CITY OF
BERGEN

MEREPUV

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"Methods and measures to enhance resilience against electric power outage in urban vital societal functions"

MEREPUV

Summary of vulnerability assessment from Bergen

Deliverable no: 2.2 Bergen

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1 Introduction

Bergen municipality has participated in the EU-funded MEREPUV project, which aims to analyze the effects of citywide power blackouts on different vital infrastructures and critical public functions. A relatively extensive analysis of the effects of such blackouts on the health care services has been performed in Bergen through a workshop-based risk and vulnerability analysis.

MEREPUV is initiated and led by The Norwegian Directorate for Civil Protection (DSB), in coordination with the Latvian State Fire and Rescue service, and the Dutch Safety Region South-Hollande South. The Norwegian cities of Oslo, Stavanger and Bergen are participating, as well as Dordrecht, Netherlands and Valmiera, Latvia. Each city is to perform an assessment of one critical public function or infrastructure.

The general objective of the project is to make the participating cities more resilient to citywide disruptions or blackouts in the power system through increased knowledge. Although long lasting citywide power outages can be considered exceedingly rare in the larger Norwegian cities, they are not unthinkable, and are expected to have wide-ranging consequences on most aspects of society.

Five major findings have been identified through the project, which will be of special importance in the forthcoming work to make the City of Bergen more resilient with regards to power outage in the health care services:

- Even if a long lasting city wide power outage is considered exceedingly rare, the consequences will be of such severity that several additional risk reducing barriers are needed to ensure the necessary resilience and function in the health care services.
- Whilst the specialist health care services are reasonably resilient in regards to power outages, the municipal healthcare services have a larger degree of vulnerability, increasing the less acute their service provisions are.
- There are some blind spots between the specialist health care services and the municipality health care services with regards to their responsibility of patients impacted by a power outage in their own homes.
- The necessary continuous fuel supply for electric generators is the major vulnerability with regards to the overall resilience towards a city wide power outage.
- The most severe consequences of a power outage in the health care services are expected to occur within the first 72 hours of a citywide power outage.

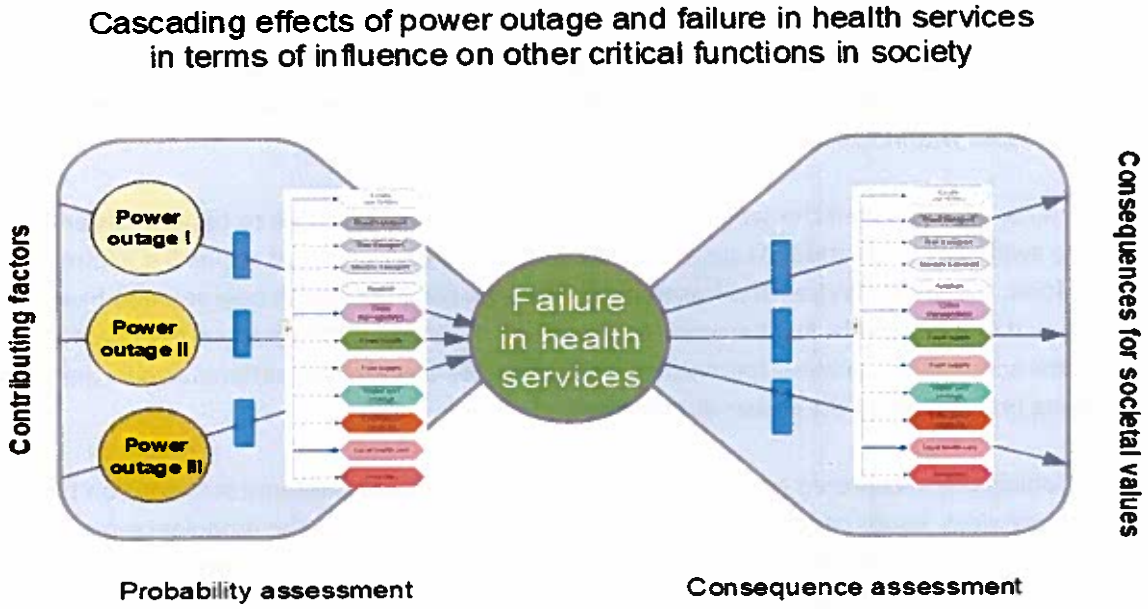
The outcome of the MEREPUV project and the cooperation between the involved cities has exceeded our expectations. It is of major importance to follow up the findings from the project as a continuously cooperation between the cities involved in order to ensure further sharing of knowledge and implementation of solutions that are beneficial for all involved regions.

2 Methodology and data collection

The analysis has been performed in accordance with the bowtie-inspired methodology approach chosen in the consortium (as seen in Figure 1 and Annex 2), and consists of assessments of the following core elements:

- Probability
- Vulnerability in the health services
- Consequences
- Uncertainty
- Steering ability
- Transferability

Figure 1 Bowtie-methodology



The data collection for the analysis has been performed as a combination of literature studies, reviews of applicable regulations, workshops, and individual consultations with some of the infrastructure providers.

The workshops were held the following dates:

- 30.08.2018
- 31.10.2018
- 07.11.2018
- 19.12.2018

In addition to the four workshops planned, an additional workshop was performed 07.03.2019 to present preliminary results and elicit clarifications and proposals of measures. All the actors involved in the previous four workshops had the opportunity to participate. See Annex 3 for a list of the participant organizations in the workshops and consultations.

Although a citywide power outage can be expected to have far-ranging societal consequences, the analysis is centered around the effects of power outages on the health care services. As such, only consequences arising in relation to loss of function in the health services are analyzed in this report.

