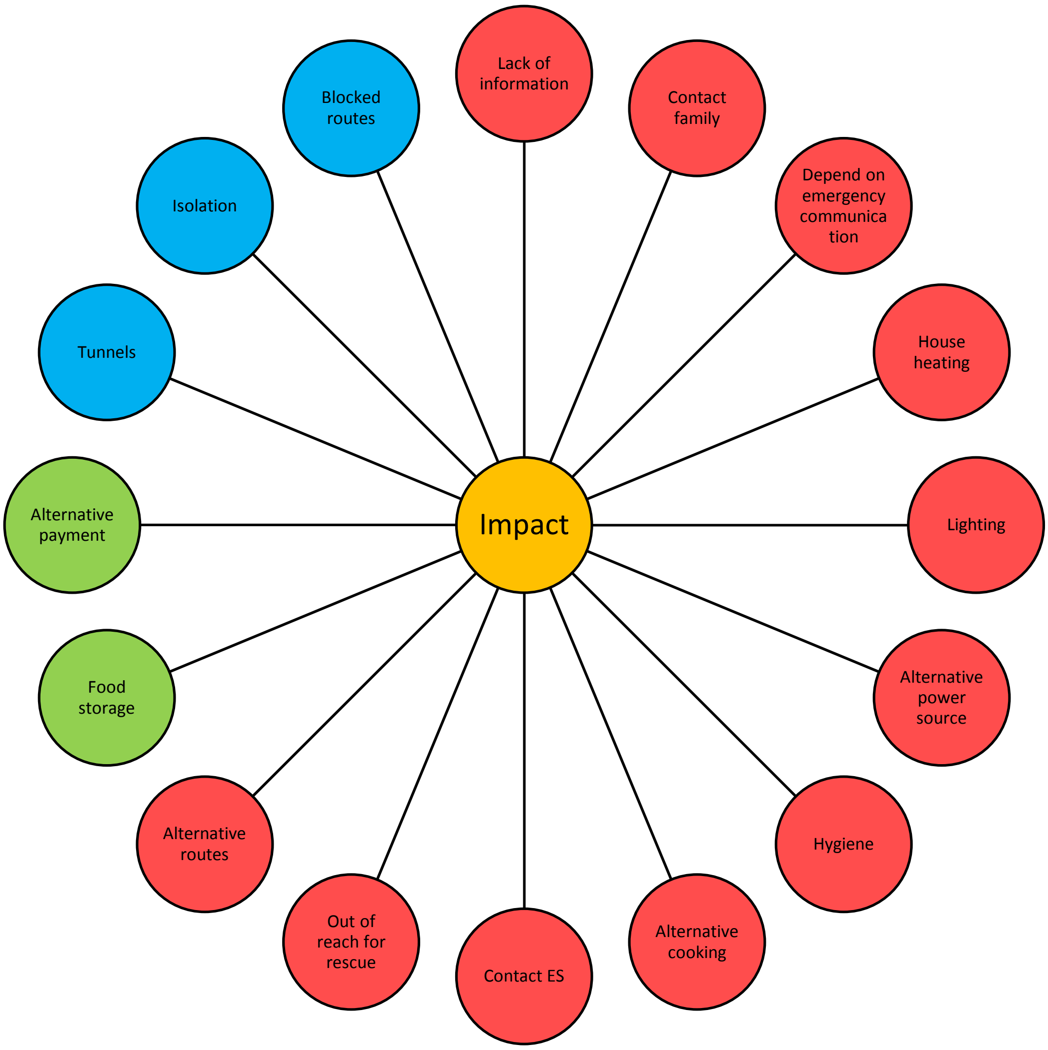


Figure 5-6: Impacts from the theoretical identification as well as the case studies.

5.4 Results

Critical infrastructures suffer significant failures when exposed to short and long term failure in electricity infrastructure. The general public on the other hand suffers from long term exposure. Identifying impact from these failures resulted in an evaluation of, threats from impacts on the general public, and resilience of critical infrastructure as well as the general public. Table 5-6 lists, impacts with the highest level of threat, least resilient infrastructures and the most crucial aspects that were lacking regarding households preparedness. Further, the most significant impacts detected were due to failure in these systems, especially when they were combined with other impacts during the event such as blocked roads etc. or from failure in other infrastructures caused by electricity failure.

Table 5-6: Summary of evaluations. The table shows impacts with the highest level of threat, least resilient infrastructures and the most crucial aspects that were lacking regarding households.

Impact	Infrastructure resilience	Household resilience
• Lack of electricity • House heating • Emergency communications • Blocking of transportation routes • Isolation	• Electricity • ICT • Transportation	• Alternative heating sources • Emergency communication

The vast majority of the general public was safe during the events. However there were various findings regarding people who suffered during the event. These difficulties were in most cases caused by electricity failure. Making people unable to keep temperature in their homes at a reasonable level or to contact others, especially emergency services, should other problems occur such as illnesses or accidents during the events.

Comparing results from the case studies to what was put forth in Chapter 3 resulted in the following discovery.

Table 5-7: Main findings from comparing case studies to the theoretical identification.

Infrastructure not affected	New infrastructure affected	Did not affect households	New Impact
• Financial systems • Food supply • Health care	• Distribution companies	• Alternative payment • Food storage	• Blocked routes • Isolation • Tunnels

5.5 Summary

In this chapter we described the two case studies as well as analysed the impact from the event as a whole. Further we categorized and evaluated the impact that occurred for the events. The Brennimelur event was a short period event that affected the whole country in some way and demonstrated well how significant impact from electricity failure in key locations in the distribution network can be. Meanwhile the Westfjords event gave a good example of impact for events that cover longer time periods as well preparedness needed during such events.

6 Analysis of public preparedness

The aim of Chapter 6 can be described with the following subjects:

- an overview of public preparedness studies conducted in other countries than Iceland; and
- an evaluation on public preparedness through surveys conducted in Iceland.

The purpose of this chapter is to evaluate the public preparedness in Iceland based on two surveys. One distributed to the general public and the other to key personnel (stakeholders). These surveys, the public preparedness survey especially, will hopefully give authorities and key personnel an idea of current preparedness of their civilians.

6.1 General on public preparedness

According to the International Organization for Standardization preparedness or “incident preparedness” is defined as:

> “Activities taken in order to prepare incident response” (ISO, 2011).

Further, “incident response” is defined as the “actions taken in order to stop the causes of an imminent hazard and/or mitigate the consequences of potentially destabilizing or disruptive event, and to recover to a normal situation” (ISO, 2011). This section as well as all of Chapter 6 will focus on the preparedness of the general public regarding electric failure. Public preparedness will be viewed as either perceived or actual preparedness. Perceived preparedness relates to, how people view their preparedness and their ability to deal with crisis scenarios. However, actual preparedness relates to people’s actual preparedness for crisis scenarios which takes into account what equipment they own, their knowledge of certain aspects, etc.

Public preparedness has been studied in many parts of the world for all sorts of hazardous events. These studies are mostly based on surveys that are directed to the public in order to evaluate their preparedness. Studies that have been conducted have had different aims. Some focus on a certain event such as a storm, flood, volcanic eruptions etc. while others trend towards a more over all viewpoint. In 2003, Ready, a government supported national public service encourages the general public in the US to be more prepared and tries to “increase the level of basic preparedness across the country” (Ready, 2013a). They list three main things which they ask individuals to do: “(1) build an emergency supply kit, (2) make a family emergency plan and (3) be informed about the different types of emergencies that could occur and their appropriate responses” (Ready, 2013a). However, people seem to prepare when they see interest in it. “Those with higher incentives to prepare and for whom the potential consequences are more salient are more likely to prepare.” (Donahue, Eckel, & Wilson, 2013). Further, public preparedness seems to relate to information present to the public. Those who are prepared are well informed since they seem to seek knowledge to prepare and vice versa (Donahue et al., 2013). During natural disasters people have experienced overwhelming lack of expectation, minimal preparation and confusion over warnings (King, 2000). If people belief a negative outcome will result from a hazardous event the more unlikely they are to act and enhance their preparedness (Paton, Smith, Daly, & Johnston, 2008). Education regarding preparedness against natural disasters and other crisis is lacking and should be taught and awareness raised (Berry & King, 1998).

FEMA, the Federal Emergency Management Agency, conducted a research in order to evaluate their nation's progress on personal preparedness and to measure the public's knowledge, attitudes, and behaviours relative to preparing for a range of hazards (FEMA, 2009). They found that 44% of the participants reported to have a household emergency plan that included instructions for household members about where to go and what to do in the event of disaster. Also close to 50% of the participants reported familiarity with alerts and warning systems, however similar percentage reported being least familiar with community evacuation routes and shelter locations.

Another study conducted by FEMA that focused on comparing multiple surveys regarding the preparedness of people varied significantly based on who performed the study. For example two studies based on similar questions regarding whether participants had an emergency supply kit were conducted for the New York City area and the results varied from 23% (a study by Marist Institute of Public Opinion 2005) to 88% (a study by New York City Office of Emergency Management 2005) (FEMA, 2005). The 2005 New York City OEM survey indicated a large difference in participant's perceived and actual preparedness. 55% of the respondents said they felt informed or very informed about what to do in the event of an emergency. However 14% of respondents said they had a household emergency plan (FEMA, 2005). 36% of the respondents had emergency supplies, which included 3 days of water and non-perishable food, a first-aid kit, flashlight, battery-operated radio, and personal hygiene items. 52% of the respondents said they had some of these supplies and only 16% said they had a "go-to" bag of supplies (FEMA, 2005). They found that 57% of participants had supplies set aside in their home to be used only in the case of disaster and the most frequent supplies were packaged food and water, flashlight, first aid kit and portable radio (FEMA, 2005). FEMA mentions other surveys such as the 2004 King County Survey which was conducted on item-by-item approach (FEMA, 2005). Their findings can be seen below in Table 6-1.

Table 6-1: Findings on public preparedness from the 2004 King County Survey. Retrieved from Butler and Safsak (2004).

Preparations Made by Households for Disasters, Emergencies	
Have a flashlight available in the house	94.3%
Smoke and/or carbon monoxide detectors	92.5%
Home fire extinguishers	76.5%
Took classes	66.6%
Food and water stored for use in the event of emergency	61.8%
Put together a kit for the car	58.9%
Developed a home escape plan	54.0%
Water heaters, etc. have been strapped down (earthquakes)	53.1%
Extra clothes and blankets have been stored	48.3%
Established a plan to communicate with family	22.4%
Selected a family meeting place	16.2%
Conducted home fire or evacuation drills	15.9%
Other	4.4%
Nothing	0.7%

As Table 6-1 demonstrates, people generally own a flashlight and other things people find use for in their daily activities. While the usage of items listed in the table becomes more specific or the item becomes more unlikely to be of use on day-to-day basis, the rate of ownership towards the items decreases significantly.

The 2004/2005 Puget Sound Regional Survey found that 49% of parents said that their children knew how to react during an emergency if the parents are not around and 48% had discussed the plan with their children (FEMA, 2005). The 2003 Citizen Corps Survey inspected how well prepared participants thought they were for three types of events with a 5-point scale. They found that 20% of people considered themselves ready for a terrorist event, 28% for a natural disaster and 54% for household emergency. Further they found that 50% of people had some kind of emergency kit at their homes, 34% in their cars and 41% at their work (FEMA, 2005).

Basolo et al. examined people’s perceived and actual preparedness for two types of hazard risks: earthquake and hurricanes. They found people’s perceived preparedness was linked to their assessment of local government’s competency to manage the consequences of a disaster. Regarding actual preparedness they found that higher levels of confidence in local government were associated with having a family plan which contradicted their hypotheses (Basolo et al., 2009).

As these studies suggest the level of public preparedness can vary drastically. Where people live, how many live in each home, etc. are factors that affect the outcome as well as who constructs and conducts the surveys. Many of the studies further show that the perceived preparedness of the public is often greater than their actual preparedness, which for the rest of this chapter an attempt will be made to determine for the general public in Iceland.

6.2 Public preparedness survey

In this section an analysis of public preparedness will be performed. The analysis will be based on a public survey of perceived and actual preparedness. The survey is divided into two parts; perceived preparedness and actual preparedness.

6.2.1 Methodology

The public preparedness survey was constructed by taking into account people's experience from the case studies, with ideas that appeared during the theoretical identification and speculation that appeared during the making of this thesis as well as considering similar surveys conducted in other countries. The questionnaire distributed and modified with the help of the Social Science department in the University of Iceland. Distribution was in the form of email delivery and modifications were done with the help of social science experts to ensure the questions were phrased correctly. The participant sample for the survey was 1200 people of which 713 people answered the survey. An attempt was made to distribute the survey as evenly as possible in relation to gender, age, education, etc. Age of participants was 18 years or older. Gender distribution was very good (around 50%), age distribution was also good were the age group 46-55 (around 23%) had the highest response rate, distribution of settlement was then 65% from the capital area and 35% outside the capital area. The worst distribution related to the education level were 45% had a university degree and 40% had a college degree.

6.2.2 Part 1 – Perceived preparedness

In this part of the survey an attempt was made to evaluate the perceived preparedness of the general public. The question focused on how well prepared individuals felt they were for certain crisis and their ability to help themselves and others.

Question 1 aimed to get participants perspective on their own preparedness. A simple Likert scale was used, ranging from very well to very bad. Respondents were aware that the electricity failure was from 24 hours up to one week. Well over half of the respondents (63%) consider themselves rather or very badly prepared for such an event (Figure 6-1). Further, only a small minority (14%) consider themselves rather or very well prepared.

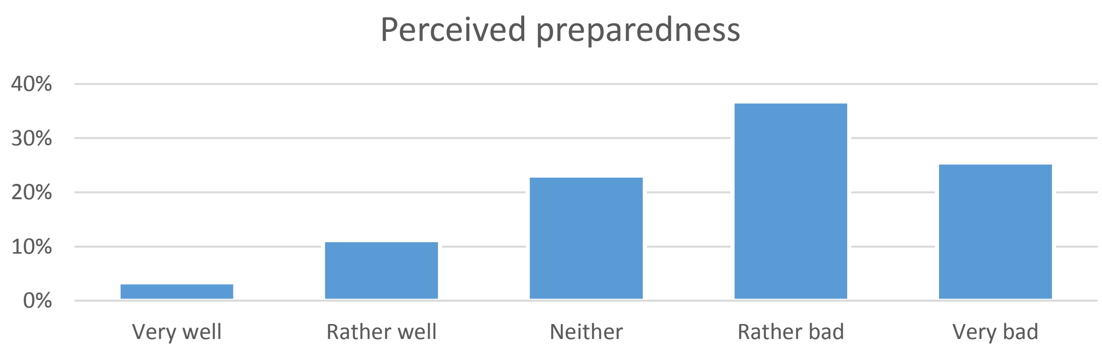


Figure 6-1: Question 1: How well or bad do you consider yourself and/or your family preparedness to be regarding a long duration electricity failure?

Question 2 was a follow up question of Question 1. If people answered rather or very well in Question 1 they were asked for further details regarding their preparedness. For this question each answer was analysed. Elements that people pointed out to own and would help them during the event were categorized. Elements were quantified by how often they appeared in the answers. Most popular elements for preparedness turned out to be *alternative lighting* (52 times) and *alternative cooking* (40 times) (Figure 6-2). This does not come as a surprise since these aspects are most likely the most routine things that people need to think about in their daily lives. What did come as a surprise is that people do not give telecommunications much thought regarding preparedness for this event.

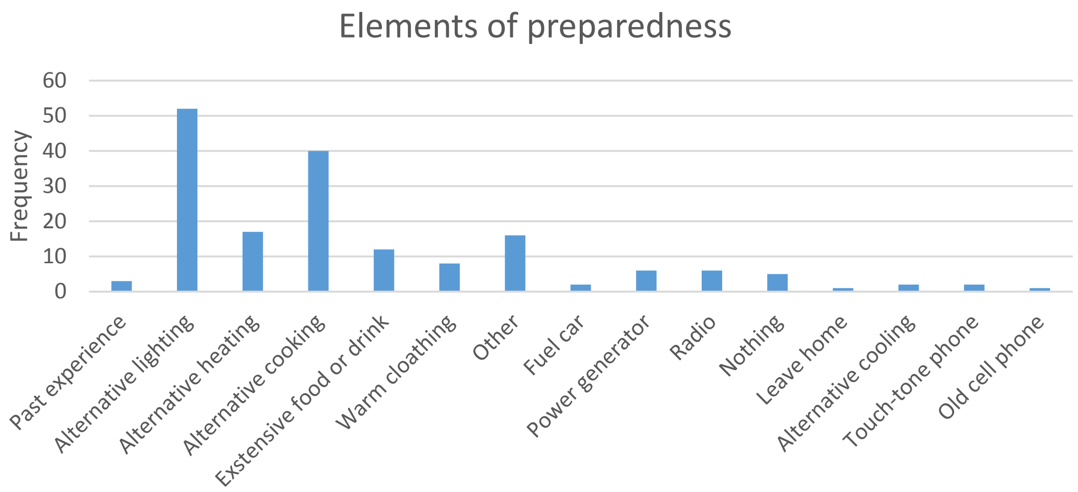


Figure 6-2: Question 2: Please describe how you and/or your family have prepared for long duration electricity failure?

When asked how prepared respondents thought they were only a minority (14%) thought of themselves as rather or very well prepared (Figure 6-1). However, when these 14% were asked to point out elements that contribute to their preparedness interesting findings were discovered (Figure 6-2). The dominating elements of what respondents referred to were alternative lighting such as flash lights, candles, etc. and alternative cooking methods such as gas stoves, etc. Alternative heating, extra food and drink and warm clothing appeared to come second to the dominating aspects however a lot less. The results suggest that elements of preparedness related to ICT are hardly given any thought and could be described as almost non-existent.

Question 3 aimed to evaluate their confidence in helping others with certain aspects which included food and drink, first aid, fuel, transport and offer people a place to stay. *Fuel* (15%) and *food and drink* (47%) appear to be aspects that people are less capable of helping with than with the rest (Figure 6-3). This could be because of the use of alternative fuel, apart from what is used in transport, has decreased over the years and people stock less up on food as they used to.