The consortium approach is based on the following scenarios:

- Citywide power outage 24 hours
- Citywide power outage 72 hours
- Citywide power outage 1 week
- Citywide power outage 1 month with rotating outages after two weeks

The scenarios all take place in winter, with subzero temperatures. In addition to the four consortium scenarios, a further one has been added in the analysis performed in Bergen, taking into account hours 0 to 4. This is due to expectation that most battery/UPS-powered equipment and infrastructures have a quite limited operational time in a power outage, leading to an expected partial or full loss within this time frame.

It has been necessary to limit the scope of the analysis somewhat, both due to time constraints and due to the available information. As such, impacts on the different logistical chains (i.e. pharmacy supplies, food, transport services and hospital goods) supporting the health care services have not been included in the analysis. Furthermore, in regards to the analysis of impact on the health services, the scope of the analysis has excluded any expected increases in patients due to the patient status being brought on by the power outage itself.

As Oslo municipality is centered around the analysis of the effects of the same scenarios on the emergency services, issues pertaining to the emergency services such as the ambulance service will be kept brief. Furthermore, as Stavanger municipality reviews telecommunications, such issues will also be kept relatively short in this analysis.

A central assumption in the analysis is that health care services dependent on reserve power through generators will have access to the necessary fuel supplies, either through out of region deliveries, or by prioritization of existing supplies in the region. Although this assumption has been used in the analysis, plans for of timely fuel resupply and prioritization of fuel continues to be an important recommendation in Section 0, as it is by no means certain in a real life power outage.

A further important assumption in regards to both critical impact factors and the overall impact on health services is that it is assumed that few or no critical impact factors (such as partial cell phone coverage) will be reestablished by means of external generator power during the following scenarios. As such, the analysis does not take into account any possibilities of reestablished critical impact factors unless these are due to power being made available in the power grid (as in Scenario 5), either on a permanent or temporary basis.

3 System description of the analytical object

The analysis is focused on the effects of power outages on the public health care system, within the municipal borders of Bergen. The Norwegian public health care system is divided into the primary healthcare services and the specialist healthcare services. The primary healthcare services are organized by the municipalities, or can be run in cooperation between municipalities, and can in general be thought of as the "care" sector, although curative elements such as general practitioners and the main municipal emergency primary care clinic are also organized as part of the primary healthcare.

The specialist healthcare services in Norway are organized as regional health authorities lying under the ministry of health, and can generally be described as the "cure" sector, although there is also an overlap with the care sector in responsibilities. Both parts of the healthcare system are present within the municipal borders of Bergen.

The public healthcare sectors included in this assessment:

- Home nursing service
- Elderly homes
- Assisted living and mental health facilities
- Main municipal emergency primary care clinic
- General practitioners

The specialist healthcare sectors included in this assessment:

- Hospitals and hospital-based policlinical services
- Ambulance services

The main legal framework regulating the healthcare services in regards to power outages is the "Forskrift om elektriske lavspenningsanlegg" § 31, mandating electrical installations with necessary redundancy where outages can be expected to lead to increased risk to people (such as patients). Furthermore, electrical medical equipment are regulated in "Forskrift om håndtering av medisinsk utstyr"§ 9 mandates that all types of medical equipment are expected to be installed and connected in such a way that it functions as expected. Implicit in this is the expectation that equipment critical to life is able to function as expected in a blackout. In addition, the norwegian NEK 400 standard specifies the electrical installation demands in rooms used in medical facilities based on expected use and risk. DSB carries out audits to supervise compliance with these regulations in hospitals. The local electricity audit also has the mandate to carry out similar audits in other health institutions. Another important law is the Health and Social Preparedness Act which requires amongst others that health services must be able to operate and if necessary expand their services during crises situations[1].

[1] Expert seminar 28. august Oslo – Presentations from Norwegian Health directorate and DSB

4 Results of the assessment of power outage

It should be noted that the following scenarios are chronologically continuous, e.g. scenario 2, 24 hours citywide outage is a continuation of scenario 1, 4 hours citywide outage and so on. As such, only new information arising in each of the following scenarios after scenario 1 will be presented.

4.1 Scenario probability

As part of the analysis all the scenarios were assessed in relation to the probability of the scenario occurring. Based on discussions within the workshops, available statistics as well as expert evaluation by the regional utility provider, the probability of all scenarios were estimated to be very low, corresponding to 0-10% percent likelihood within 50 years.

This is due to the considerable redundancy present in the region, with four interconnects between the central transmission grid and the regional/local grid. In addition, large parts of the municipality lays within a masked grid, meaning that power usually can be routed through at least two points to the end users (as opposed to a radial grid, where one break is sufficient to cause a localized outage).

4.2 Scenario 1, 4 hours citywide outage

Electrical power outage 4 hours

Sunday night 30 December 2019 the electrical power suddenly disappears in Bergen municipality. The power outage affects all citizens in the municipality. It is cold outside with temperature between -5 and 0 degree celsius. After 4 hours all citizens have regained access to electrical power.

4.2.1 Changes in critical input factors for health services

In addition to the immediate effects on the end users, a citywide power outage is expected to have both immediate and cascade effects on most of the infrastructure and critical functions serving the end users.

As such, the scenario is expected to have two distinct phases, an immediate phase where power is lost in general and where loss of all non-redundant infrastructures is expected, and a second phase where redundant equipment lose functionality due to the depletion of batteries/UPS systems. The general consensus from the different workshops is that one will expect some loss of hardened equipment before the scenario ends, but with the majority of the losses taking place in the next scenario. The health care services are to a varying degree dependent on most of the following critical input factors, depending on the level and intensity of health care services provided. Some services, such as hospitals and inpatient institutions are expected to be dependent on all the below input factors.