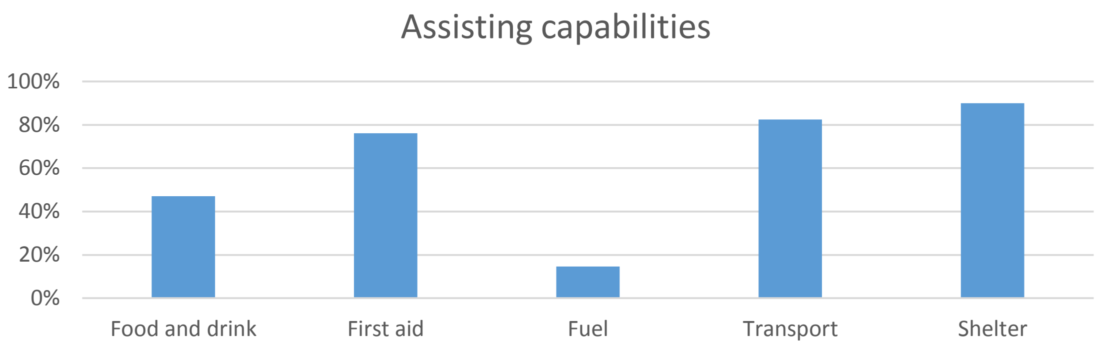


Figure 6-3: Question 3: If a long duration electricity failure were to happen, do you consider yourself being able to assist others (for example, people in your neighbourhood) with the following aspects? The figure shows which aspects they considered themselves being able to help with.

Question 4 was a follow up question of Question 3 and aimed to evaluate their confidence in helping others with the same aspects as in Question 3 but for longer periods of time. For this question, only those who responded that they could help with a certain aspects were able to answer this question for these aspects. *First aid* was neglected, since it was considered not to change with time. *Shelter* was the only aspect which people seemed being able to assist with for extended electricity failure (Figure 6-4). This can be considered as natural since *food and drink*, *extra fuel* and *transport* are all limited resources.

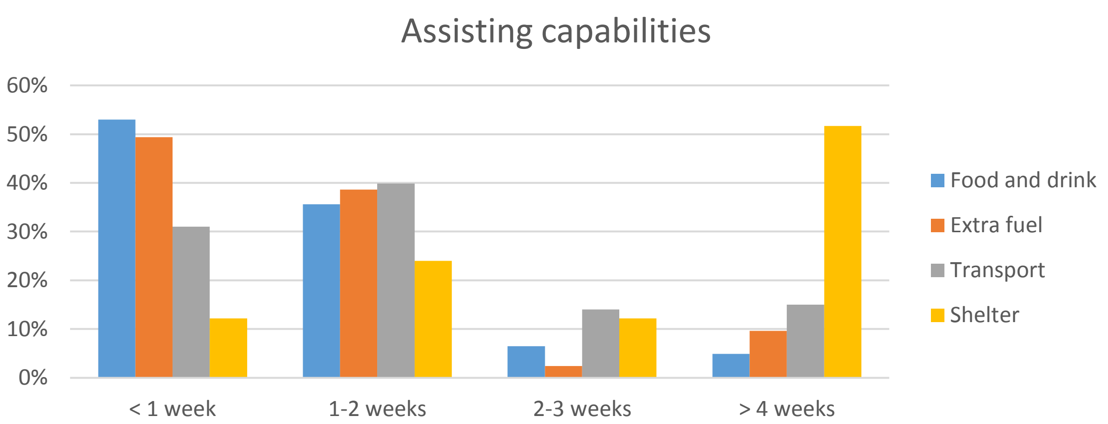


Figure 6-4: Question 4: For how long of a time period do you consider yourself being able to help the people in your neighbourhood regarding the following aspects?

When respondents were asked about their perception of their assisting capabilities during an electricity failure event the findings somewhat contradict the findings from their perceived preparedness (Figure 6-3). At least 76% of respondents perceived themselves as being able to assist with first aid, transport. Further 47% of respondents thought of themselves being able to assist regarding shelter but only 15% regarding fuel such as oil, timber, gas, etc. (Figure 6-3). When asked for how long they could assist with what was previously mentioned, first aid was excluded, a rapid decrease in assisting capabilities appeared for food and drink, fuel and transport (Figure 6-4). Shelter turned out to be the only aspect people considered themselves being able to assist with long-term or more than 4 weeks.

Question 5 aimed to evaluate their confidence in infrastructure during certain types of crisis/natural hazards. In this question the Likert scale was used ranging from very well to very bad. The results show that people have great confidence towards infrastructures during crisis (Figure 6-5). Not only confidence for *electricity failure* but a rather great consistency appears for all the crisis/natural hazards. At least 72% demonstrate a rather good or a very good trust in government when it comes to electricity failures, volcanic eruptions, earthquakes and pandemics.

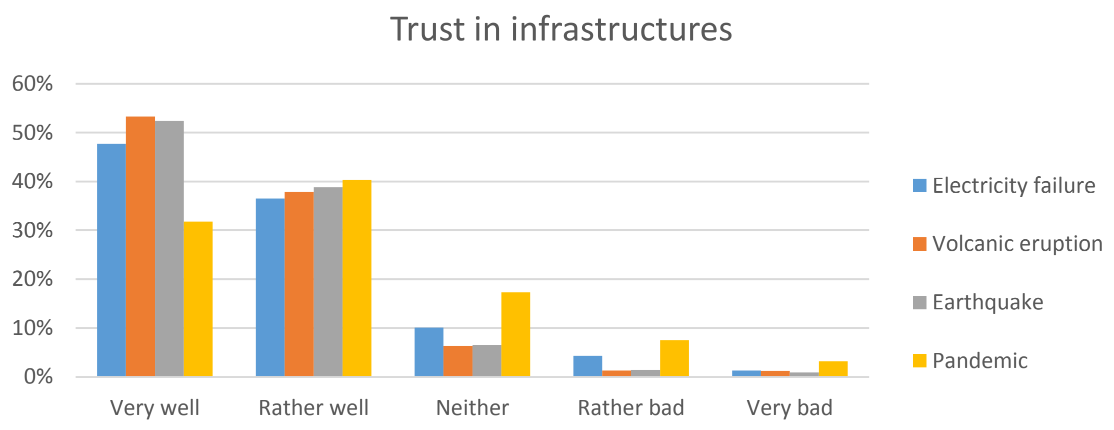


Figure 6-5: Question 5: How well or bad do you trust infrastructure (for example SAR, law enforcement, government, distribution companies, etc.) to deal with the following crisis?

6.2.3 Part 2 – Actual preparedness

In this part of the survey an attempt was made to evaluate the actual preparedness of the general public. The question focused on items present at household that would help in case of crisis, emergency plans for the household, etc.

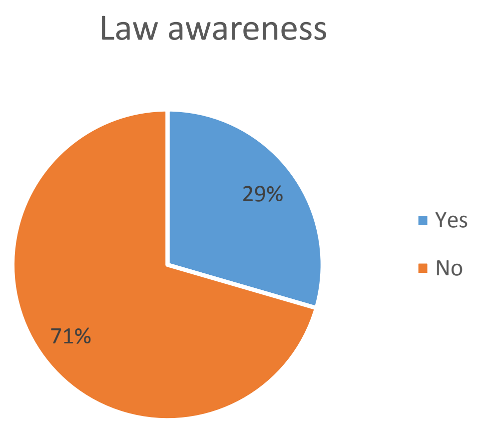


Figure 6-6: Question 6: Did you know that according to law, the police can demand people from the ages of 18-65 years old to help authorities during crisis?

Question 6 aimed to evaluate people's *law awareness* regarding crisis which relates to certain age group of people being able to help during crisis. Close to one third of the respondents was familiar with these laws which results in the majority of the public ignorant regarding this matter (Figure 6-6). This question does not demonstrate the respondent's knowledge of law regarding crisis, civil defence, etc. in Iceland. However the law was chosen due to its relation to the public.

The next three questions (Q7, Q8 & Q9) in part 2 were concerning household contingency plans regarding electricity failure and other possible crisis events.

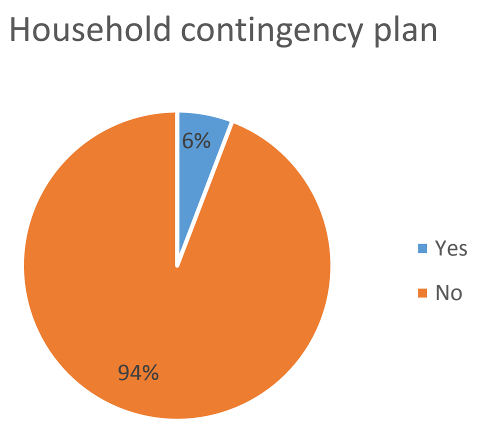


Figure 6-7: Question 7: Do you and/or your family have any contingency plans for a long duration electricity failure?

Question 7 aimed to find out if individuals or families had any *contingency plans* for electricity failure events. A very low percentage of respondents (6%) said they had a contingency plan (Figure 6-7). These findings are at the same time surprising and not. The number of respondents claiming they have a contingency plan is very low. However, if one had to speculate the outcome beforehand the difference in response would have been similar but perhaps but perhaps with few more respondents claiming they had a plan.

Question 8 was a follow up question of Question 7 and aimed to identify aspects of the contingency plans. Respondents that declared having a contingency plan were only able to answer this question. A variety of aspects regarding contingency plans were detected when analysing the results. No aspect turned out to be significantly more popular than others (Figure 6-8). Most surprising findings were that though people had concluded from Question 7 that they had a plan only 3 respondents turned out to have something that could be considered as a *defined plan*. Further, for data representation purposes a category of *not relevant* occurred 21 times. That category consisted of items resembling answers from Question 2 such as flash lights etc.

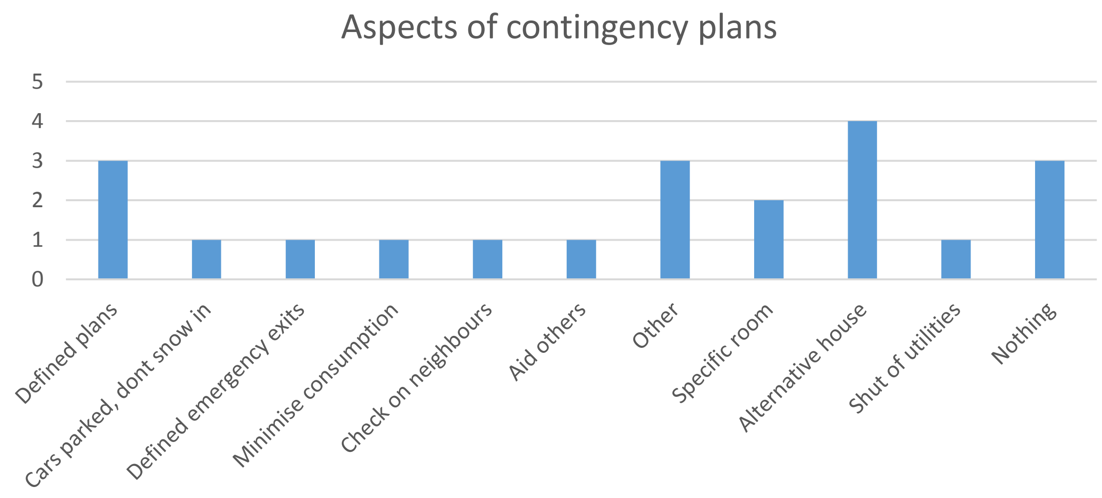


Figure 6-8: Question 8: Please describe what your contingency plan regarding long duration electricity failure includes?

Question 9 aimed to find out if individuals had any contingency plans related to other crisis/natural hazards. Though a rather small percentage of respondents say they have a contingency plan it is clear that contingency plans for *volcanic eruption* are at least two times more frequent than any other (Figure 6-7).

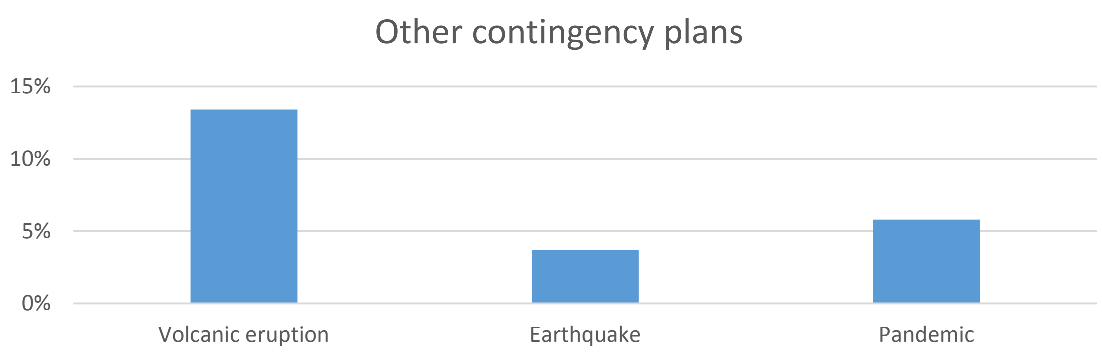


Figure 6-9: Question 9: Do you and/or your family have any contingency plans for the following crisis?

When asked if respondents had a contingency plan for their households only a small minority (6%) stated that they had one (Figure 6-7). However when asked to describe what the contingency plan included a variety of aspects appeared from the responses but from very few respondents. Only three respondents turned out to have a contingency plan that could be described as a defined or a solid contingency plan. Very few respondents included aspects that could contribute to a contingency plan. Majority of the responses (21 responses) were classified as not being relevant since those aspects that were pointed out related to much to previous question regarding preparedness such as having a flash light or a candle. The most popular response of an aspect for a contingency plan was alternative housing (3 responses) which demonstrates the lack of aspects when looking at over all responses.

The next two questions (Q10 & Q11) were related to practical and useful items or equipment during an electricity failure. Findings from the questions are displayed together in Figure 6-10.

Question 10 aimed to find out what practical equipment with an item-by-item approach for each household. Question 11 was a follow up question of Question 10 where the aim was to identify if the items were easily reachable. Only respondents who declared owning certain equipment/item were able to respond to accessibility of those particular items. As one might wonder everyday items such as *warm clothing*, *lighting equipment*, *flash light and first aid kit* are the most present in households (Figure 6-10). When items become less useful for everyday routine such as *walkie-talkies* and *power generators* the ownership drops drastically. The accessibility of the equipment/items turned out to be consistent and only varies from around 60 to 80%.

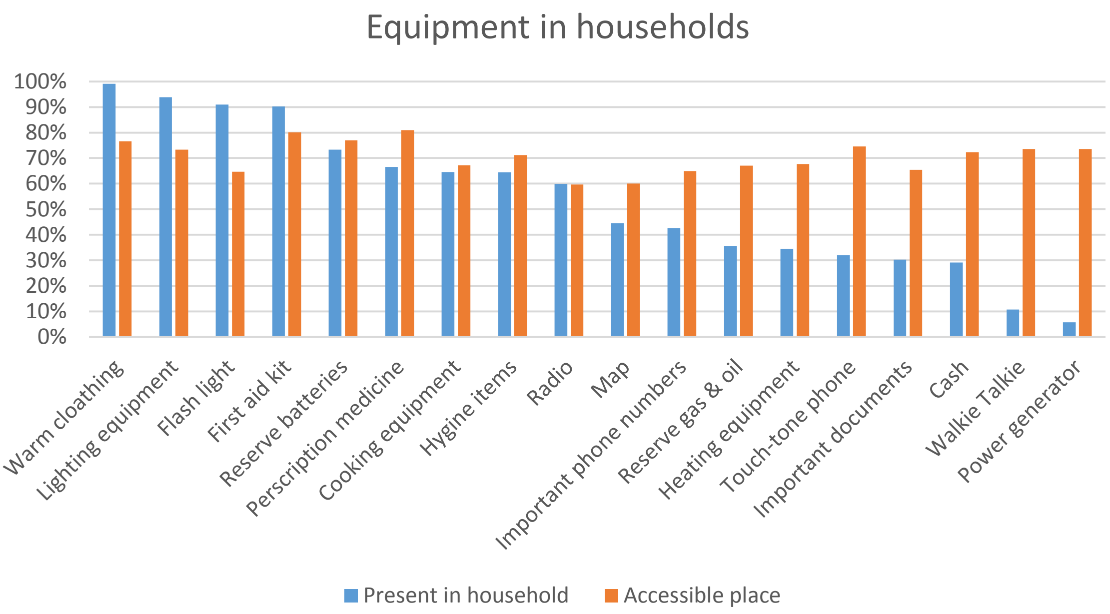


Figure 6-10: Question 10: What of the following is present in your home? Question 11: What of the following do you store in a certain place that you can access it during crisis?

When asked to identify which items, out of 18 items/equipment listed, were present in their households interesting findings appeared. For 9 items/equipment a 50% or more ownership ratio appeared from the 18 item list. Items such as warm clothing (99%), lighting equipment (94%), etc. turned out to be what respondents owned in general. Ownership of equipment related to ICT such as Touch-tone phones (32%) and handheld radios (11%) was rather lacking except for a battery or hand powered radios which 60% of respondents had. Further, a great consistency (60-80%) appeared when respondents were asked if the items/equipment were located in an accessible place where they could easily get to them in case of emergency. Further analysis shows that ownership of 10 items from the list was most common (87 respondents), the highest ownership was 18 items and that 14 respondents owned nothing. Also, the average ownership rate of respondents that stated in Question 1 that they were well prepared turned out to be around 11.4 items which was around 2 items more than for the overall respondents. This analysis can be seen in Appendix D.

The next four questions (Q12, Q13, Q14 and Q15) were related to food supply in households. The point was to see if people had any unperishable food and further if anything was set aside for crisis events.

Question 12 aimed to evaluate the type of food and in what volume food exists in people's homes. Majority of respondents have either rather or very little food in general (Figure 6-11). People determining they have a lot of food turn out to have mostly food that needs cooling, both with short and long shelf life. Very few people own a lot of food with long shelf life without the need for cooling.

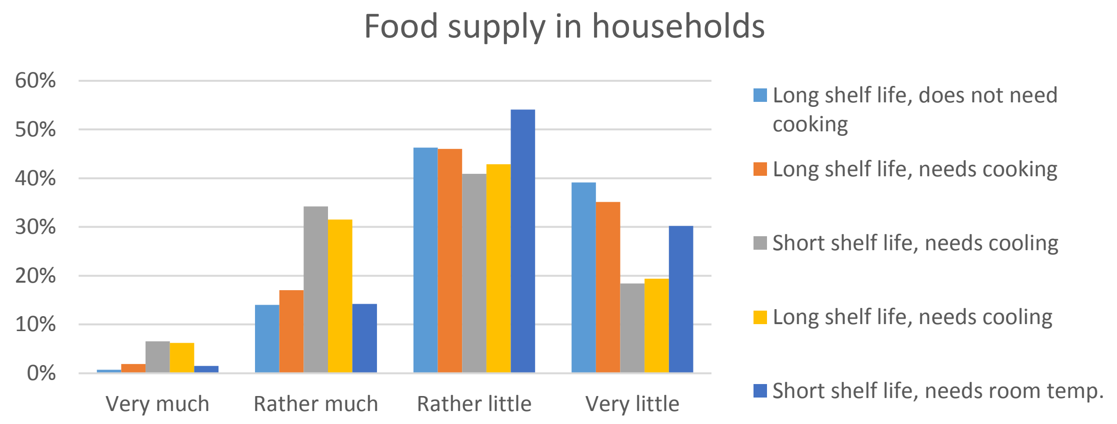


Figure 6-11: Question 12: How much or little do you have of the following foods?

Question 13 aimed to get their evaluation of how long the food supply present in respondent's households would last. Majority of respondents (around 75%) value their food supply either as enough for *less than one week* or *from one to two weeks (Figure 6-12)*. Very few responders (8%) consider themselves sustainable for *more than four weeks*.

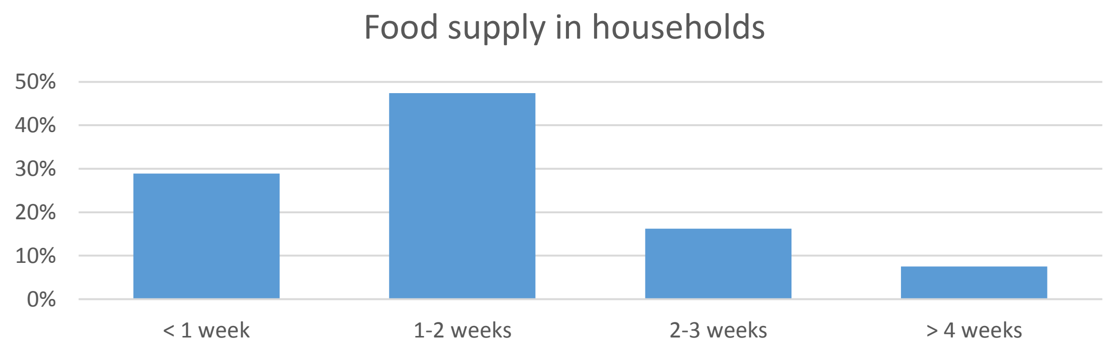


Figure 6-12: Question 13: How long do you consider yourself and/or your family to be able to live long on the food present in your household?

Question 14 aimed to determine if households were equipped with special supply of food to use only during emergencies. Question 15 was a follow up question of Question 14 determining whether or not this specially stored food was upgraded on regular basis. Only those who responded *yes* for Question 14 were able to answer Question 15. A very small percentage (2%) of respondents turned out to have a *special supply of food* (Figure 6-13).

However, the majority (69%) of these 2% appeared to *upgrade their supplies* on a regular basis (Figure 6-14).

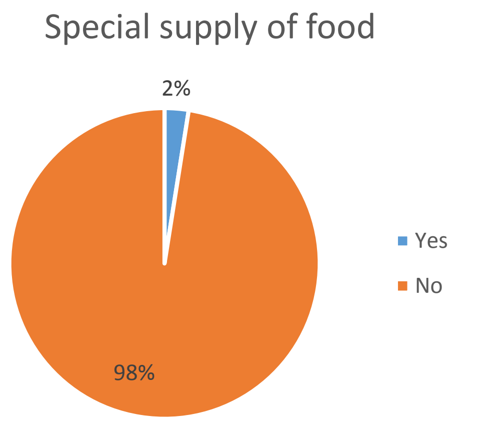


Figure 6-13: Question 14: Do you have food stored specially to use during crisis?

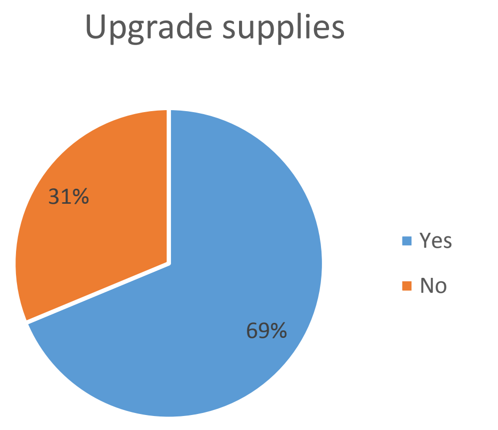


Figure 6-14: Question 15: Do you and/or your family upgrade the specially stored food supply regularly? (For example, once a year or every other year).

When asked about food quantity in their households the majority of respondents have either rather or very little food in general (Figure 6-10). People determining they have a lot of food turn out to have mostly food that needs cooling both with short and long shelf life. Very few people turned out to own a lot of food with long shelf life without the need for cooling. Further when asked to evaluate how long they could live on the food present in their household the majority of respondents (75%) valued their food supply either as enough for less than one week or from one to two weeks of which 29% felt they had enough for 1 week (Figure 6-12). Very few responders (8%) consider themselves sustainable for more than four weeks. Further respondents were asked if they had a special food supply which only to use in emergencies which revealed that only 2% of respondents claimed to that special supply of food (Figure 6-13). Further analysis regarding food in households showed that no respondent had "very much" of the five food categories presented and only 1 had "very much" of 4 categories. Also, the ownership of special food supply was not noticeably different between those stating they were prepared or the others. Only 7% of the prepared appeared store that kind of food. This analysis can be seen in Appendix D.

The last questions (Q16 & Q17) focused on how aware people were regarding aspects needed regarding crisis. It was concluded that medical skills and some knowledge of contingency plans were useful attributes.

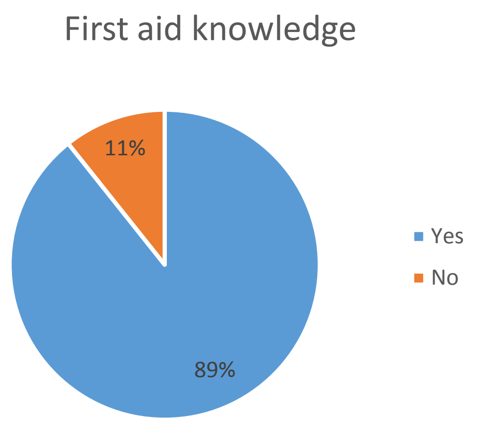
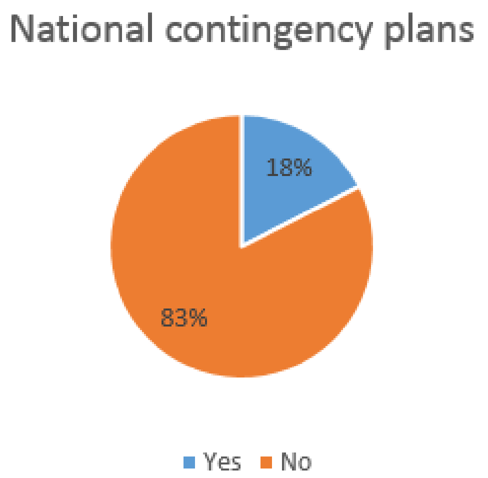


Figure 6-15: Question 16: Have you or anyone in your family taken a first aid class, first responder class or similar courses?

Question 16 aimed to evaluate people's *first aid knowledge*. The vast majority (89%) of respondents declared that they or someone in their family had taken a first aid course or something similar. This is not surprising since a lot of the general public serves in SAR, and people are taught first aid classes in various jobs and schools.

Question 14 aimed to see if people had familiarized themselves with contingency plans at all. Respondents were asked to answer separately for national and regional contingency plans. There turned out be consistency between awareness regarding *national contingency plans* and *regional contingency plans* (Figure 6-16) or 18% and 11% respectively. However the findings demonstrate that the general public is very ignorant when it comes to contingency plans. Further, it could come as a surprise that outcome for the national contingency plans is slightly better than for regional contingency plans. However, when considering well known hazards in Iceland such as volcanic activity and earthquakes it is understandable that people would rather focus on such events regarding their preparedness.



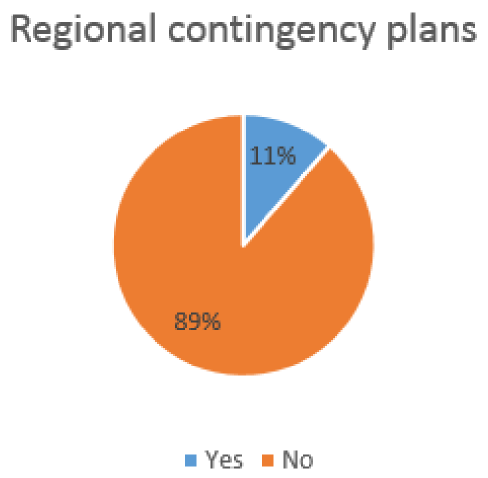


Figure 6-16: Question 14: Have you familiarized yourself with the following?

Knowledge and awareness concerning certain subjects that were included in the survey lead to various findings. When asked about a law regarding duties towards civilians during crisis 29% of the respondents claimed to know about it. 89% of the respondents claimed to have knowledge of first aid or something similar. 18% of the respondents claimed to be informed about national contingency plans and only 11% claimed they were informed about regional contingency plans. Further analysis demonstrated that respondents stating that they were well prepared were 100% familiar with first aid, 29% with national contingency plans and 14% with regional contingency plans. This analysis can be seen in Appendix D.

6.3 Stakeholder survey

In this section an analysis is presented on the confidence that government functions, stakeholders, and the public protection agency show towards public preparedness and the reliability of the electricity and ICT infrastructure. The questions were nine in total for this survey.

The survey is divided into two parts. The first part focuses on identifying the respondents, their role, experience etc. The second part focuses on their view towards the public and infrastructure.

6.3.1 Methodology

The stakeholder survey was distributed towards certain companies, government agencies, etc. Each stakeholder could contribute more than one respondent to the survey. This survey was less formal than the public preparedness survey. The questionnaire was with emails to the stakeholders containing a link to enable participants to answer. The Survey Monkey online survey service was used for this survey. The survey was sent to total of twenty stakeholders from which 9 responses were gathered. This survey did not address gender, age, residence, etc. since its purpose was to receive expert opinion.

6.3.2 Part 1 – Stakeholders knowledge

Question 1 aimed to figure out how good the distribution of answers the survey would be. Distribution of jobs appeared to be really good since each sector answered at least once (Figure 6-17).

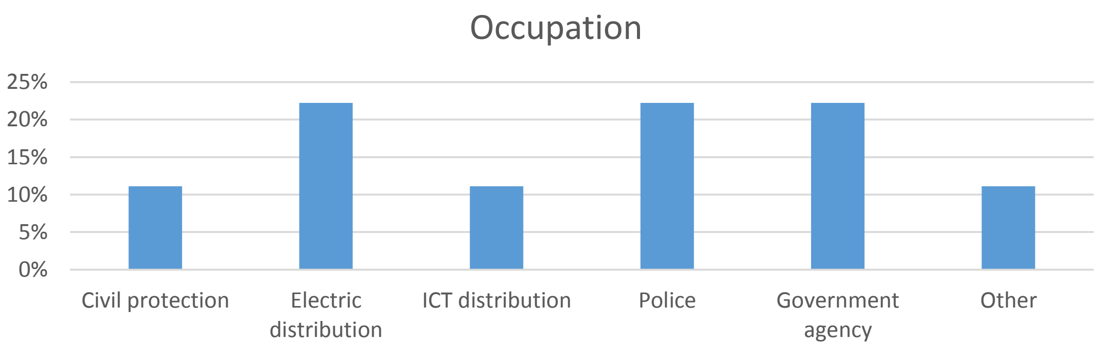


Figure 6-17: Question 1: What does your job relate to the most? Options where civil defence (green), electricity distribution, ICT distribution, police, government agency and other.

Question 2 was represented to get some insight into the respondent's job and see if their job entailed anything related to emergency management which affected the public. The majority of the respondents (89%) appeared to be have some emergency related duties and only 11% of respondents had no such duties (Figure 6-18).

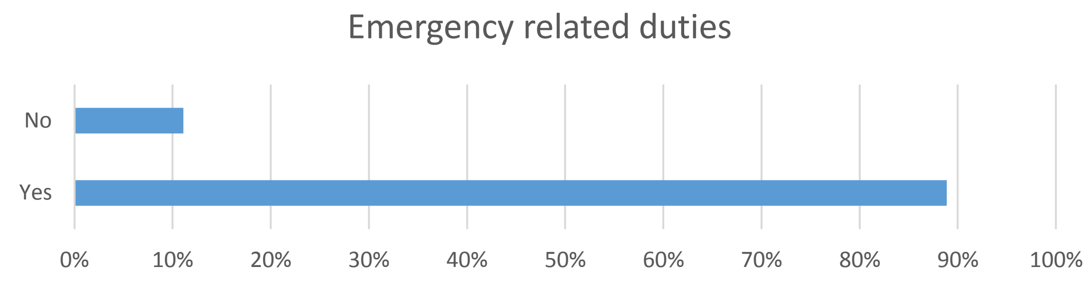


Figure 6-18 Question 2: Does your job include any duties that relate to response or emergency – management that affects the public?

Question 3 was a follow up question of Question 2. This question asked respondents to identify their main duties during emergencies. Duties of individual respondents varied which makes better answers since people have knowledge in different fields (Figure 6-19).

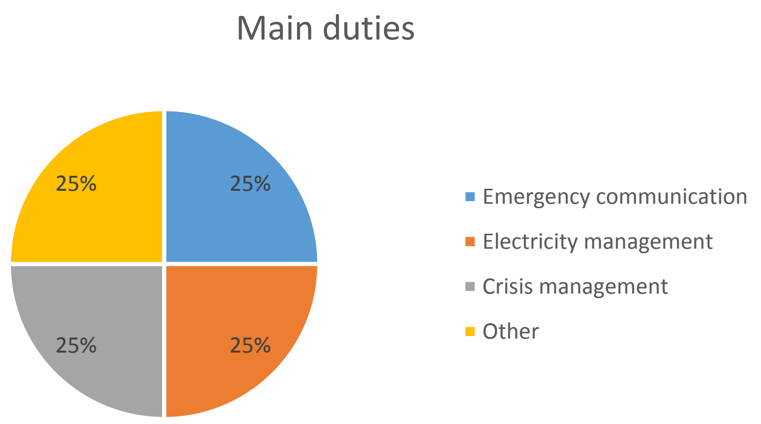


Figure 6-19: Question 3: If yes, what are your main duties? Answers can be seen in Appendix CII.

Question 4 aimed towards individual respondent's experience of electricity failure. The majority of respondents (78%) appeared to have experience from their work that relates to an emergency situation that has occurred from failure in electricity Figure (6-20). The outcome is viewed as good because of the potential experience the respondents may have regarding public preparedness and the resilience of critical infrastructure.

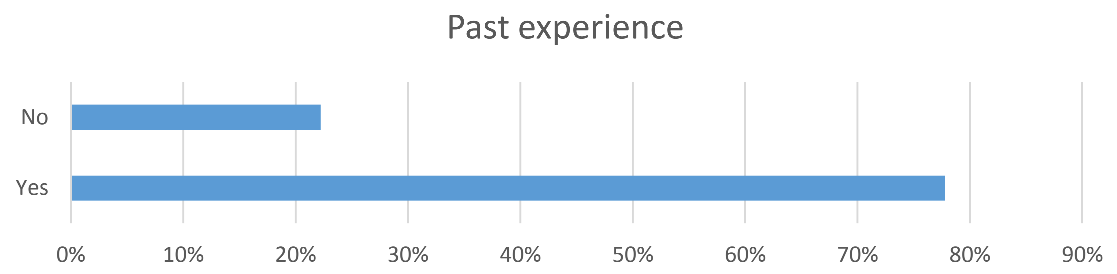


Figure 6-20: Question 4: Do you have experience from work that relates to an emergency situation which has occurred from electricity failure?

6.3.3 Part 2 – Stakeholders opinion

Question 5 aimed to get the respondents opinion on faults in the distribution system for electricity and ICT. The main concerns regarding electricity and ICT distribution appeared to relate to transmission lines being above ground and that emergency power is lacking (Figure 6-21).

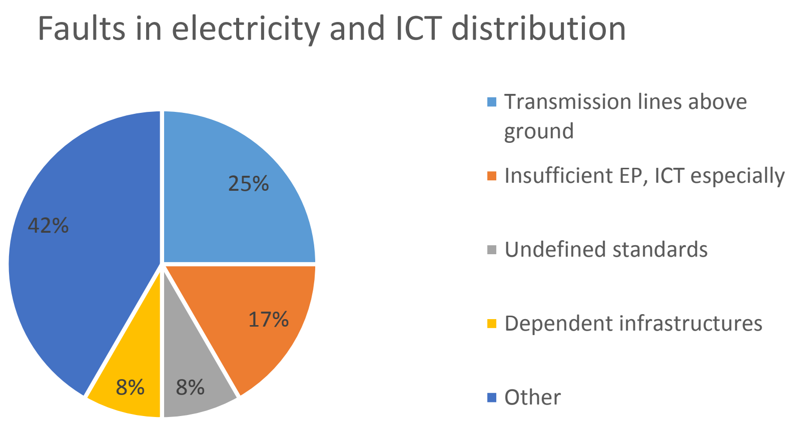


Figure 6-21: Question 5: What do you consider the main faults in electricity and ICT –distribution systems in Iceland? Answers can be seen in Appendix CII.