Partial or full outages are thus expected in the following critical input factors:

- **ICT and Telecommunications**, including cell phone, fiber and copper based network services, are expected to have full or partial loss of service within the timeframe of the scenario [2]. Municipal computer network services (and thus IP-based telephone services) are expected to

[2] Stavanger municipality, «Merepuv Delrapport Stavanger kommune».

have full loss of service within minutes of the scenario start[3]. Cell phone coverage is expected to have partial to full loss of service 2-4 hours after the start of the scenario due to depletion of UPS systems in most cell towers, Tetra radio is expected to remain operational throughout the scenario due to UPS.

- **The road network** including bridges and tunnels are expected to remain operational, but with a reduced capacity. Due to expected loss of road network surveillance systems and concurrent reduction or loss of cell phone coverage, ordinary road accidents are expected to lead to long lasting traffic jams, as dispatch of first responders and tow trucks will be delayed[4].
- **The district hot water distribution system** will continue production and distribution of hot water, but without the possibility of prioritization, as most end user regulator valves are expected to be inoperable due to loss of power. Most end users will not be able to distribute hot water or heating due to powerless distribution centrals in each building[5].
- **The water distribution network** is expected to continue production and distribution of potable water for most end users. End users at high elevations are expected to have loss of water pressure or total loss of water due to powerless pressure support pumps[6].
- **Sewage transport** is expected to function as expected for approximately 95% of end users, as the system is mainly based on gravity transport. Less than 5% of the total end users in Bergen are dependent on electrical sewage pumps to avoid sewage backflow. If power is lost, sewage will go directly to the recipient waterway without sewage treatment[7].
- **Fuel distribution** from gas stations are expected to be inaccessible due to loss of electrical fuel pumps and payment solutions.

4.2.2 Overall impact on health services

Specialist health care services:

The main findings from the second expert workshop was that the specialist health care services (i.e. hospitals, hospital-based policlinic consultations and the ambulance service) are relatively well prepared against power outages, and will be affected by the scenario in a relatively low degree.

- The two main hospitals within Bergen municipality are equipped with efficient barriers in the form of no-break UPS and diesel generators, no loss of electric power is expected in any hospital areas essential for patient care. No need for fuel-resupplies during the scenario.
- However, both hospitals are dependent on the district hot water distribution network for heating, and a small loss of residual building heat can be expected to occur during the timeline of the scenario.
- Loss of potable water to the hospitals is not expected.
- Although the power loss can be expected to lead to offsite power loss in the telecommunications infrastructure, most of the core ICT systems in the hospitals have local backups, leading to an expectation of at least the basic systems needed for patient care being accessible.

[3] Consultation Bergen municipality, EDD.
[4] Consultation Statens Vegvesen, Region Vest.
[5] Consultation BKK Energi.
[6] Consultation Bergen Vann, Vanndistribusjon.
[7] Consultation Bergen Vann, Avløpstransport.

- Due to expected loss or reduction of cell phone coverage in the municipality, it is expected that a large portion of the populace will be unable to reach the regional emergency medical communication centre (AMK) by phone. Patients can be expected to arrive unannounced at the emergency wards.
- It is expected that the emergency services tetra radio network (Nødnett) will continue to function in TMO-mode (e.g. ordinary operations) during the scenario, allowing communications between the emergency services and health care services equipped with tetra.

Municipal healthcare services:

The main findings from the third and fourth expert workshops was that the municipal health care providers are to a varying degree prepared for a power outage lasting up to four hours, and will be affected by the scenario in a relatively low to a relatively high degree. All municipal health services are expected to experience full loss of ICT systems and IP-based telephone systems from the start of the scenario.

- **The main municipal emergency primary care clinic** (Legevakten) is equipped with UPS and diesel generators, and is expected to be able to retain its core functions during the scenario.
    - No or short loss of power is expected in areas essential for patient care. No need for fuel resupplies during the scenario.
    - Expected loss of electronic patient journal systems and other ICT-based tools.
    - Due to expected loss or reduction of cell phone coverage in the municipality, it is expected that a large portion of the populace will be unable to reach the primary care hotline (116117) by phone. Patients can be expected to arrive unannounced at the clinic in a larger degree than usual.
    - The primary care clinic is dependent on the district hot water distribution network for heating, and a small loss of residual building heat can be expected to occur during the timeline of the scenario.

- **General Practitioners:** As these mainly operate during normal business hours, the GP services are not expected be affected by the scenario. If the scenario took place during daytime, one would expect the GP services to be severely affected by the blackout, with a greatly reduced capacity of treatment.

- **Elderly homes, assisted living and other institutions/institution-like living arrangements** are expected to vary to a certain degree, with a few institutions being well prepared, and the majority being close to an ordinary home in regards to vulnerability. A small number of institutions will not be able to operate due to loss of potable water.
    - Institutions with UPS systems or reserve power through permanent diesel generators are expected to be able to retain core capacities without major issues only if trained personnel are available to start and maintain the generators.
    - Institutions without UPS or permanent diesel generators, but that are prepared for external generator hookup are expected to be able to retain core capacities without major issues only if generators are available, and trained personnel are available connect, start and maintain the generators.
    - Institutions without UPS or generator support are expected to be vulnerable, and are building-wise comparable to what can be expected in in **outpatient care/home nursing**. As the majority of such institutions have round the clock personnel, it is expected that

some actions can be taken to limit the effects of the outage in regards to i.e. light and heating. Patients depending on electromedical equipment for upkeep of life will need to be evacuated to other facilities by the end of the scenario to ensure continued function.