Question 6 aimed to evaluate respondent's opinion on the ability of infrastructures to handle certain types of crisis. Respondents showed fair amount of trust (around 45%) towards infrastructure during a shorter electricity failure (Figure 6-22). However for electricity failure longer than a week the majority of participants (around 66%) express their lack of confidence in infrastructure dealing with the scenarios.

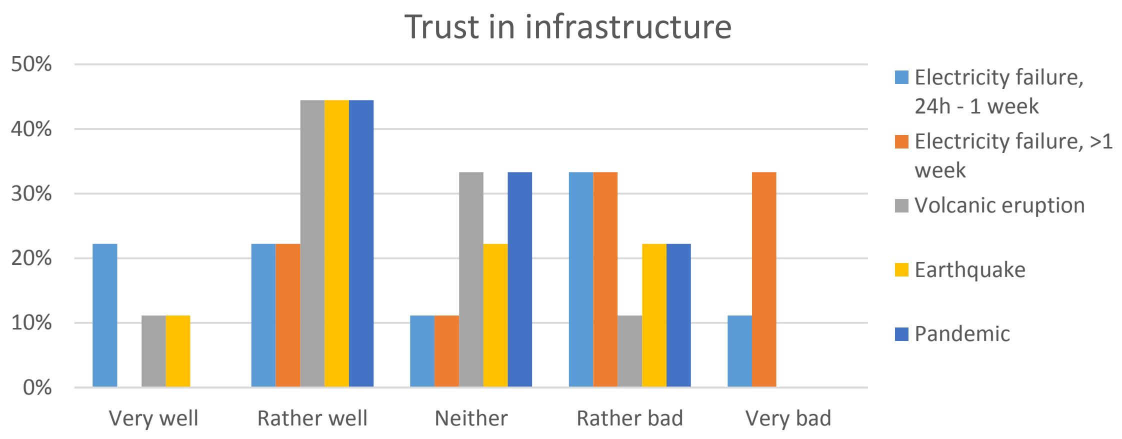


Figure 6-22: Question 6: How well or bad do you consider infrastructure (for example government, police, electricity and ICT –distribution systems, SAR, etc.) in Iceland capable of dealing with the following? The findings are displayed in percentage (%).

Question 7 aimed to get the respondents opinion on the preparedness of the general public. Respondents demonstrated drastically their lack of confidence regarding public preparedness. For a shorter electricity failure only 11% of respondents declare the public to be rather or very well prepared and in a longer failure 100% of them declare the public as unprepared.

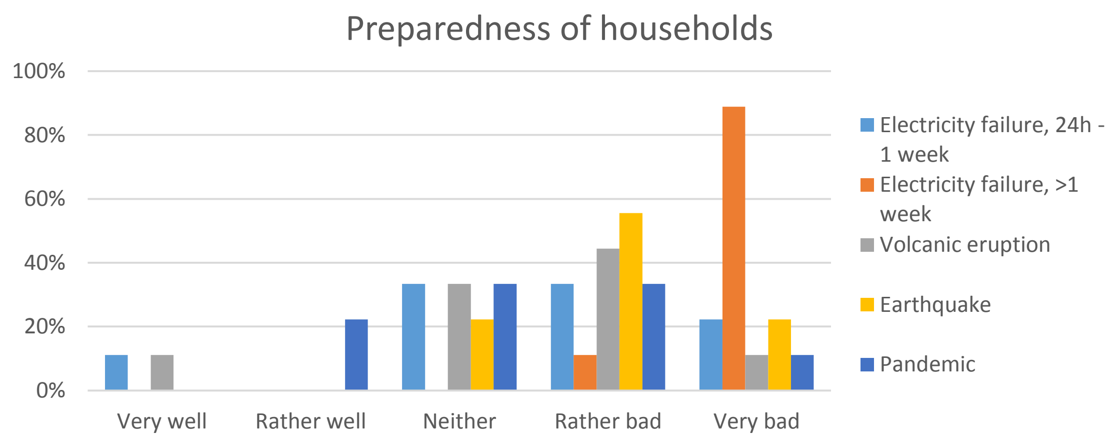


Figure 6-23: Question 7: How well or badly prepared do you consider households (the general public) for the following scenarios? The findings are displayed in percentage (%).

Question 8 aimed to get the respondents opinion on how well people are informed regarding contingency plans. Respondents demonstrated lack of confidence regarding the awareness of the general public. In both cases around 50% of respondents assume the public rather or very badly aware of contingency plans.

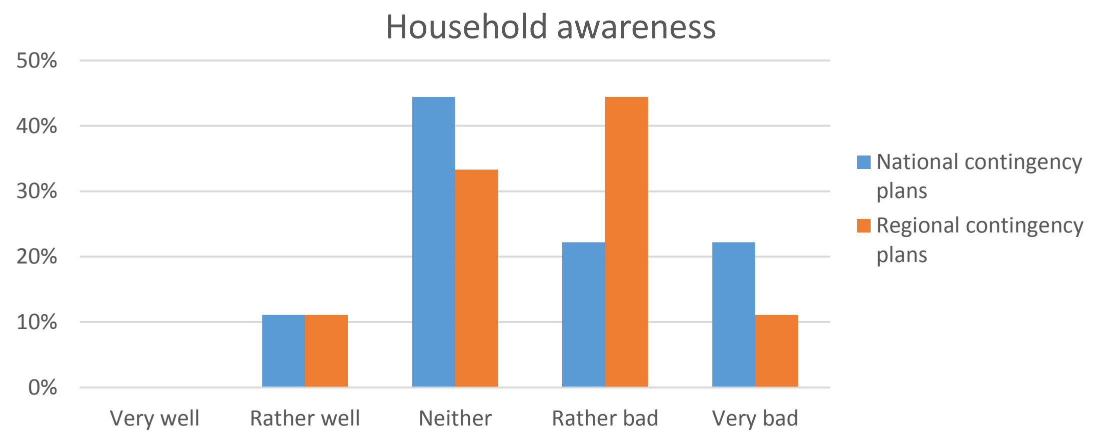


Figure 6-24: Question 8: How well or badly do you consider households (the general public) informed regarding the following aspects? The findings are displayed in percentage (%).

The last question, Question 9 aimed to identify roles for the general public during crisis. Duties and responsibilities of the general public appeared to vary and are poorly defined (Figure 6-25). Keeping away from hazardous zones, keep calm and try not to bother first responders unless there is actual need for it can be viewed as their duties according to responses.

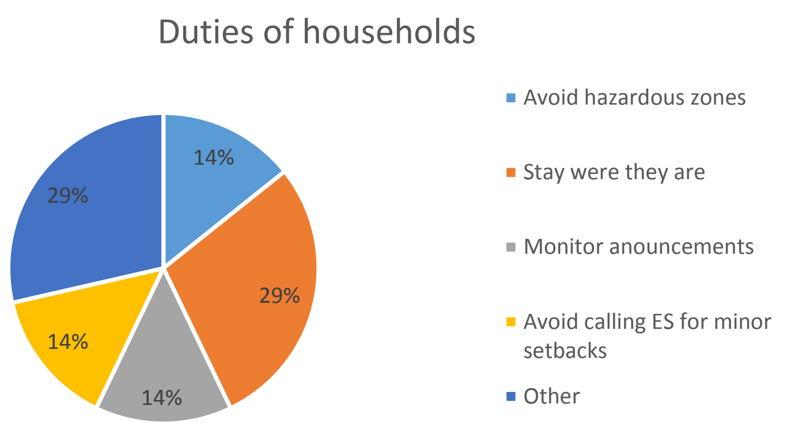


Figure 6-25: Question 9: Can you make an example regarding what is expected of the public during times of crisis? (For example duties, preparedness, how long people have to endure, etc.) Answers can be seen in Appendix CII.

6.4 Results

This section will address the main results from the two surveys.

6.4.1 Public preparedness survey

Part 1 – Perceived preparedness

It turns out that respondents view their preparedness, regarding electricity failure, in general as bad however their confidence in being able to assist others during such events appears to be a lot higher. This could lead to the conclusion that respondents do not view their preparedness as indicator of their ability to help others or their lack of understanding regarding that they have to be able to manage themselves first in order to help others. Further, the amount of respondents that demonstrate rather high or very high level of confidence towards infrastructure in dealing with electricity failure is very close to the amount of respondents that consider themselves as rather badly or very badly prepared (63%) for electricity failure. This could lead to the conclusion that respondents do not feel the need to be prepared for a crisis when they are confident that others will manage it for them.

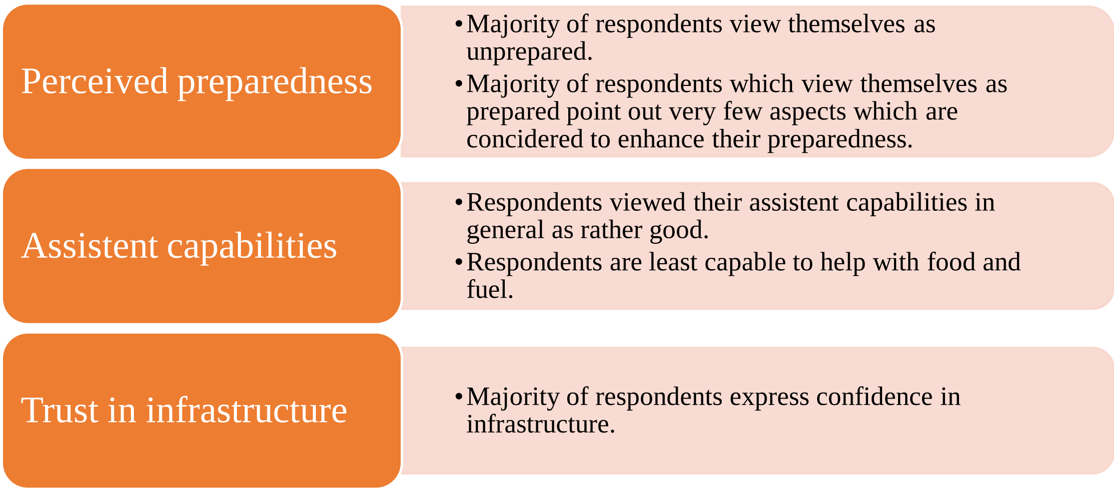


Figure 6-26: Summary of findings from part 1 in the public preparedness survey.

Part 2 – Actual preparedness

For an estimate of actual preparedness there is no clear conclusion. However, the lack contingency plans is clear since few people claim to have one. In most cases there appears to be no plan even when people consider themselves to have a plan. Ownership of items/equipment, which was assumed to be of help during crisis, appears to be relatively high however lacking when it comes to ICT equipment and alternative source of electricity. Regarding food most respondents estimated their food supply as little and appeared to own more of food that relied on cooling when stored. Further, a special food supply for emergency was almost non-existent. Knowledge and awareness regarding first aid was really good however, when it comes to contingency plans the knowledge is really poor. Further analysis showed that respondents stating they were rather or very well prepared were in fact more prepared then the rest of the respondents. They generally owned more equipment, had more knowledge of first aid and national contingency plans and were more likely to store special food supply.

Contingency plans	• Majority of respondents state they don't have contingency plans. • Majority of respondents that state they have a contingency plan appear not to have one when asked to point out aspects of their plan.
Equipment	• Ownership of units was rather high in general. • Ownership of specialized and ICT related equipment was lacking.
Food	• Majority of respondents estimated their food supply sufficient for either less than 1 week or 1-2 weeks. • Ownership of food with long shelf life which did not require cooling was fairly little.
Knowledge and awareness	• Knowledge of first aid was very high. • Knowledge regarding contingency plans in general was lacking.

Figure 6-27: Summary of findings from part 2 in the public preparedness survey.

In summary the actual preparedness could be viewed as poor or at the very best rather poor except for ownership of equipment. However, owning various equipment which enhances their preparedness and not knowing that it does contribute to the fact that the respondents are poorly prepared. Respondents seem to perceive their preparedness as rather or very poor which in this case is good since apparently they are not underestimating themselves.

6.4.2 Stakeholder survey

Part 1 – Stakeholders knowledge

Part 1 of the survey shows that the majority of participants are affiliated with emergency situations regarding electricity failure to some extent. In a way that makes them a good example of officials to express their opinion towards public preparedness. Further their duties contribute to their expertise both in electricity and general ICT distribution as well as emergency communication.

Part 2 – Stakeholders opinion

Part 2 of the stakeholder survey demonstrates clearly the lack of confidence from government regarding certain aspects of public preparedness, especially when it comes to electricity failure. Further the survey contributes to the lack of clearly stated duties that the public should uphold during crisis. This corresponds to the comparison of the National Risk Assessment Plans, Chapter 3, where this aspect is hardly addressed or not at all.

The survey also points out faults in the distribution systems in Iceland where the main factors relate to the lack of emergency power and that transmission lines are above ground which corresponds to one answer regarding certain aspects of the system being badly equipped to handle bad weather. Further, it is clear that confidence from stakeholders regarding the ability of critical infrastructure to function during electricity failure is a lot less than their confidence towards the ability of critical infrastructure for other crisis such as volcanic eruption and earthquakes. It is also interesting that the stakeholders have a lot more confidence in infrastructure than in the general public. The statements made in the answers correspond towards what happened both in the theoretical impact identification and impacts identified in the case studies.

6.4.3 Comparing to foreign surveys

When it comes to essential items or equipment such as flashlights, etc. results for Iceland are very similar to other studies. However when it comes to a special supply kit or a household plan Iceland is very far behind. The results further contradict the results from the survey Basolo et al. (2009) conducted where high trust in government resulted in higher level of preparedness, for Iceland this did not appear.

6.5 Surveys limitations

6.5.1 Public preparedness survey

One of the limitations of the public preparedness survey is that participants can change their view on their perceived preparedness while/after they have answered the questions regarding their actual preparedness. Another limitation is the amount of participants since 1200 participants correspond to around 0.35% of the general public in Iceland. Of these 1200 participants the response rate was around 60%.

6.5.2 Stakeholder survey

Main limitation of the stakeholder survey is the number of participants. Though the participants come from various sectors and have experience regarding crisis it would be ideal to have a larger response pool to analyse. The survey was sent to around 20 companies/agencies of which there were 9 replies.

6.6 Summary

In this chapter studies on public preparedness were discussed. They show that public preparedness can vary greatly and furthermore results can be very different based on who performs them. Two surveys were conducted in Iceland in relation to public preparedness. One of them was distributed to the general public and the other one to stakeholders. Findings suggest that public preparedness is rather lacking for the most part however a couple of aspects suggest otherwise. Further, the results reveal that those who view themselves as prepared appear to be more prepared than those who don’t and in very few cases individuals are extremely well prepared.

7 Conclusion and discussion

Connectivity between households and critical infrastructures is highly complex. Households as well as critical infrastructures, such as first responders, water supply, etc., are extremely dependent on electricity to maintain normal operation. It is of the upmost importance that key personnel and the general public are informed and well aware of the consequences which can occur during an extensive failure in electricity infrastructure. Analysis in Chapter 3 showed that failure in electricity and ICT infrastructure can lead to various impacts on households resulting in households being effected by every critical infrastructure. Impacts caused directly on households by failure in electricity and ICT can include no lights or phone service. Impacts caused indirectly by these failures include inadequate house heating where insufficient electricity supply effects water distribution, and lack of emergency response caused by ICT failure which originates from electricity failure.

Comparison of National Risk Assessment Plans in Iceland, Norway and Sweden revealed that events causing failure in electricity and ICT infrastructure are covered in detail. However, impacts that were discussed in Chapter 3 and the case studies are for the most part poorly addressed or neglected. While Iceland includes a more detailed description of infrastructures and natural hazards in general, Norway gives the most comprehensive analysis on impact from failure in electricity. Sweden is the only country that includes a detailed analysis on ICT infrastructure however that analysis is for a very specific system. In Iceland especially, impact analysis are poorly performed and creation of specific scenarios for these failures is lacking. This demonstrates the need to analyse impact from failure in electricity infrastructure as well as ICT in much more detail. All the countries hardly address the general public in the assessments. Expectations towards the general public during times of crisis are given little thought and are almost non-existent.

The case studies carried out, for two electricity failure events in Iceland, demonstrated clearly that critical infrastructures are highly vulnerable against both short- and long-term failure in electricity infrastructure. The general public is more resilient against short-term failures even though other aspects, such as time of year, weather, etc., can affect their resilience. The case studies demonstrated the importance of functioning electricity as well as ICT for the general public's dependence on critical infrastructures. Further the importance is especially clear in the second case study when failure in these systems collides with other crisis for a significant amount of time. Other critical infrastructures that depend on electricity but still service households, such as ICT, hot water etc., seem to be most threatening to households. The strongest evidence of this is ICT failure in addition to snowed in households, making them out of reach both in terms of communications and transport and unable to receive help. Impacts caused directly from electricity on households turn out to have less effect except when households rely on electricity for house heating. Further, the case studies revealed a great lack of resilience of ICT and electricity infrastructure in terms of emergency power. Conducting such case studies by actively analysing information from such events while at the same time looking at them from a broad perspective, and ask "what if", a more comprehensive analysis can be made.

The surveys conducted in this thesis revealed that perceived preparedness of the general public is not consistent with their confidence in helping others. Further, their answers to certain question demonstrate a great lack of understanding of infrastructure electricity dependence as well as which essentials are required during failure in electricity. The public's confidence in key personnel, such as response units, government, etc., to handle electricity failure is very high while at the same time the confidence, from authorities, key personnel, etc., in the public's preparedness is very low. Further the stakeholder's confidence in infrastructures during electricity failure is lower than from the general public. Aspects such as owning essential equipment and knowledge of first aid contribute towards a rather good actual preparedness of the general public. However, other aspects such as their lack of understanding consequences, contingency plans and food suggests their preparedness is poor. Compared to other studies conducted on public preparedness the preparedness of the general public in Iceland is similar regarding essential equipment they own. However, when comparing these studies regarding others aspects of preparedness such as having a plan to follow when crisis occur the findings suggest that the general public in Iceland gives preparedness little thought.

From conducting this thesis it appears that households as well as critical infrastructures in general operate poorly when electricity and ICT are not present. Resilience against electricity failures of both subjects needs to be improved. Infrastructures should be able to function for a longer period of time on emergency power and households need to improve their preparedness in order to fully function during these failures. Further studies regarding this subject should include detailed analysis on infrastructure resilience in order to make them more robust. Risk Assessment Plans should include the general public specifically, their roles and required preparedness level should be specified. Impact identification from electricity and ICT failures on households should be performed in far greater detail, especially in Iceland. Investigation into public preparedness should be conducted in order to get better understanding regarding the actual preparedness of the general public. Authorities should focus on presenting educational material to the general public and raise awareness regarding possible consequences from these types of events and other crisis. Public preparedness must be increased in order to form a more functional society during crisis.

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Appendix A

Appendix A will describe the major organizations that distribute electric energy in Iceland, their main purpose and areas they operate. There are a few others that are neglected in these listings however it should give broad vision of the market.

A-I

Electricity distribution

The main purpose of Landsnet is to handle distribution and handling of the electric network. More accurately their purpose can be listed as:

- “Ensure balance between supply and demand of electric power.
- Be responsible for the operational safety of the distribution network as a whole.
- Maintain the capability of the network over a long time and shape the future of the network in the country.
- Ensure accessibility to the network promote increased activity in the electric market” ((Landsnet, 2011).

Landsnet owns and operates all the main transmission lines in Iceland. “The highest voltage that is distributed is 220 kV. A large part of the network is 132 kV and parts of it are 66 kV and 33 kV. Some of their lines in the South-West part of the country have been constructed to handle 420 kV but they are operated at 220 kV” (Landsnet, 2013). However higher voltage is transported to heavy industrial companies such as aluminium smelters.

Orkuveita Reykjavíkur focuses mainly on selling hot water and electricity. “They serve the capital area, Reykjavík, Kópavogur, Mosfellsbær, and Garðabær and also Akranes, which makes up for around half the population in Iceland” (Reykjavíkur, 2013).

Rarik is one of the larger companies in Iceland that handles electric power distribution. It was founded in 2006 and is owned by the government. The main focus of the company today is electric distribution but Rarik has also contributed to development and construction of electric distribution in the countryside which Rarik operates 90% of. Rariks distribution network reaches to all parts of the country and also to 43 towns. The distance of their distribution system is 8000km long, 43% of which is underground. Rarik also owns and operates five hitaveitur (Rarik, 2009).

HS Orka produces and sells electricity and hot water to many parts of the country, to homes and industry. They operate two geothermal plants, Svartsengi (75 MW) and Reykjanesvirkjun (100 MW), and were the first in Iceland to produce electricity alongside with geothermal production (Orka, 2010)

In this appendix a summary from each report from the jurisdictions in Iceland can be found. The summary contains material that was pointed out regarding electricity and ICT stability in each region.

A-II

Regional risk assessments

Electric power failure was considered little since Akranes is located near one Landsnets substations called Brennimelur and the fact that electric distribution lines are under ground. Just a year after that assessment was made the substation at Brennimelur malfunctioned resulting in power failure in Akranes. Water supply was not considered threatened in terms of power failure since power backup had been established to the purification and distribution systems (A. Lögreglustjórinn, 2011). One year after the assessment came out there was a power failure in Akranes when the substation in Brennimelur malfunctioned.

Phone connection is good and present everywhere in the region. It is either copper or fibre optic –cables. General emergency units in the area rely on TETRA communications and there is one transmitter that covers the whole region. There are minimum blinds spots in the area when it comes to the TETRA system. VHF transmitters from the Search and Rescue teams are also present in the area however the emergency response units have switch over to TETRA. It is noted that work was being done to switch over to fibre optic cables completely. Television broadcasting is transmitted through antenna and fibre optic cables (A. Lögreglustjórinn, 2011)

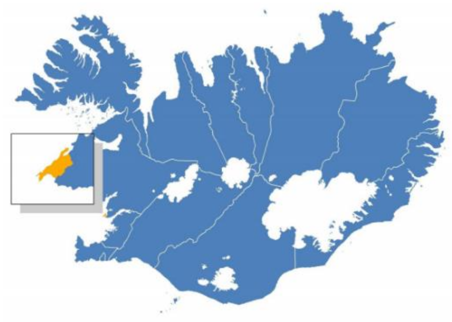

Figure A-1: Region 1 containing Akranes in Iceland. Retrieved from Almannavarnir.

Electric distribution for this region is mainly in the hands of RARIK. The region gets power from a few transmission lines owned and operated by Landsnet and are also equipped with a hydro power plant called Andakílsárvirkjun. In the region power failure is not considered as a possible threat and blackouts occur rarely (B. Lögreglustjórinn, 2011). Scenarios for electric power failure are not considered nor consequences. Furthermore nothing is mentioned about emergency power in the region nor the effect of power failure on curtain infrastructure.

Phone network is through a landline to most houses in the region and GSM network covers most areas in the region. According to Neyðarlínan the TETRA coverage is good in the region however blinds spots can occur because of landscape. Search and Rescue units in the area operate a few VHF and TETRA transmitters (B. Lögreglustjórinn, 2011). Skoða samfélagsöryggi

Figure A-2: Region 2 containing Borgarbyggð, Dalabyggð, Hvalfjarðarsveit and Skorradalsreppur in Iceland. Retrieved from Almannavarnir.

There are two power plants in the region, Rjúkandavirkjun 849 KW and Múlavirkjun 3100 KW. In Grundarfjörður schools and swimming pools are heated with oil and electricity is mainly used for house heating. There is emergency power located in Grundarfjörður, Ólafsvík (Rjúkandavirkjun) and Stykkilshólmur, the amount of power is not specified except that Rjúkandavirkjun has 849 KW capacity. It is however acknowledged that emergency power for water distribution and the distribution system is required and to strengthen protections around transformers (S. Lögreglustjórinn, 2011).

The GSM network in the region has many blind spots on the main road around the region. The TETRA network contributes a lot and covers more region and fibre optic cables are present in towns. However there is not backup for the fibre optic cable in the region (S. Lögreglustjórinn, 2011), which is being worked on (J. Á. Sigurjónsson, 2015). Search and Rescue units in the region still rely on VHF. Long-wave transmitting is still in the region but fewer people have equipped that supports that technology. It is also noted that many telecommunication transmitters and fibre optic cables not well protected in the region (S. Lögreglustjórinn, 2011). The threat of communication breakdown in the region was considered as probable.

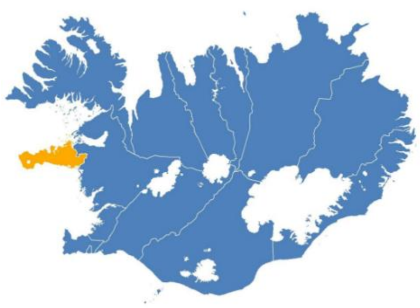

Figure A-3: Region 3 containing Snæfellsnes. Retrieved from Almannavarnir.

In the winter distribution of electricity in this area is considered unsafe especially outside of the towns which most of contain emergency power generators. In Ísafjörður the waste water treatment relies on two pumps which rely on electricity. Vestfirðir rely on power from the main transmission line in the national grid and from a few hydro power plant, the largest on being Mjólkárvirkjun. It is noted that power distribution safety for the region is being considered by the ministry of the interior. In the region heating is based on electricity for the most part. The threat of power failure in the region was considered as high threat (á. V. Lögreglustjórinn, 2011).

Phones network in the region is both through landlines and microwaves and fibre optic cables lies on land and through the sea. TETRA transmitters cover the area quite well however because of the landscape in the region there are quite a few blind spots in the coverage and the highways included. VHF is also operational in the area if needed (á. V. Lögreglustjórinn, 2011). The threat of a communication breakdown in the region was not evaluated.

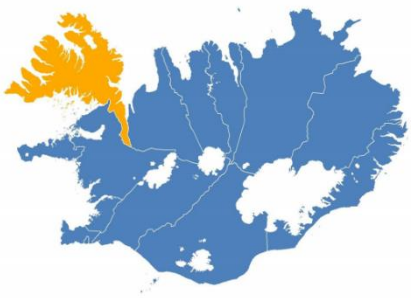

Figure A-4: Region 4 containing Vestfirði. Retrieved from Almannavarnir.

In the region there is a 150 MW hydro power plant called Blönduvirkjun. The power plant is connected to the main transmission line is Iceland. Emergency power is present in Skagaströnd for the Town's use. In Blönduós and Hvammstangi there is emergency power for the hospitals and for most of distribution except for cold water in Blönduós. The threat of electric power failure was considered possible. Cases regarding causes for power failure where a damn breaks, which Landsvirkjun has contingency plan for (á. B. Lögreglustjórinn, 2011).

Phone network is present through landlines in most households in the region and the GSM network covers most areas. The worst connection appears to be in valleys. The TETRA network covers the area quite well except for a few blind spots and the fire department and the Search and Rescue teams in the region use both VHF and TETRA (á. B. Lögreglustjórinn, 2011). The threat of communication breakdown in the region was believed not to be worth considering.

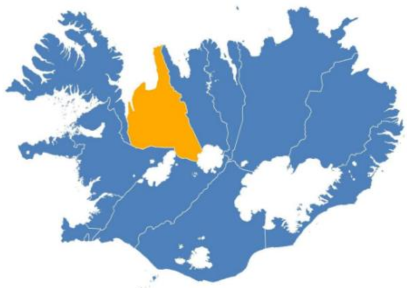

Figure A-5: Region 5 containin, Blönduós (town), Húnavatnshrepp, Húnaþing vestra, Skagabyggð and the municipality Skagaströng. Retrieved from Almannvarnir.

The countries main distribution line goes through the region. A single line transports electricity to Sauðárkrókur. Rarik handles distribution of electricity within the region. There are two power stations in the region, one in Sauðárkrókur and one in Brimnes. There is one hydro power plant in the region called Skeiðfossvirkjun 480 KW (á. S. Lögreglustjórinn, 2011). There are emergency diesel engines in Sauðárkrókur. The hot water supply has emergency power for their pumps and the hospital has one solely for itself. The threat of power failure in the region is considered as possible and the need to ensure emergency power in the region and Sauðárkrókur especially is required (á. S. Lögreglustjórinn, 2011). Nothing is mention about communication in the region except that it is noted that TETRA is present.

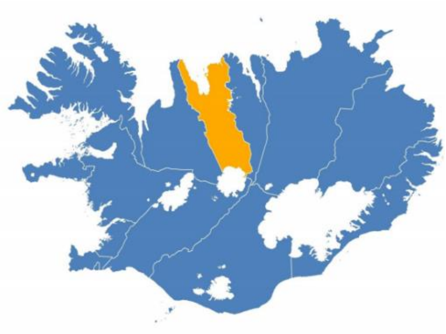

Figure A-6: Region 6 containing Akrahreppur and municipality Skagafjörður. Retrieved from Almannvarnir.

The main power distribution for Akureyri and the nearby towns comes from a distribution line in Laxá (e. Salmon River) in Aðaldal (e. Main Valley) and from the country's main transmission line. Some of the other towns are dependent on small hydro power plants nearby. Main distributors of electricity in the region is RARIK and Norðurorka (á. A. Lögreglustjórinn, 2011). Emergency power is present in some form for different towns in the region. In Akureyri the police department and the hospital are equipped with emergency power however the fire department is not. In Dalvík there is emergency power for hot and cold water supply. Ólafsfjörður is equipped with a 300 KW power station and Siglufjörður has the hospital equipped with emergency power along with 70% of other needs (á. A. Lögreglustjórinn, 2011). No possible scenarios are mentioned as possible threats to power failure however it is mentioned that one of the dams failed in 2006 and has been repaired

Phones network in the region is considered to be good and is mostly underground. Broadcast relay stations are quit frequent in the region. The GSM network is not fully secured in the region and the TETRA network needs improvement around the coastline. Fibre optic cables are present in some of the larger towns. It is noted that the fire department has once been without communication with Neyðarlínana, for a whole day, in the capital area where a fibre optic cable malfunctioned (á. A. Lögreglustjórinn, 2011). According to the assessment the GSM network in the region needs improvements along with the previously mentioned improvements on the TETRA network (á. A. Lögreglustjórinn, 2011). Risk of communication breakdown in the area is not evaluated in the region.

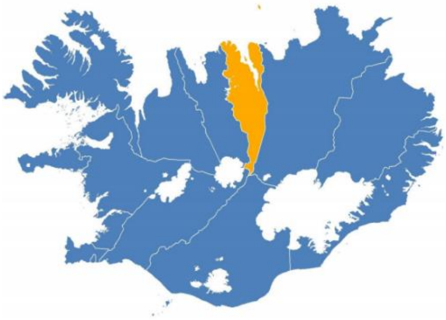

Figure A-7: Region 7 containing Akureyri, Eyjafjarðarsveit, Dalvíkurbyggð, Fjallabyggð, Grýtubakkahrepp, Hörgársveit and Svalbarðsstrandahrepp. Retrieved from Almannvarnir.

Rarik handles the distribution of electricity in the region. There are a few geothermal and hydro power plants in the region which cover most of the power usage for the region. The region contains a lot of volcanic activity, one large eruption under a glacier, Gjálpargosið 1996, destroyed a fairly large part of electric lines and phones lines. In 2009 a mudslide fell on a private home power station. Accumulation of ice on power lines is considered a threat to power failure in the region. Work is in progress to use underground power lines (H. Lögreglustjórinn, 2011). Emergency power in the region is 0,5 MW in Húsavík for hospitals, police station and municipality offices, 1,5 MW in Raufarhöfn, 2,3 MW in Þórshöfn and a power station in Bakkafjörður which meets the village's needs. The threat of power failure in the region is considered as a possible threat (H. Lögreglustjórinn, 2011).

The GSM network in the area has known blind spots that need improvement, however the network has been getting better and it covers quite a large part of the highlands. The TETRA network is also quite good in the region except for two places which have to be improved. The VHF network will still be operated by the Search and Rescue units in the area. Internet connection is quite good in urban areas but wireless in rural areas (H. Lögreglustjórinn, 2011). The threat of communication breakdown in the region is considered as a possible threat and it is noted that telecommunications need to be improved in several areas (H. Lögreglustjórinn, 2011).

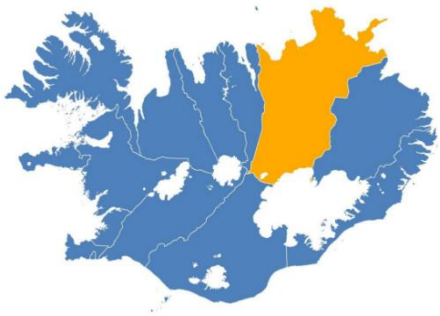

Figure A-8: Region 8 containing Langanesbyggð, Norðurþing, Skútustaðahrepp, Svalbarðshrepp, Tjörneshrepp and Þingeyjarsveit. Retrieved from Almannavarnir.

Power usage in the region is mostly from the country's main transmission line. There are several power plants in the region, the largest being Kárahnjúkavirkjun 690 MW. Many homes are dependent on electricity for house heating in the region. Electric distribution safety is not stable in the countryside outside of towns (í. S. Lögreglustjórinn, 2011).

Emergency power is present in Seyðisfjörður, Vopnafjörður and Borgarfjörður eystri (í. S. Lögreglustjórinn, 2011). The threat of power failure is considered significant in the region. No special contingency plans are present and emergency personal are activated if needed. Nothing is specified regarding emergency power regarding lifesaving operations, hospitals, police etc. It is also worth mentioning that few of the hydro power plants eru teknar út fyrir hryðjuverkum eða sabotage.

According to the assessment emergency communications are TETRA and VHF networks are used (í. S. Lögreglustjórinn, 2011). The need for risk assessment was not considered relevant in the region, or as a small threat.

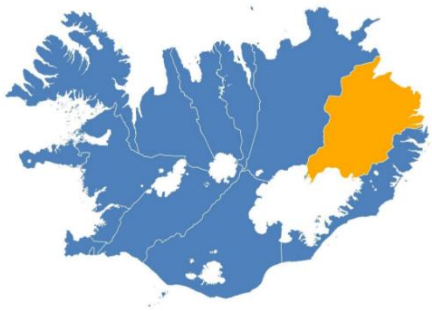

Figure A-9: Region 9 containing Borgarfjarðarhrepp, Fljótsdalshérað, Fljótsdalshrepp, Seyðisfjarðarkaupstað and Vopnafjarðarhrepp. Retrieved from Almannavarnir.

Main power plants in the region are Smyrlabjörg 1.5 MW, Rafveita Reyðarfjarðar and one in Eskifjörður. Electric distribution is quite good except in very bad weather during winter. Norðfjörður, Fáskrúðsfjörður and Stöðvarfjörður are equipped with emergency power diesel generators. Some transmission lines in Breiðamerkursandur are vulnerable to land erosion. It is noted that the need may rise for ships to be the source of electric power for Höfn í Hornafirði in case of power failure from sea floods. Water supply seems to be quite regarding emergency power, both Fjarðarbyggð and Hornafjörður, since distribution of electricity is not guaranteed in the region. Nothing is mentioned about emergency power for water supply in Eskifjörður, Neskaupsstaður and Reyðarfjörður. Electric distribution lines are also in danger from river/glacial floods in the region. The threat from electric power failure in the region is not evaluated at all (E. Lögreglustjórinn, 2011).

Many areas in the region lack TETRA, GSM and radio –connection. In the West part of the region the TETRA is good except for one place. VHF network is used by the Search and Rescue units but the integrity of the network is not mentioned (E. Lögreglustjórinn, 2011). Iimprovements on the networks mentioned above are needed and telecommunication in road tunnels needs to be secured (E. Lögreglustjórinn, 2011). The threat of communication breakdown is not valuated in particular.

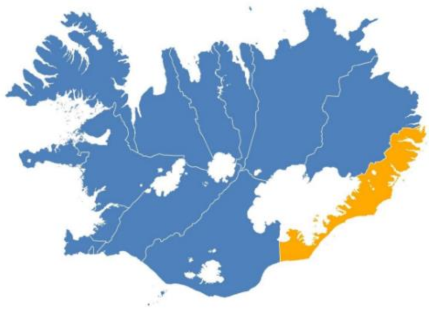

Figure A-10: Region 10 containing Breiðdalshreppur, Djúpavogshreppur, Fjarðabyggð and the municipality Hornafjörður. Retreived from Almannavarnir.