- **Outpatient care/Home nursing** is expected to be severely affected by such a power outage. Few or no barriers against the direct effects of outage have been identified, except for electromedical equipment with integrated or external battery backup/UPS.
    - Expected loss over time of physical access to home nursing patients as the electronic lock system used in the municipality is dependent on smart phone authentication through 3G. No backup systems, except for mobile patients that can give caregivers access.
    - Expected loss of potable water to all buildings at higher elevations.
    - Expected loss of light and heating in majority of patients buildings. Loss of room temperature depending on type of building, insulation, other heating sources, personal capacity of care recievers.
    - Immediate loss of any electromedical equipment without battery backup or external UPS. Loss over time of most electromedical equipment with battery backup or external UPS, which is expected to tend to have an operational supply for 3-4 hours [8]. Such equipment includes oxygen concentrators, ventilators and ventilation assist devices, pain management equipment and IV infusers. Patients with equipment deemed necessary for upkeep of life is expected to have to be evacuated to other facilities by the end of the scenario to ensure continued function.
    - Expected loss of IP-based communication. Networked medical devices loose function.
    - Expected reduction in cellular communication. 3G-based medical devices and "smart" devices such as personal safety alarms will not function as planned, alarms will not be communicated with the municipal alarm centre.
    - Home care services will need to prioritize patients in this scenario, as patients with reduced cognitive capacities are thought to be especially vulnerable in regards to power outages.
    - As outpatient/home care is mainly provided by car, and as municipal cars mainly are electric (approx. 80%), the scenario will lead to a charging backlog, reducing the available cars when the morning shift starts.

4.2.3 Cascading effects

It is expected that the scenario will lead to cascading effects in relation to rescue services, governance and crisis management, as existing systems and resources will be stretched to evacuate and accommodate especially vulnerable individuals, and at the same time as most of the ordinary infrastructure systems are impacted. Of special importance is the expected reduction of cell phone coverage. Cascading effects on other critical functions or infrastructures due to the effects on the health services have not been identified.

4.2.4 Consequences for societal values

The societal values focused in this assessment in terms of impact and consequences are:

- Life and health
- Societal stability

[8] Findings from Expert workshop 2 and 3.

The scenarios impact on the health care services is mainly expected to affect "life and health" of institution or home nursing patients dependent on life-supporting electromedical equipment such as ventilators. All such patients are expected to have some degree of redundancy or battery backup, and most have continuous or intermittent care. As noted, such patients are expected to need to be evacuated within the scenario to reduce risk, an evacuation that can prove practically difficult due to several reasons, including expected communication issues. Patients dependent on electromedical equipment that is not considered life-supporting are expected to be affected by the loss of power, but mainly without life-threatening effects. From the discussions in workshop 2 and 3, up to five deaths are thus expected, as well as a somewhat larger number of patients with temporary or permanently reduced health due to the scenario.

"Societal stability" is not expected to impacted due to the expected loss of health services during the scenario (but is expected to be impacted moderately by the power outage itself).

4.3 Scenario 2, 24 hours citywide outage

Electrical power outage 24 hours

Sunday night 30 December 2019 the electrical power suddenly disappears in Bergen municipality. The power outage affects all citizens in the municipality. It is cold outside with temperature between -5 and 0 degree celsius. After 24 hours all citizens have regained access to electrical power.

4.3.1 Critical input factors

The scenario is seen as a continuation of Scenario 1, e.g. that the following description details the hours 4-24 in a citywide power outage. In addition to the critical input factors seen in the previous scenario, it is expected that some critical infrastructure and functions dependent on backup diesel generators with day tanks will be in need of resupply during the timeline of the scenario. In addition to this, loss of function is expected in the majority of UPS-based infrastructure due to depletion of battery banks.

- **ICT and Telecommunications**, including cell phone, fiber and copper based network services, are expected to have full loss of service within the timeframe of the scenario[9]. Tetra radio is expected to have reduced network coverage and function during the scenario.

4.3.2 Overall impact on health services

Unless otherwise specified, impacts identified in scenario 1 are also present in this scenario. As such, only the additional impacts encountered in hours 4-24 are presented.

Specialist health care:

The additional effects identified will affect the specialist health care sector to a moderate degree. Changes from scenario 1 include:

- The two main hospitals within Bergen municipality are equipped with efficient barriers in the form of no-break UPS and diesel generators, no loss of electric power is expected in any

[9] Stavanger municipality, «Merepuv Delrapport Stavanger kommune».

hospital areas essential for patient care in the timeframe of the scenario. No need for diesel supplies during the scenario.

- Both hospitals are dependent on the district hot water distribution network for HVAC, and a loss of residual building heat can be expected to occur during the timeline of the scenario, leading to low indoor temperatures at the end of the scenario.
- It is expected that loss of cell phone coverage in the municipality will lead to the majority of large portion of the populace being unable to reach the regional emergency medical communication centre (AMK) by phone. Patients can be expected to arrive unannounced at the emergency wards.
- Tetra radio communications (Nødnett) in TMO are expected to lose coverage, necessitating DMO-mode operations between the different actors. DMO mode will limit both geographical coverage and functionality.

Municipal healthcare:

The main findings from the third and fourth expert workshops was that the municipal health care providers are to a varying degree prepared for a power outage lasting up to four hours, and will be affected by the scenario in a moderate to a high degree.

- **The main municipal emergency primary care clinic** (Legevakten) is equipped with emergency generators, and will be able to retain its core function if diesel can be resupplied during the scenario.
    - Tetra radio communications (Nødnett) in TMO are expected have reduced or spotty coverage, necessitating DMO-mode operations between the different actors. DMO mode will limit both geographical coverage and functionality.
    - The primary care clinic is dependent on the district hot water distribution network for heating, and a large loss of residual building heat can be expected to occur during the timeline of the scenario.

- **General Practitioners:** GP services are thought to be severely affected by the scenario, with a greatly reduced capacity of treatment, as most of these reside in commercial buildings, without generator support. Journal systems, communications, laboratory and diagnostics is expected to be unavailable, as well as payment systems.

- **Elderly homes, assisted living and other institutions/institution-like living arrangements** are expected to vary to a certain degree, with a few institutions being well prepared, and the majority being close to an ordinary home in regards to vulnerability.
    - Institutions with permanent or mobile generators running are expected to be able to retain core capacities without major issues only if timely supplies of diesel can be secured.
    - Institutions without UPS or generator support are expected to be vulnerable, and are building wise comparable to what can be expected in in **outpatient care/home nursing**. All patients in institutions without adequate possibilities for heating, lighting and other basal needs should be evacuated within the scenario.

- **Outpatient care/Home nursing** is expected to be severely affected by such a power outage. Few or no barriers against the direct effects of outage have been identified.

- Expected loss of light and heating in majority of patients buildings. Loss of room temperature depending on type of building, insulation, other heating sources, personal capacity of care receivers.
- Expected loss over time of most electromedical equipment with and without UPS. Patients dependent on electromedical equipment is expected to have to be evacuated to a more suitable location within the scenario.
- Home care services will need to prioritize patients in this scenario, vulnerable patients will need to be moved to other locations
- As outpatient/home care is mainly provided by car, and as municipal cars mainly are electric (approx. 80%), a majority of service cars will be out of commission by the end of the scenario.

4.3.3 Cascading effects

As in the previous scenario, it is expected that the scenario will lead to cascading effects in relation to rescue services, governance and crisis management, as existing systems and resources will be stretched to evacuate and accommodate an increasing number of vulnerable individuals, and at the same time as most of the ordinary infrastructure systems are impacted. Some cascading effects on other critical functions or infrastructures are expected due to parts of the work force prioritizing taking care of vulnerable family members such as home nursing patients due to decreased service levels from the public health care sector. The effect of this is thought to be significant, but uncertain.

4.3.4 Consequences for societal values

The societal values focused in this assessment in terms of impact and consequences are:

- Life and health
- Societal stability

The scenarios impact on the health care services is mainly expected to affect "life and health" of institution and home nursing patients dependent on electromedical equipment not defined as critical for life support. As noted, such patients are expected to need to be evacuated within the scenario to reduce risk, an evacuation that can prove practically difficult in the scenario. In addition, the significant reduction in cell phone/phone communication between the health care services and the public is expected to lead to unnecessary mortality and morbidity due to delays in treatment of acute injuries or illnesses. From the discussions in the workshops, up to 20 such deaths are expected, as well as a large number of patients with temporary or permanently reduced health due to the scenario. The general consensus from the workshops is that the estimate can be considered uncertain.

"Societal stability" is not expected to impacted due to the expected loss of health services during the scenario (but is expected to be impacted to a large degree by the power outage itself).

4.4 Scenario 3, 72 hours citywide outage

Electrical power outage 72 hours

At 1900 o`clock Wednesday 9 January 2019 the electrical power suddenly disappears in all of Bergen municipality.
The whole muncipality are without power until 1900 o`clock Saturday 12 January. It is cold outside with temperatures between -5 and 0 degree celsius.

4.4.1 Critical input factors

The scenario is seen as a continuation of Scenario 1 and 2, e.g. that the following description details the hours 24-72 in a citywide power outage. In addition to the critical input factors seen in the previous two scenarios, it is expected that some critical infrastructure and functions dependent on backup diesel generators with larger tanks will be in need of resupply during the timeline of the scenario or risk loss of function.

- **ICT and Telecommunications**, including cell phone, fiber and copper based network services, are expected to have full loss of service within the timeframe of the scenario Tetra radio is expected to have lost network coverage and function during the scenario [10].

4.4.2 Overall impact on health services

Unless otherwise specified, impacts identified in scenario 1 and 2 are also present in this scenario. As such, only the additional impacts encountered in hours 24-72 are presented.

Specialist health care:

The additional effects identified will affect the specialist health care sector to a moderate degree only if resupply of diesel can be achieved. Changes from Scenario 1 and 2 include:

- The two main hospitals within Bergen municipality are equipped with efficient barriers in the form of no-break UPS and diesel generators, no loss of electric power is expected in any hospital areas essential for patient care in the timeframe of the scenario. Expected need for large quantities of diesel during the scenario.
- Tetra radio communications (Nødnett) in TMO are expected to have lost all coverage, necessitating DMO-mode operations between the different actors. DMO mode will limit both geographical coverage and functionality, reducing effective communications.

Municipal healthcare:

The main findings from the third and fourth expert workshops was that the municipal health care providers are to a varying degree prepared for a power outage lasting up to 72 hours, and will be affected by the scenario in a moderate to a high degree.

- **The main municipal emergency primary care clinic** (Legevakten) is equipped with emergency generators, and will be able to retain its core function only if diesel can be resupplied during the scenario.

[10] Stavanger municipality, «Merepuv Delrapport Stavanger kommune».

- Tetra radio communications (Nødnett) in TMO are expected to have lost all coverage, necessitating DMO-mode operations between the different actors. DMO mode will limit both geographical coverage and functionality, reducing effective communications.

- **General Practitioners:** As in the previous scenario.

- **Elderly homes, assisted living and other institutions/institution-like living arrangements** are expected to vary to a certain degree, with a few institutions being well prepared, and the majority being close to an ordinary home in regards to vulnerability.
  - Institutions with permanent or mobile generators running are expected to be able to retain core capacities without major issues only if timely supplies of diesel can be secured.
  - Institutions without UPS or generator support are expected to be vulnerable, and are building wise comparable to what can be expected in in **outpatient care/home nursing**. All patients in institutions without adequate possibilities for heating, lighting and other basal needs should be evacuated within the scenario.