The region contains a large part of all electric production in Iceland. Rarik handles electric distribution within the region. The east part of the country does not have fully guaranteed power distribution (H. Lögreglustjórinn, 2011). Emergency power is present in Krikjubæjarklaustur and Vík í Mýrdal, no operators are present (H. Lögreglustjórinn, 2011). There are also private power stations in Þorvaldseyri and Neðri-Dalur. The threat of power failure in the region is considered as possible and the documentation of emergency power was found to be needed.

Phone network in the region is bad in some areas an on the countryside internet connection is rather bad. The TETRA network is not secured in the region but its worst part is in the eastern part of the region. Telecommunication in the highlands of the region is not good. In case of emergency the TETRA network is used by emergency units in the region (H. Lögreglustjórinn, 2011). The importance of a reliable communication network in the region is noted to be critical because of threats from volcanic eruption and glacial floods (H. Lögreglustjórinn, 2011). The threat of a communication breakdown in the region is considered as a possible threat.

Figure A-11: Region 11 containing Ásahrepp, Mýrdalshrepp, Rángárþing eystra, Rangárþing ytra and Skaftárhrepp. Retrieved from Almannavarnir.

In the region emergency power is present in few forms. Pumps for water distribution, the hospital and collage and the fishing industry all have backup power. HS Veitur handle the distribution of hot water in the region and are equipped with emergency power. Furthermore heat from waste disposal in Vestmannaeyjar is used for house heating. Large part of the cold water supply comes from the mainland and if power failure should happen there a shortage of cold water would be a reality for Vestmannaeyjar. The threat of a power failure was considered as significant and the scenario considered was a glacial flood through Markarfljót from a volcanic eruption in Katla (V. Lögreglustjórinn, 2011).

Phone and internet network in the region is through fibre optic cables and microwaves. The microwave connection is mainly for emergencies as a backup system. One location in the islands that is important to these networks called Klifið and is vulnerable to sabotage and natural disasters (V. Lögreglustjórinn, 2011). The threat of a communication breakdown is considered as a possible threat and the importance of Klifið is mentioned.

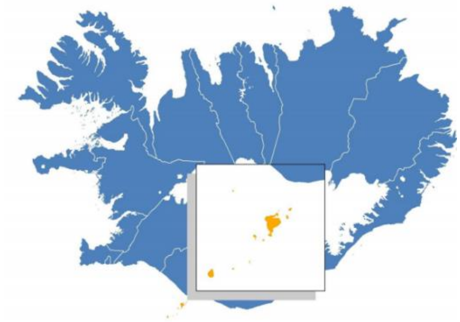

Figure A-12: Region 12 containing Vestmannaeyjar. Retreived from Almannavarnir.

Rarik handles most of electric distribution for the region. There are known cases of electric masts falling down because of bad weather and ice accumulation. Failure of power was not considered as a threat in the region and no grounds for further investigation regarding the subject. Furthermore nothing is mentioned regarding emergency power for any infrastructure (Lögreglustjóri, 2011).

Regarding the safety of telecommunication in the region nothing is mentioned about the possibility of that kind of threat. It is mentioned that no special plans are needed and also that the TETRA and VHF networks are used in case of emergency (Lögreglustjóri, 2011).

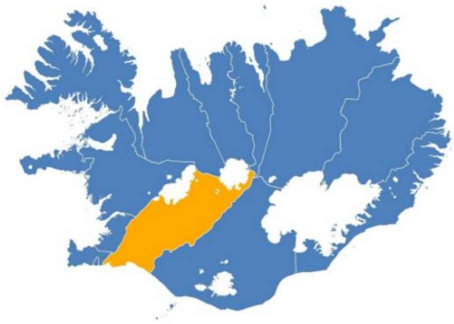

Figure A-13: Region 13 containing Bláskógabyggð, Flóahrepp, Grímsnes- and Grafningshrepp, Hrunamannahrepp, Hveragerðisbæ, Skeiða- og Gnúpverjahrepp and the municipalities Árborg and Ölfus. Retreived from Almannavarnir.

HS Orka handles distribution of electricity and hot water supply in the region. They also own and operate a few geothermal power plants. Volcanic eruption in the region could stop distribution of electricity along with hot and cold water (S. Lögreglustjórinn, 2011). Emergency power is present for the fire department in Grindavík and the main hospital for the region. The national airport also has backup power for several of their buildings along with the runway lights. Hot water supply station in Fitjar can draw power from two separate lines. Furthermore fish farms have backup power along with a privately owned data centre (S. Lögreglustjórinn, 2011). The threat from a power failure in the region is considered as a possible threat.

The TETRA network in the region has got a good coverage however the GSM network does have a few blind spots and does not handle rush hours i.e. carnivals. The usage of satellite phones for critical locations in the region is pointed out (S. Lögreglustjórinn, 2011). The threat of a communication breakdown in the region is considered as a significant threat.

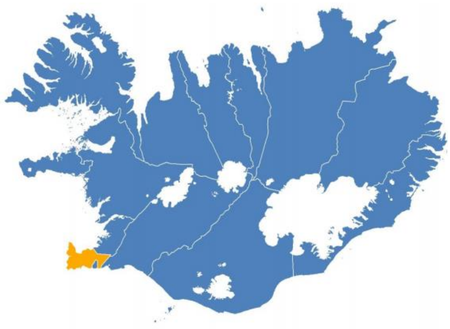

Figure A-14: Region 14 containing Grindavíkurbæ, Reykjanesbæ, Sandgerðisbæ and the municipalities Garður and Vogar. Retrieved from Almannavarnir.

It is noted that power failure could have very serious effects on traffic in urban areas. Inturruption electric and water production for the area could lead to crisis (almannavarnarástands). The threat was valued as small to a significant threat depending on the municipality. Nothing is mention conserning emergency power in the region (á. H. Lögreglustjórinn, 2011).

Great danger can arise in case of communication breakdowns espiecally for the operation of emergency units which operate in live saving operations. Furthermore it is noted that communcation breakdown to other countries could resault in a great financial lost for many organizations (á. H. Lögreglustjórinn, 2011). The threat of communication breakdown was evaluated in five municipalities in the region from litle to a possible threat. No weak spots in the networks are mentioned nor possible scenarios which they would fail in.

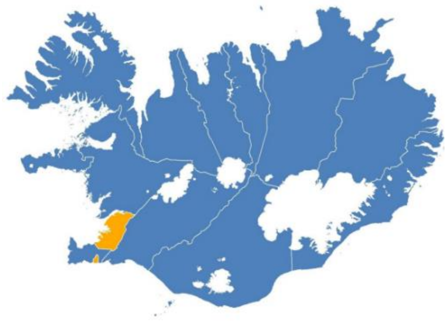

Figure A-15: Region 15 containing Álftanes, Garðabæ, Hafnarfjörð, Kópavog, Mosfellsbæ, Reykjavík and Seltjarnarnes. Retrieved from Almannavarnir.

A-III

Summary on contingency plans

When looking at contingency plans, one can only speculate on what is expected from the public. In these plans it is highly emphasised that distribution of information should be as much as possible towards the public from personnel dealing with the crisis. Information on such issues as closed roads or areas and home quarantine. For example a ban on the gathering of people and that people should not travel to places that many have been known to be deceased is mentioned in the case of influenza outbreak (Almannavarnir, 2008). These statements could lead to the conclusion that the public has a part to play in following guidelines or rules regarding certain crisis events.

Further distribution of information during crisis would consist of educational material towards the public on how to deal with that crisis. This emphasises the importance of the general public to actually follow media, news and other official statements made during the crisis. Further in contingency plans regarding a damn failure in Hálslón and a volcanic eruption in Eyjafjallajökull it is emphasised that rescue is needed for people who are still in dangerous zones (Lögreglustjórinn, 2013); (Almannavarnadeild, 2009). Here one could conclude that it is the responsibility of the public to uphold evacuation plans, report weather they have made it out of danger zones or are still trapped and further, to stay out of known dangerous zones during high risk periods.

Appendix B

B-I

Appendix B contains further description of locations affected by the electricity failure in the Brennimelur case study.

Akranes is an old port town in the West part of Iceland. The population is around 6700 making it the largest town in West part of Iceland. The main source of employment is through the fishing industry. To Akranes lies a 17km transmission line, called the Akranes line, which travels from Brennimelur to Akranes. It is the main source of electric power for people living in Akranes.

Vegamót, Vogaskeið and Grundarfjörður are all located on Snæfellsnes which is a part of West Iceland. Vegamót and Vogaskeið are parts of Snæfellsnes that have very few residents and no large towns. Grundarfjörður on the other hand has a population of almost 900 people located in the north part of Snæfellsnes and is quite isolated. The transmission line that leads to Grundarfjörður is in fact three lines. They are the Vegamóta line 1 (64km), Vogaskeiðs line 1 (25km) and Grundarfjarðar line 1 (35km).

Hvolsvöllur is a small town located in the South part of Iceland with a total populations of 860 people. It plays a big part in servicing farmers who live in the area and tourists who are passing through on their way to Vatnajökull national park. There are two transmission lines that lead to Hvolsvöllur. One is from Búðarháls, a hydro power plant, called Hvolsvallarlína 1 (45km) and the other called Hellulína 2 (13km) from Hella a small town near Hvolsvöllur.

Rimakot is a substation for the transmission line Rimakotslína 1 (22km) on its way to Vestmannaeyjar. There are two transmission lines going from Rimakot to Vestmannaeyjar which are called Vestmannaeyjarlína 1 (15km) and 3 (16km). Vestmannaeyjar are islands south of Iceland with a population around 4300 people. Their main source of electric power comes from the mainland on these two transmission lines over the see.

Breiðidalur is located in the Westfjords, more accurately in Önundarfjörður. Electricity is distributed to Breiðidalur from Mjólkárvirkjun trough the main distribution network. There the voltage is reduced from 132 kV to 66 kV before going on a transmission line called Breiðadalslína 1. There is a substation that delivers electricity to Bolungarvík (950 habitants) and Ísafjörður which has around 3400 habitants, making it the largest town in the Westfjords. The electric power that goes through Breiðidalur comes from the hydro power plant in Mjólká as well as the main power network which connects to the power plant. From Breiðidalur lie two transmission lines, Ísafjarðarlína 1 which goes to Ísafjörður and Bolungarvíkurlína 1 which goes to Bolungarvík. Ísafjörður and Bolungarvík are also connected with a transmission line called Bolungavíkurlína 2. Breiðadalslína 1 and parts of Ísafjarðalína 1 are equipped to handle 132 kV (Landsnet, 2007).

Keldeyri is located in the southern Westfjords. The substation at Keldeyri is connected to the only transmission line in the southern Westfjords coming from Mjólkárvirkjun. In Mjólkárvirkjun the voltage from the main distribution network is reduced from 132 kV to 66kV. Keldeyri supplies Patreksfjörður, around 650 inhabitants, with electricity through a transmission line owned by Orkubú Vestfjarða (Landsnet, 2007).

Brennimelur was one of the locations and was described in the beginning of Section 4.1.1.

Selfoss is the largest town in the southern Iceland with around 6500 inhabitants. It is located on the banks of Ölfusá and has Icelands main road (the ring road) going through it. Selfoss is connected with the hydro power plant in the river Sogið through a transmission line called Selfosslína 1 and also to Hella through Selfosslína 2.

Austurland is a name for the whole East part of Iceland which roughly covers the area from the south of Skaftafell under Vatnajökull (glacier) to Þórshöfn in the northeast. Austurland is connected to the distribution network on two sides, from the north and from the south (both single 132 kV lines). In Fljótsdalur there is a hydro power plant called Kárahnjúkar that has 690 MW capacity (Landsvirkjun, 2015) and supplies the aluminium smelter in Reyðarfjörður with electricity.

Vestfirðir or the Westfjords is a special part of Iceland and covers the area northwest of Hrútafjörður and North of Snæfellsnes. The Westfjords are connected to the distribution grid with a single 132 kV transmission line and the hydro power plant in Mjólká.

Norðurál is an aluminium smelter located on the north side of Hvalfjörður in Grundartangi, close to Iceland's main road and Brennimelur. It is owned by Century Aluminium located in Illinois in the USA and has been from 2004. Norðuráls production has gone up to 290,000 tons of aluminium and is one of the largest industry company in Iceland. It is connected to the electric distribution network through the substation at Brennimelur (Norðurál, 2011).

Elkem has been operating since 1979 in Grundartangi and is owned by Elkem AS in Norway and produces ferrosilicon (Elkem). Like Norðurál, Elkem connects to the distribution network through the substation at Brennimelur.

B-II

Duration of power failure and interruption

On the 10th of January the interruptions started at 18:23:10 and lasted until 00:00 (end of that day). For the nine main locations the longest duration of the interruptions occurred at Brennimelur for 2.6 hours and the shortest at Vegamót / Vogaskeið / Grundarfjörður for 0.18 hours. Selfoss was neglected in terms of lowest value since it was 0 hours. Mean value of power interruption was 0.54 hours, see Figure B-16.

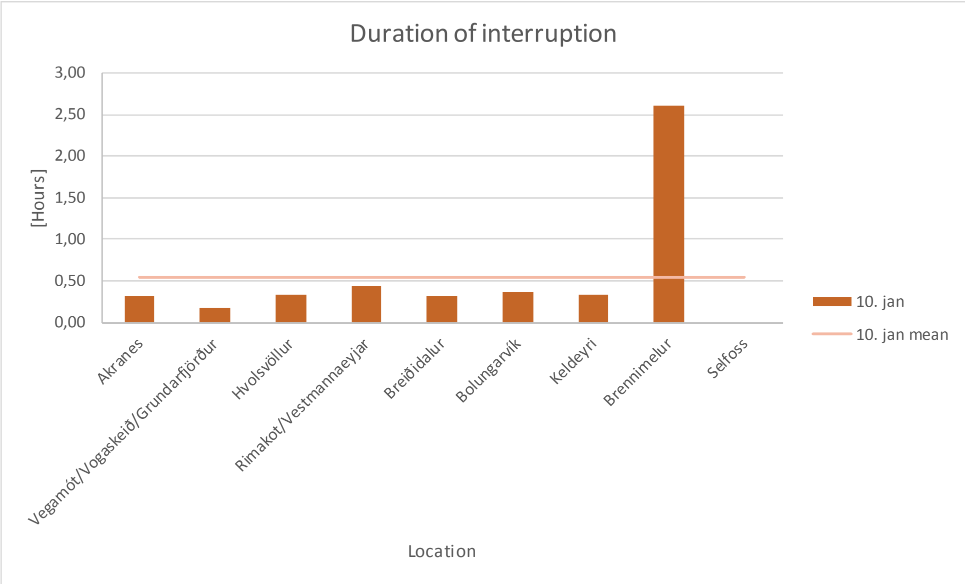

Figure B-16: Duration of electric down time from start of the incident to 00:00 for January 10th.

On the 11th of January the interruptions continued from 00:00 until the crisis was resolved at 09:27:26 in the morning. The longest duration of interruption on this day was at Vegamót / Vogaskeið / Grundarfjörður for 0.167 hours and the shortest at Selfoss when all zero values are neglected. Mean value of power interruption was 0.033 hours, see Figure B-17.

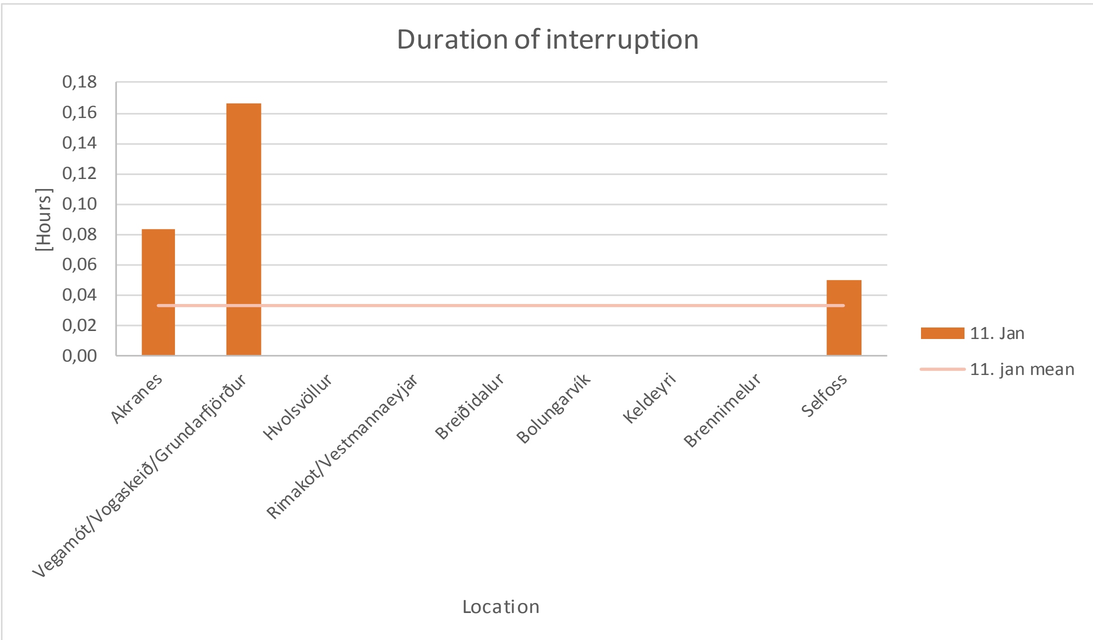

Figure B-17: Duration of electric down time from 00:00 to 09:27 for January 11th.

As the seen in the figures above the power interruptions are far shorter on the 11th then on the 10th of January. This can be explained by the fact that mitigation methods had already been applied on the evening of January 10th and continued throughout the night in order to control the situation and reduce the further failures in the electric grid.

Other locations which experienced limited power or power failure are listed in the graph below. The duration of interruption that they experienced are listed in the column chart below, see Figure B-18. The chart demonstrates very clearly that Elkem suffered most from the power loss and for businesses in the aluminium industry that can be very harmful.