- **Outpatient care/Home nursing** is expected to be severely affected by such a power outage. Few or no barriers against the direct effects of outage have been identified.
  - Expected loss of light and heating in majority of patients buildings. Loss of room temperature depending on type of building, insulation, other heating sources, personal capacity of care receivers. Expected need to evacuate all patients with any significant disabilities or medical needs and/or residing in buildings with limited possibilities in regards to heating, lighting, water supply.
  - As outpatient/home care is mainly provided by car, and as municipal cars mainly are electric (approx. 80%), only petrol or diesel cars are expected to remain operational through the scenario, and only if resupply of fuel can be established.

4.4.3 Cascading effects

As in the previous scenarios, it is expected that the scenario will lead to cascading effects in relation to rescue services, governance and crisis management. Furthermore, cascading effects on other critical functions or infrastructures are expected due to larger parts of the work force prioritizing taking care of vulnerable family members such as home nursing patients due to the expected service levels from the public health care sector. As with the last scenario, the effect of this is thought to be significant, but wrought with uncertainty.

4.4.4 Consequences for societal values

The societal values focused in this assessment in terms of impact and consequences are:

- Life and health
- Societal stability

The scenario impact on the health care services is expected to affect "life and health" in all types of in-patient health services without reserve power through generators, or without adequate backup systems to provide basic needs such as heat, light and necessary food preparation.
Outpatients/home nursing patients are also expected to be severely affected, depending on housing conditions. Furthermore, the effect of lack of communication during the scenario is expected to lead

to a low degree of response possibilities in regards to acute medical issues usually responded to by the ambulance services. Attempts to quantify the consequences in terms of mortality was done in the workshops, with upper estimates ranging between 50-100 such deaths, but the quantifications can be considered to be uncertain.

"Societal stability" is not expected to impacted due to the expected loss of health services during the scenario (but is expected to be impacted to a very large degree by the power outage itself).

4.5 Scenario 4, One week citywide outage

Electrical power outage for one week

Tuesday morning 15 January 2019 the electrical power suddenly disappears in all of Bergen municipality. The citizens in the municipality are without electrical power until Monday morning 21 January. It is cold outside with temperatures between -5 and 0 degree celsius.

4.5.1 Critical input factors

The scenario is seen as a continuation of Scenario 1-3, e.g. that the following description details the expected progression between 72 hours and one week in a citywide power outage. No changes in critical input factors have been identified in the workshops or consultations performed in the analysis.

- **The water distribution network** will be dependent on significant daily fuel resupply to several locations if potable water production and distribution to end users at lower elevations is to continue.

4.5.2 Overall impact on health services

Unless otherwise specified, impacts identified in scenario 1-3 are also present in this scenario. As such, only the additional impacts encountered between 72 hours and one week are presented.

Specialist health care:

No additional effects have been identified, given the assumption of timely resupply of fuel. The scenario will thus affect the specialist health care sector to a moderate degree.

Municipal healthcare:

Few additional effects have been identified, given the assumption of timely resupply of fuel. As in the last scenario, the municipal health care services are expected to be affected by this scenario in a moderate to a high degree.

4.5.3 Cascading effects

As in the previous scenarios, it is expected that the scenario will lead to cascading effects in relation to rescue services, governance and crisis management. Furthermore, cascading effects on other critical functions or infrastructures are expected due to larger parts of the work force prioritizing taking care of vulnerable family members such as home nursing patients due to the expected service levels from the public health care sector. As with the last scenario, the effect of this is thought to be significant, but wrought with uncertainty.

4.5.4 Consequences for societal values

The societal values focused in this assessment in terms of impact and consequences are:

- Life and health
- Societal stability

No reliable consensus on the estimates of effects on life and health of this scenario have been reached in the workshops or consultations, due to the several large uncertainties present.

As in the previous scenarios, societal stability is not expected to be impacted due to the expected loss of health services.

4.6 Scenario 5, 1 month citywide outage

Electrical power outage for one month

Night to New Years Eve 31 January 2019 the electrical power suddenly disappears in all of Bergen municipality. After two weeks electricity rationing is implemented. Access to electrical power is regained for all citizens in the municipality 28 January, after one month. It is cold outside during the whole period with temperatures between -5 and 0 degrees celsius.

4.6.1 Critical input factors

The scenario is seen as a continuation of Scenario 1-4, i.e. that the following description details the expected progression between one week and four weeks in a citywide power outage. As the scenario includes electricity rationing by week two, either by rotational rationing where smaller areas of the grid are given grid power for a certain amount of time, or rationing and prioritization of vulnerable end users such as health service providers and critical infrastructures, no further negative changes in critical input factors have been identified in the workshops or consultations performed in the analysis. As both forms of rationing will enable some functionality in affected infrastructure, it is believed that some of the critical impact factors will have improved functionality compared to the other scenarios.

4.6.2 Overall impact on health services

Unless otherwise specified, impacts identified in scenario 1-4 are also present in this scenario. As such, only the additional impacts encountered between 72 hours and one week are presented.

Specialist health care:

No additional negative effects have been identified, given the assumption of timely resupply of fuel. The scenario will thus affect the specialist health care sector to a moderate degree.

Municipal healthcare:

Few additional effects have been identified, given the assumption of timely resupply of fuel. As in the last scenario, the municipal health care services are expected to be affected by this scenario in a moderate to a high degree.

4.6.3 Consequences for societal values

The societal values focused in this assessment in terms of impact and consequences are:

- Life and health
- Societal stability

No reliable consensus on the estimates of the effects on life and health of this scenario have been reached in the workshops or consultations, due to the several large uncertainties present (as seen in section 4.7).

As in the previous scenarios, societal stability is not expected to be impacted due to the expected loss of health services.

4.7 Uncertainty and steering ability

The uncertainty of the results of the analysis is deemed to be high due to several factors. Power outage as an incident type is relatively well known, both nationally and internationally. But large scale and long lasting outages as the ones described in the scenarios are very uncommon in a Norwegian perspective. As the power distribution network is tightly intertwined with other infrastructures, failures and dependencies in critical infrastructure and critical public services can be expected to exist and propagate in ways not identified through the workshops or consultations, adding to the uncertainty of the end analysis.

As seen in Scenario 4 and 5, the estimation of consequences for the longer scenarios have been difficult, due to the large uncertainties regarding emergency measures such as evacuation and relocation of patients. Due to the uncertainty inherent in these measures, reaching a consensus on the consequences of the scenarios have been difficult. Furthermore, the analysis is based on the assumption that several barriers (such as generators) will function as planned, whereas one in real life would expect a percentage of barriers to fail.

The uncertainty is also affected by the fact that the effects of the different scenarios are deemed to be sensitive to changes, E.g. as many of the UPS-powered infrastructures discussed in the workshops is estimated to have a 2-4 hour operating reserve, a 50% increase of the timeframe of Scenario 1 is expected to lead to a majority of drained UPS-systems and thus non-functional infrastructure, whereas one in the current four hour scenario is expecting that parts of such systems will be operation when the scenario ends. The time of day used in the scenarios also contributes to the sensitivity of the analysis, as the scenario takes place outside of normal business hours. As such, effects on e.g general practitioners are low in the first scenario, but could be expected to be high if the scenario had a timeframe including normal business hours.

As to the steering ability, the general consensus from the different workshops is that the probability of large outages is affected mainly by technological innovation (both negatively and positively), the national and transnational power market and national and international regulation. As such the steering ability is low seen from a local perspective. In regards to reducing the impacts on the assessed health care services, there are several opportunities to improve resilience, both on a local and regional level, as can be seen in Section 0.

4.8 Identified vulnerabilities

A large number of vulnerabilities have been identified through the workshops and consultations. Of these, the most important are:

- Ordinary communication, coordination and control in and between the different health services are mainly based on ICT tools and telecommunication, and will be reduced or lost in a power outage, concurrent with an expected increase in the need for effective communication. Although backup-systems exist, these are not expected to meet the increased demands.
- As with the above, communication between the public and the health care services is mainly based on ICT tools and telecommunication. Few or no backup systems exist readily available in the public, leaving the public unable to contact the health care services.
- Home nursing patients depending on life supporting electromedical devices have few efficient barriers able to be able to cope with electrical outages lasting longer than hours. Said patients are supplied the equipment through the specialist health services, but are mainly seen on a day-to-day basis by home nursing staff. The operational limits (battery life) for the safe use of each patients equipment is insufficiently communicated between the services, resulting in an expectation that not all patients will receive appropriate and timely intervention in case of a long-lasting power outage.
- Health care services have to a large degree replaced regular visits from health care personnel with different forms of wireless technology such as personal safety alarms, which is expected to lose functionality in a long lasting power outage.
- Healthcare buildings are to a certain degree operated without viable options for continued and safe function in case of power outages, meaning that basic patient needs will not be met in a power outage.
- Healthcare buildings that are equipped with generators will be dependent on steady resupply of fuel and maintenance to ensure continued and safe core functions.
- Infrastructure remaining in operation during the longer scenarios will be dependent on steady resupply of fuel and maintenance to ensure continued functions.
- The majority of municipal service cars (approx.. 80%) is expected to be unavailable due to loss of charging possibilities in a power outage lasting longer than 24 hours. Home nursing and other services will need to reduce service or find alternative transports.
- Although access to potable water is expected to be as usual for most end users, a few institutions are at a higher elevation and will be without potable water.

4.9 Identified proposals of measures

4.9.1 Preventive measures proposed

- A more thorough and detailed review should be performed in the municipality, defining minimal operational parameters for the safe function of institutions and institution-like facilities like nursing homes in regards to power outages. The review should lead to recommendations in regards to need for UPS/generator support, backup communications, auxiliary or emergency heating systems and other infrastructure needs.
- Based on the above, the current municipal emergency plan should be updated to ensure that vulnerable patients can be evacuated to suitable facilities within the necessary timeframe of a power outage. The review should include nomination of suitable facilities in each borough in Bergen. Said facilities should also be able to facilitate medical consultations by the GP services and basic information services by the municipality. This work dovetails with the proposed project Care4Power, see Section 4.10.
- More detailed information about expected cell phone coverage in an outage should be collected in collaboration with DSB. If few or no cell phone base stations are without generator support, different possibilities for increasing resilience through the municipality should be explored.
- A review should be performed in regards to the strategy of continued electrification of municipal service cars in regards to the vulnerability this introduces in a power outage.

4.9.2 Preparedness measures proposed

- A work package ensuring continuous exchange of information between the specialist and primary healthcare sector in regards to patients depending on electromedical equipment is needed. As these patients are equipped with the equipment through the specialist healthcare sector, information about the equipment, expected battery life and thus the necessary response time in a power outage is not readily available to the home nursing service, which are expected to be the primary respondent. The information about said equipment needs to be available through the patient journal. The work package should also review if the UPS/battery capacity of said equipment should be standardized and/or increased based on expected response time.
- All sectors of the healthcare system delivering time-critical treatment should ensure that backup journal systems and other systems critical for patient care have the needed functionality to be used in a citywide power outage.
- A review should be performed in regards to the municipal ICT and telecom systems and subsystems, aiming to introduce resilient features in critical points of the system such as wireless redundant features or UPS capacity. The review should also address the need for backup communication channels such as Tetra-based radio (Nødnett) in the different parts of the primary health services.
- National guidelines for fuel access and prioritization in emergencies should be clarified and finalized. Authority to enact prioritization should be delegated to appropriate levels (i.e. county governor).
- Each organization should review its expected use of diesel during a power outage. Agreements with suppliers with the capacity to deliver during power outages should be finalized.