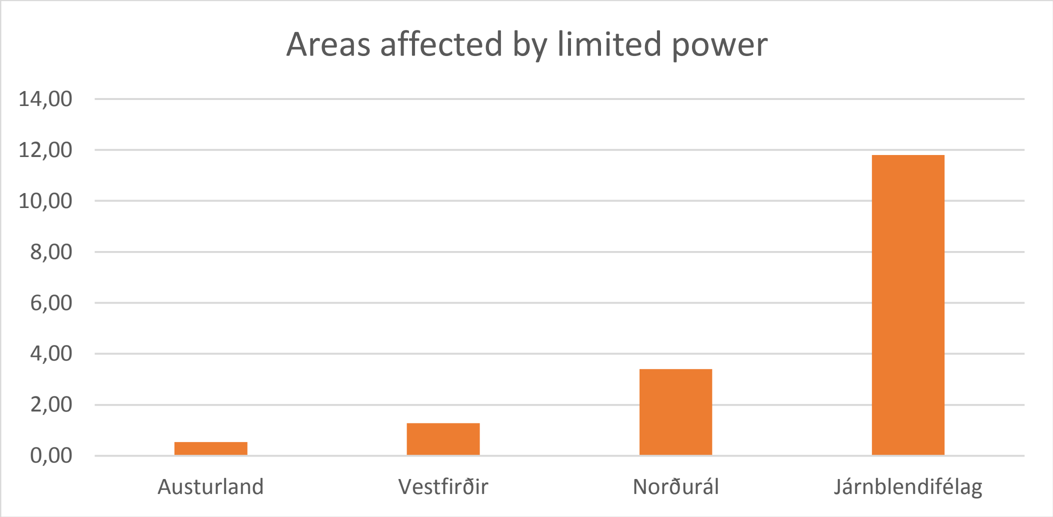

Figure B-18: Two country parts (Austurland and Vestfirðir) and two energy intensive industries (Norðurál and Járnblendifélagið) affected by the power failure during the Brennimelur event.

Figure B-19 shows how the aluminium smelters were affected by the power failure. Norðurál, Járnblendið (Elkem) and Alcan were the first once to experience power failure. Alcan could still operate at low capacity however Norðurál and Elkem experienced complete power failure, Elkem longer than Norðurál. Alcan had some fluctuations in their electricity but was soon stabilised. Norðurál started to get power back around 10:00 PM and kept getting better until around 7 am where it experienced a sudden drop in power which was quickly resolved. Alcoa Fjarðarál experienced no real interruptions except just before the power failure was resolved which was probably on request from Landsnet. Becromal did not experience any disturbances worth mentioning.

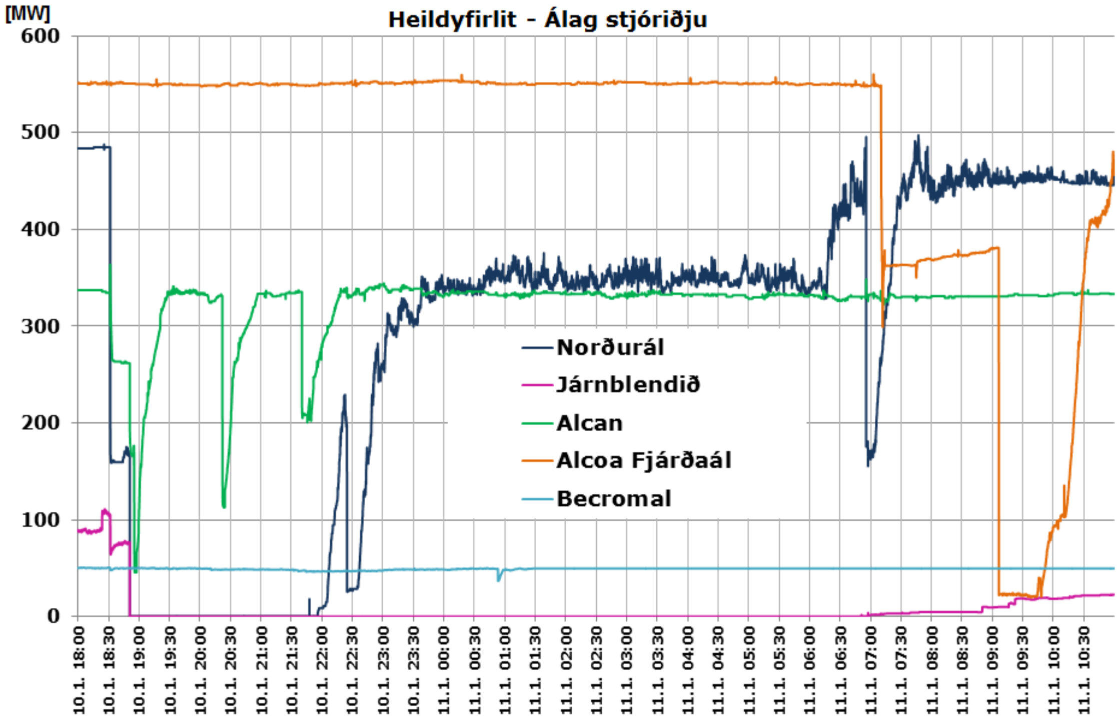

Figure B-19: Electricity used by different aluminium smelters in Iceland. Retrieved from Landsnet.

B-III

Events and mitigation methods

In this section an attempt was made to analyse and quantify the events that occurred spontaneously in the electric grid and the mitigation methods that were made to prevent further failures and restore the network.

Events that occurred in the distribution network from the incident in Brennimelur were mainly power outages which happened 46 times throughout the night and were the cause for power failure around the country which happened 14 times, see Figure B-20.

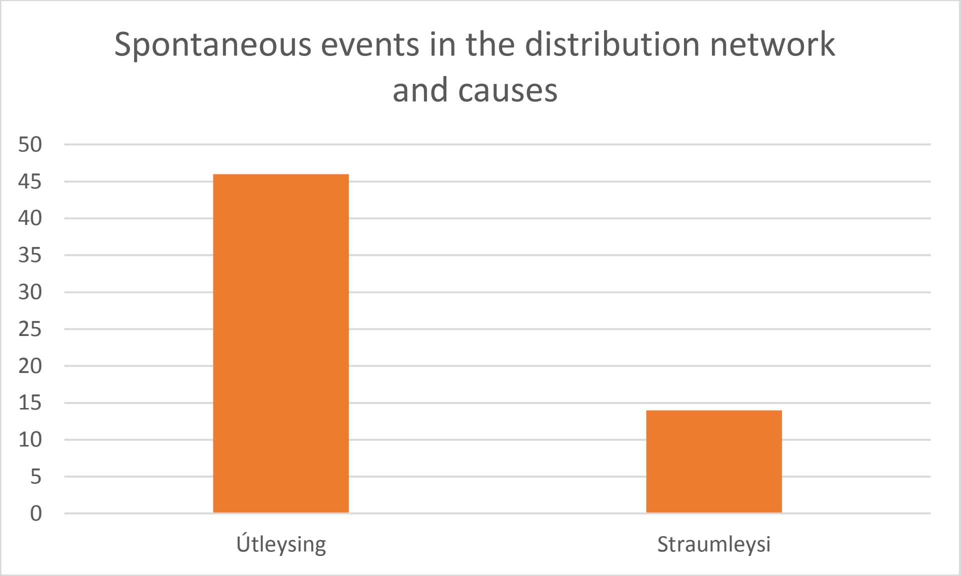

Figure B-20: Spontaneous events in electricity distribution, power outages (46) and power failure (14).

Mitigation methods are of the upmost importance for companies like Landsnet when reacting to situations such as these. As seen in the column chart below the number of mitigations, Figure B-21, outweigh the number of spontaneous events, Figure B-20, in the electric grid. This could explain how well Landsnet managed to deal with the problem and control it considering bad weather conditions and the size of the area that went out of service.

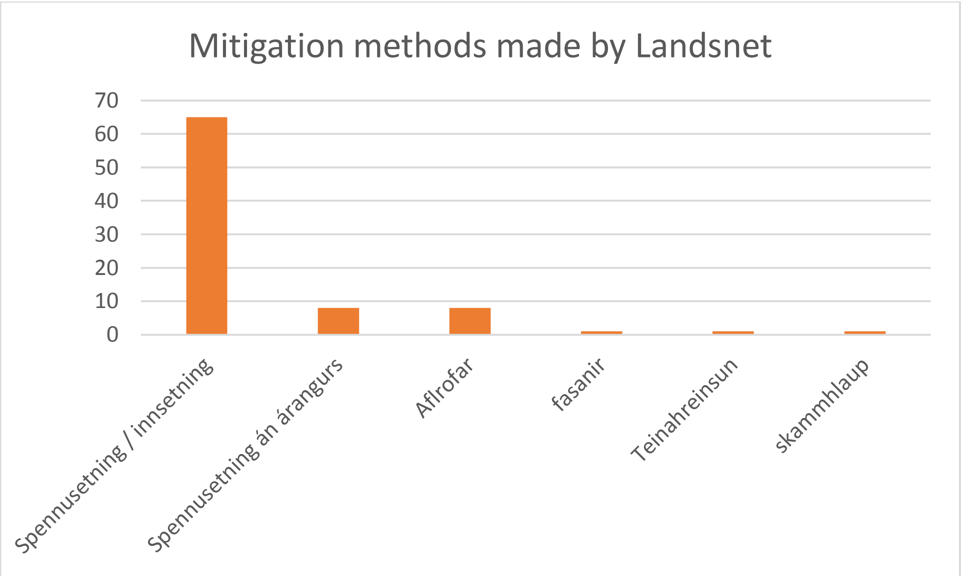

Figure B-21: Mitigation methods, restoring power (65), failing in restoring power (8), power switches (8) that occurred during the Brennimelur event.

Figure B-21 shows mitigation methods by Landsnet. The act of restoring power was performed most often, 61 times and 72 times in total if counted the times that did not work at all.

Appendix C

C-I

Appendix CI contains the questioner for the public preparedness survey that was conducted in this research.

Spurningalisti – GMP

[Allir]

Spurning 1. Hversu vel eða illa telur þú þig og/eða fjölskyldu þína vera undirbúna fyrir langvarandi rafmagnsleysi á heimilinu?

Miðað er við að langvarandi rafmgnsleysi standi yfir í 24 klst og allt að viku

a) Mjög vel
b) Frekar vel
c) Hvorki vel né illa
d) Frekar illa
e) Mjög illa
f) Veit ekki
g) Vil ekki svara

[Ef spurning 1=a eða b]

Spurning 2. Vinsamlegast lýstu því hvernig þú og/eða fjölskylda þín hafið undirbúið þig/ykkur fyrir langvarandi rafmagnsleysi? ______________________

Miðað er við að langvarandi rafmagnsleysi standi yfir í 24 klst og allt að viku

[Allir]

Spurning 3. Ef til langvarandi rafmagnsleysis kæmi, telur þú þig geta aðstoðað aðra (t.d. fólk í hverfinu sem þú býrð í) með eftirfarandi atriði?

	Já	Nei	Veit ekki	Vil ekki svara
Mat og drykk	1	2	88	99
Auka eldsneyti (gas, olíu, timbur og fleira)	1	2	88	99
Skyndihjálparaðstoð	1	2	88	99
Flutning milli staða	1	2	88	99
Húsaskjól	1	2	88	99

[Ef spurning 3=1]

Spurning 3b. Í hvað langan tíma telur þú að þú gætir aðstoðað fólk í hverfi þínu hvað varðar [hér birtast bara þeir þættir sem svarendur merktu „já“ við í spurningu 3]?

	Minna en viku	1-2 vikur	2-3 vikur	Meira en 4 vikur	Veit ekki	Vil ekki svara
Mat og drykk	1	2	3	4	88	99
Auka eldsneyti (gas, olíu, timbur og fleira)	1	2	3	4	88	99
Skyndihjálparaðstoð Veit ekki	1	2	3	4	88	99
Flutning milli staða	1	2	3	4	88	99
Húsaskjól	1	2	3	4	88	99

[Allir]

Spurning 4. Hversu vel eða illa treystir þú innviðum samfélagsins (t.d. björgunarsveitum, lögreglu, yfirvöldum, þjónustufyrirtækjum og fleirum) til að takast á við eftirfarandi neyðarástand?

		Treysti þeim mjög vel	Treysti þeim frekar vel	Treysti þeim hvorki vel né illa	Treysti þeim frekar illa	Treysti þeim mjög illa	Veit ekki	Vil ekki svara
A.	Rafmagnsleysi	1	2	3	4	5	88	99
B.	Eldgos	1	2	3	4	5	88	99
C.	Jarðskjálfta	1	2	3	4	5	88	99
D.	Sjúkdómsfaraldur	1	2	3	4	5	88	99

[Allir]

Spurning 5. Vissir þú að samkvæmt lögum getur lögregla hvatt fólk á aldrinum 18-65 ára til starfa ef almannavarnarástandi (neyðarástandi) er lýst yfir?

a) já
b) nei
c) Vil ekki svara

[Allir]

Spurning 6. Hefur þú og/eða fjölskylda þín einhverjar viðbragðsáætlanir ef langvarandi rafmagnsleysi verður?

a) já
b) nei
c) veit ekki
d) vil ekki svara

[Ef spurning 6=1]

Spurning 6b. Vinsamlegast lýstu því hvað felst í viðbragðsáætlun þinni/ykkar um langvarandi rafmagnsleysi____

Spurning 7. Hefur þú og/eða fjölskylda þín einhverjar viðbragðsáætlanir fyrir eftirfarandi neyðartilvik?

	Já	nei	Veit ekki	Vil ekki svara
Eldgos				
Jarðskjálfta				
Sjúkdómafaraldur				

[Allir]

Spurning 8. Hvað af eftirtöldu er til staðar á heimili þínu?

	Er til staðar	**Er ekki til staðar**	**Veit ekki**	**Vil ekki svara**
Vara-rafstöð af einhverju tagi.				
Vasaljós.				
Útvarp sem gengur fyrir batteríum eða er handtrekt.				
Talstöð, TETRA eða VHF.				
Auka batterí fyrir vasaljós, útvarp og talstöð.				
Borðsími sem tengist einungis gegnum símtengingu en ekki í rafmagn.				
Fyrstu hjálpar búnaður, (plástrar, grisjur, teygjubindi, verkjalyf, skæri, o.fl.)				

Lyfseðilsskyld lyf				
Upphitunarbúnaður sem gengur fyrir öðru en rafmagni (t.d. olíu, gas, timbur o.fl.).				
Eldunarbúnaður, t.d. prímus, sem gengur fyrir öðru en rafmagni. T.d. olíu eða gasi.				
Auka olía, gas eða annað fyrir upphitunar- og eldunarbúnað.				
Kerti og/eða olílampa og eldfæri.				
Afrit af mikilvægum skjölum (t.d. bankaupplýsingar, lyfseðla, o.fl.).				
Listi yfir mikilvæg símanúmer.				
Reiðufé sem dugir fyrir vikulegri neyslu.				
Hlýr fatnaður.				
Kort af svæðinu sem þú býrð á.				
Annar auka persónulegur hreinlætisbúnaður (t.d. sjampó, tannkrem, tannbursti, sápa, hreinsiþurrkur (t.d. blautþurrkur) o.fl.). ATH þetta er umfram það sem notað er dags daglega.				

[Ef „er til staðar“ í spurningu 8. Hér koma þau atriði inn í Catglobe sem var merkt við í spurningu 8]

Spurning 9. Hvað af eftirtöldu geymir þú saman á ákveðnum stað sem gerir þér kleift að nálgast í þá neyðartilvikum? Vinsamlegast merkið við allt sem við á.

[Allir]

Spurning 10. Hversu mikið eða lítið átt þú af eftirfarandi matvælum?

	Mjög mikið	**Frekar mikið**	**Frekar lítið**	**Mjög lítið**	**Veit ekki**	**Vil ekki svara**
Endingagóðum mat (t.d. dósamatur) sem þarf ekki að elda						

Endingargóðum mat (t.d. dósamatur, þurrmatur eða duft) sem þarf að hita eða elda með vatni						
Endingarlítinn ferskan mat sem þarf að kæla svo hann skemmist ekki.						
Endingargóðan mat (ekki ferskan) sem þarf að kæla svo hann skemmist ekki						
Endingarlítinn mat sem geymist við stofuhita.						

[Allir]

Spurning 11. Hvað telur þú að þú og/eða fjölskyld þín gæti lifað lengi á matvælum sem eru til á heimili þínu?

a) Minna en 1 viku
b) 1-2 vikur
c) 3-4 vikur
d) Lengur en 4 vikur
e) Veit ekki
f) Vil ekki svara

[Allir]

Spurning 12. Geymir þú sérstakar birgðir af matvælum til að nota í neyðarástandi?

a) Já
b) Nei
c) Veit ekki
d) Vil ekki svara

[Ef spurning 12=1]

Spurning 12b. Endurnýjar þú og/eða fjölskyldan þín reglulega birgðir af matvælum sem eiga að notast í neyðarástandi? (t.d. á eins til tveggja ára fresti).

a) Já
b) Nei
c) Veit ekki
d) Vil ekki svara

[Allir]

Spurning 13. Hefur þú eða einhver í fjölskyldu þinni tekið námskeið í fyrstu hjálp, skyndihjálp eða sambærileg námskeið?

a) Já
b) Nei
c) Veit ekki
d) Vil ekki svara

Spurning 14. Hefur þú kynnt þér eftirfarandi?

	Já	nei	Veit ekki	Vil ekki svara
Viðbragðsáætlanir á landsvísu (t.d. varðandi eldgos, inflúensu o.fl.)				
Viðbragðsáætlanir sveitafélaga (t.d. varðandi inflúensu, sérstakar áætlanir skóla o.fl.)				

Spurning 15. Hvað búa margir á heimili þínu að þér meðtöldum/meðtalinni?

a) 1
b) 2
c) 3-5
d) Fleiri en fimm
e) Veit ekki
f) Vil ekki svara

C-II

Appendix CII contains the questioner for the stakeholder survey that was conducted for this thesis. Also the written answers.

1. Hverju tengist starf þitt best?

- ◯ Almannavörnum
- ◯ Dreifikerfi rafmagns
- ◯ Dreifikerfi upplýsingakerfa
- ◯ Lögreglu
- ◯ Ráðuneyti
- ◯ Annað (vinsamlegast nefndu tengingu en ekki nafn fyrirtækis)

2. Felur starf þitt í sér einhverjar skyldur sem varðar viðbragðs- eða neyðarstjórnun sem hefur áhrif á almenning.

- ◯ já
- ◯ nei

3. Ef já, hverjar eru þínar helstu skyldur?

4. Hefur þú reynslu úr starfi sem snýr að neyðarástandi sem skapast hefur út frá rafmagnsleysi?

- ◯ já
- ◯ nei

5. Hverja telur þú helstu veikleika dreifikerfa rafmagns og upplýsingakerfa (ICT) á íslandi vera?

6. Hversu vel eða illa telur þú innviði (t.d. yfirvöld, lögreglu, dreifikerfi rafmagns og upplýsingakerfa, björgunarsveitir, o.fl) á Íslandi vera í stakk búna að fást við eftirfarandi?

	Mjög vel	Frekar vel	Hvorki vel né illa	Frekar illa	Mjög illa
Langvarandi rafmagnsleysi frá einum sólarhring upp í viku.					
Langvarandi rafmagnsleysi sem stendur lengur en viku.					
Eldgos					
Jarðskjálfta					
Sjúkdómafaraldur					

7. Hversu vel eða illa telur þú heimili (almenning) vera undirbúin fyrir eftirfarandi tilvik?

	Mjög vel	Frekar vel	Hvorki vel né illa	Frekar illa	Mjög illa
Langvarandi rafmagnsleysi frá einum sólarhring upp í viku.					
Langvarandi rafmagnsleysi sem stendur lengur en viku.					
Eldgos					
Jarðskjálfta					
Sjúkdómafaraldur					

8. Hversu vel eða illa telur þú heimili (almenning) vera upplýstan um eftirfarandi atriði?

	Mjög vel	Frekar vel	Hvorki vel né illa	Frekar illa	Mjög illa
Viðbragðsáætlanir á landsvísu (t.d. varðandi eldgos, inflúensu o.fl.).					
Viðbragðsáætlanir í þeirra sveitarfélagi eða næsta nágrenni (t.d. varðandi inflúensu, sérstakar áætlanir skóla o.fl.).					

9. Getur þú nefnd dæmi um til hvers er ætlast af almenningi meðan neyðarástand ríkir? (t.d. skyldur, viðbúnað, hvað fólk þarf að geta þraukað lengi án hjálpar o.fl.).

Table C-1 Answers to question 3, stakeholder survey.

Respondent	Answer
1	Keep TETRA communication and emergency and safety – communication operational as well as guarantee 100% answering of the emergency dispatch (112).
2	System to help Icelanders in foreign countries
3	Transportation
4	Supervision of energy affairs during crisis
5	Electricity distribution management
6	Emergency management during crisis
7	Law enforcement is part of response and emergency –networks as well as I am affiliated with civil defence
8	Oversight on telecommunication equipment for TETRA and monitor station for sea traffic

Table C-2 Answers to question 5, stakeholder survey.

Respondent	Answer
1	Transmission lines are above ground and ICT distributers do not have enough emergency power
2	Undefined and incompatible standards for emergency power for distribution and insufficient action for prevention. Insufficient information to stakeholders regarding status on emergency power, especially for socially important telecommunication and information infrastructure.
3	Insufficient emergency power (diesel engines)
4	To dependent infrastructures. Electric Magnetic Pulse. Command centres open for viruses or hacks.
5	Electricity distribution: Not meshed well enough, transmission lines and substations are not equipped to handle big storms. ICT: Not meshed well enough, not prepared for long duration electricity failure.
6	Bad distribution network. Needs n+1 connection
7	Transmission lines above ground

Table C-3: Answers to Question 9, stakeholder survey.

Respondent	Answer
1	Keep away from hazardous zones.
2	It came clear the other day that endurance and tranquillity of the public even regarding short period storm is small and has probably lessened in recent years. It does not take much for 112 to fill up on small complains. I think in general the public depends too much on emergency and rescue personnel and therefore does not give household sustainability enough consideration for long duration crisis.
3	No.
4	Stay where they are.
5	Keep calm, monitor announcements and follow instruction.
6	No, have not seen anything regarding that subject. However I know according to law that, civilians from age 18-65 years old, have a duty to operate for civil defence during crisis from directions from the Police Commissioner.

Appendix D

Appendix D contains a link to the data from the public preparedness survey in pdf format:

https://www.dropbox.com/s/c6mg715ggwj8q1i/Gogn_GMP_04april_skil_Excel_290415.pdf?dl=0

Further access to the data contact the author of this thesis.

This appendix also shows further analysis of certain questions from the public preparedness survey.

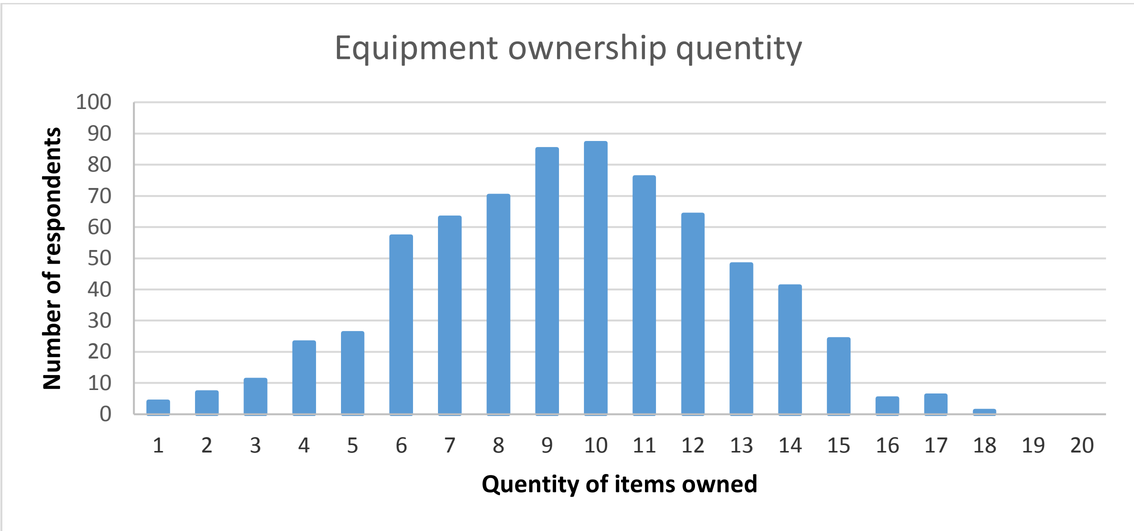

Figure D-22: Further analysis on Question 10. Number of respondents and the number of items they own can be seen on the column chart.

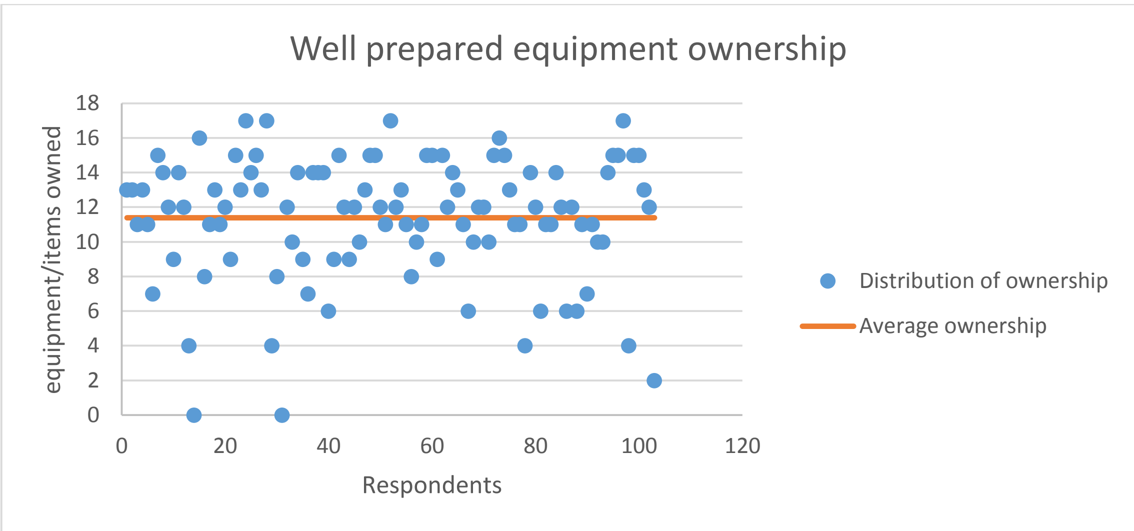

Figure D-23: Further analysis on Question 10. The graph shows the distribution of equipment ownership for respondents stating they were well prepared for electricity failure. The average ownership was around 11,4 items which was around 2 items more than for all respondents.

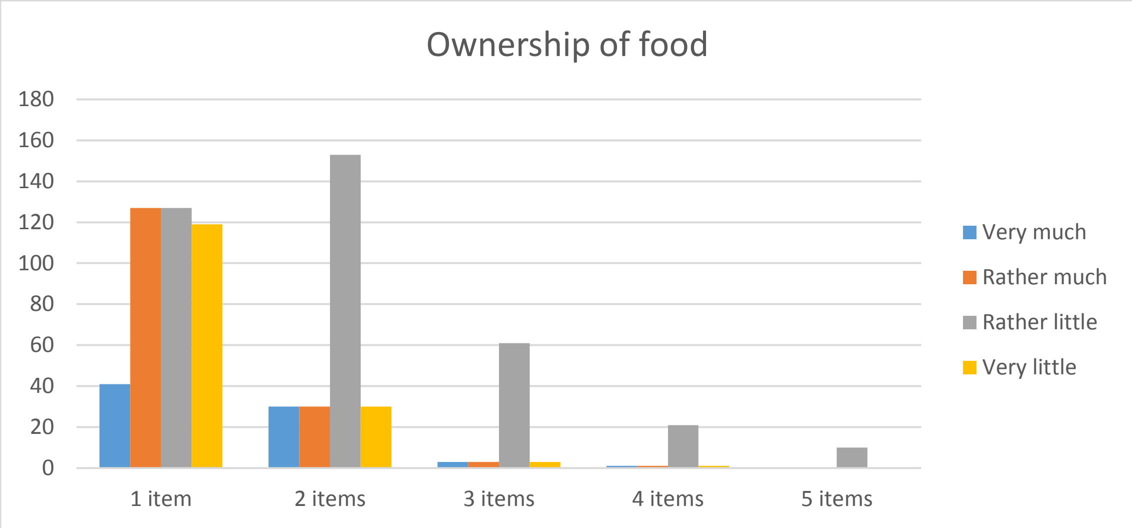

Figure D-24: Further analysis on Question 12. The column chart shows the number of items (this case food categories from question 10) respondents thought they had in their household. For example the graph shows that around 40 respondents had "very much" of 1 item from the category, around 150 respondents had rather little of 2 items, etc.

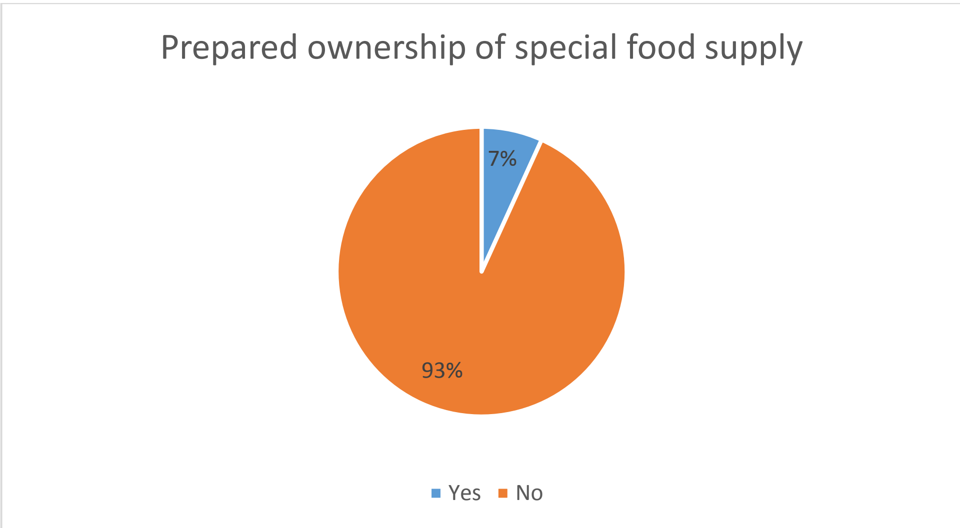

Figure D-25: Further analysis on Question 14. The graph shows how many percentage of prepared respondents owned emergency supply of food.

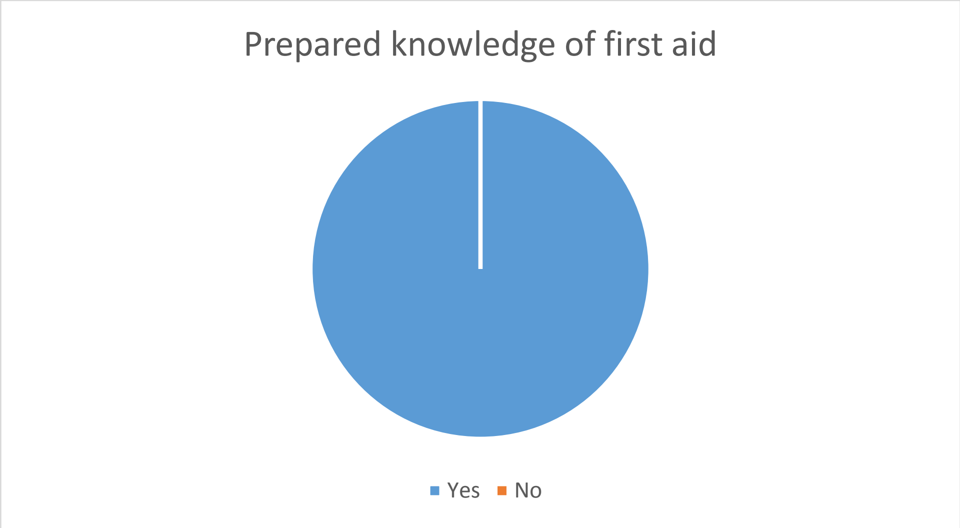

Figure D-26: Further analysis on Question 15. The graph shows that every prepared respondents say they or someone in their family knows first aid.

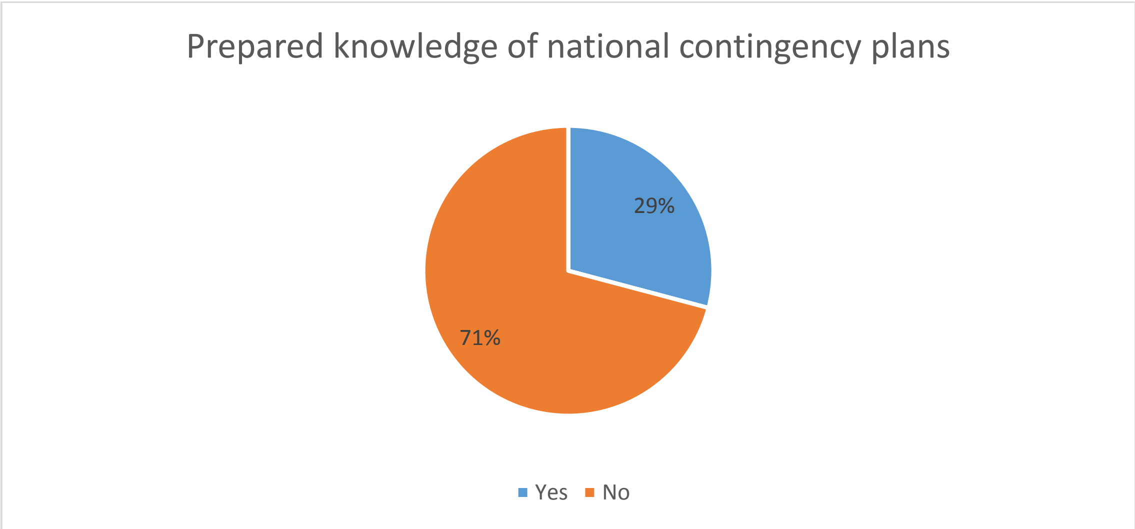

Figure D-27: Further analysis on Question 16. 29% of prepared respondents are familiar with national contingency plans which is 11% higher than for the whole group of respondents.

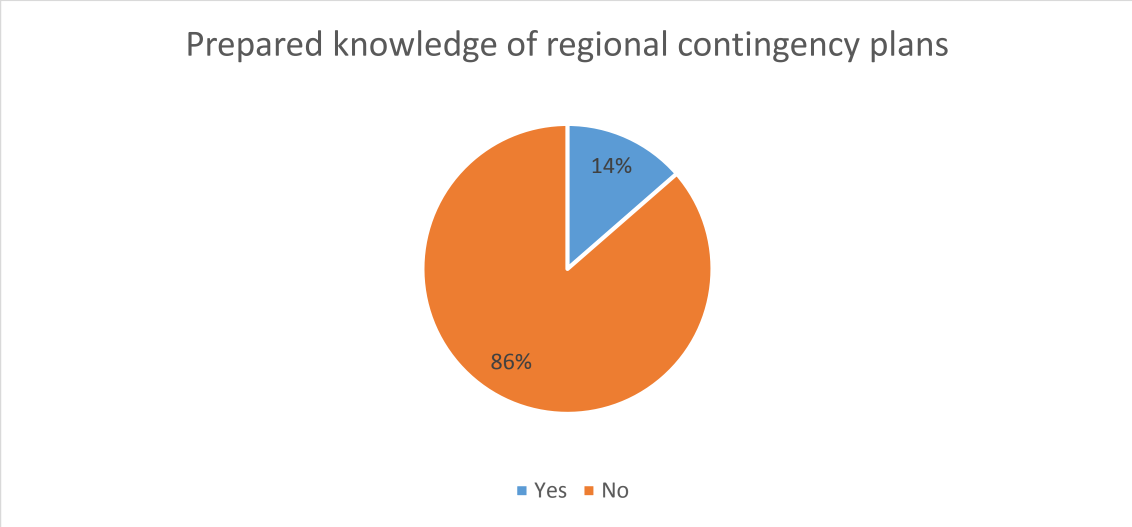

Figure D-28: Further analysis on Question 16. 14% of prepared respondents say they are familiar with regional contingency plans which is very similar to the whole group of respondents.