4.10 Way forward

An important remark on the analysis is that most effects and consequences identified have been found to take place within the third scenario, i.e. taking place within 72 hours, with the most effects in the first scenario, i.e. within 4 hours. Although the early onset of effects is not completely surprising, the clear grouping in time can be considered to be a somewhat unexpected find, with a significant importance for emergency planning and further risk reduction.

The findings are deemed to be of great importance to overall risk management, both on a municipal level, as well as for the different involved stakeholders. As such, the key findings will be implemented in the next planned risk evaluation for Bergen municipality (BergenROS 2019), which is the main instrument in the risk management process in regards to public safety for the municipality.

The process and findings also indicate a need to further clarify responsibility and coordinate efforts in emergency planning for large power outages, for all sectors of the health care services, and in all levels of governance. As a natural follow-up of this project, Bergen municipality is participating in the DG ECHO 2019 proposal "Care4Power", which aims to develop inter-sectors plans based on the findings in MEREPUV. Such plans will naturally detail solutions to several of the identified vulnerabilities in this summary, such as evacuation plans for the different vulnerable patient groups. The proposal involves several of the actors participating in MEREPUV, including the cities of Stavanger and Valmiera.

In addition to the above, the findings are also expected to lead to several municipal efforts in relation to the findings. One such effort is in the early planning process, involving several of the stakeholders regarding the need for increased resilience in the different health care institutions in the municipality. Another effort is in relation to the vulnerabilities related to e-health initiatives, where a risk management process of existing and expected technologies is expected.

The Norwegian-language report from Bergen will be disseminated to all involved stakeholders on completion of draft status for comments. On completion of the report, this will be distributed to all stakeholders, as well as other relevant actors such as the major cities in Norway, the DSB and other government agencies.

5 Experience with the method and process

5.1 Methodology

A functioning power grid is vital for the successful upkeep of other infrastructures, as well as upkeep of the different end users. Massive power outages as the ones discussed in the scenarios are thus expected to lead to a large degree of cascading effects in other infrastructures, in turn impacting the different health care services.

Some of the cascading effects are relatively straightforward to identify, i.e. parts of the municipal water system loosing pressure due to powerless electric pumps. But, some other effects are harder to identify, as the complexity of the different infrastructures demands that successful identification of all applicable risks would entail a full hazard review of the different systems and subsequent subsystems of the different infrastructures, also taking into account interactions between the different infrastructures. Such detailed reviews have not been possible within the scope of this analysis, both due to time constraints, but also due to the different issues of secrecy surrounding some of the infrastructures such as telecommunications.

As such, although the analysis can be considered to be thorough in relation to the different input factors affecting the different health care providers in a power outage, it is expected that some cascading effects have not been identified or sufficiently analyzed. As for the methodology, it is our experience that the chosen approach (bowtie influenced coarse risk analysis) is sufficient to elicit the necessary input for the analysis, i.e. that the process generates appropriate levels of knowledge about the combined effects of power outages on healthcare services.

However, as the identified risk mainly is due to the effects imparted by powerless infrastructure systems, and the interaction between said systems, it can be argued that the methodological approach is limited as to presenting said risk. E.g. the mainly text-based approach has some limitations in how risk can be presented. In this regard, model-based methods such as different forms of network analysis or fault trees would probably be able to better present the complex and interconnected issues with more precision. At the same time, such an analysis and presentation would probably be far more demanding and time-consuming to complete, and would to a certain degree exclude some of the different healthcare practitioners that have been integral to the project.

Although the methodology allows for sufficient identification of a wide variety of negative effects on the health services, a common theme during the workshops have been that quantifying the consequences of these effects in terms of loss of life/health has been challenging. E.g., the workshop participants have easily identified the rather drastic effects of the power loss and affected impact factors on the ability to provide necessary health care services, but the process of quantifying loss of life/health due to loss of services has been problematic. This is due to the large uncertainties in regards to key emergency planning factors such as the efficacy of regional actors, expected inflow of needed fuel to the region, and the expected efficacy of out of region evacuations. To be able to fully understand the actual consequences of the different scenarios would entail performing a full emergency preparedness analysis, taking into account all factors thought to affect the outcomes.

5.2 Stakeholder involvement

There has been a wide stakeholder involvement, both in regards to the preparatory work leading up to the different workshops, but also in the workshop execution. However, as with most projects, continued stakeholder involvement has been challenging, due to the different aspects governing the

different involved organizations. As such, some areas of the health care services involved have been analyzed to a greater degree, whereas the scope of the analysis in other sectors might be narrower than originally expected.

Due to time constraints, this report has not been disseminated in its entirety to all involved stakeholders before publication. The main findings in the different scenarios, as well as the proposed measures, have been presented in the final workshop, where all involved actors were invited and had the opportunity to comment.

6 Annexes

Annex 1 Joint objectives for project MEREPUV:

The general objective of the project is to make cities more resilient to disruptions in power supply by improving knowledge of cities` role in protecting their vital societal functions from such disruptions, and by identifying efficient measures available at the local level for protecting citizens against severe consequences of power outage.

Specific objectives

1. Improved understanding of and experience with methodological approaches for assessing vulnerability in societal functions with emphasis on interdependencies

2. Improved knowledge of risks of severe power outage in the cities and efficient measures available at the local level

3. Better understanding of the municipalities` role vis a vis other actors` responsibilities in preventing severe consequences of undesirable incidents hitting urban vital functions

4. Closer cooperation and sharing of experience nationally and internationally between cities and national authorities in efforts aimed at improving urban resilience

Annex 2 Joint methodology in MEREPUV

Analytical model

The assessment conducted is done within the framework of the so-called bow tie model. The model is adapted and specified on basis of purpose, analytical object and main questions to be examined in the assessments. The following risk elements are assessed:

- Probability
- Vulnerability
- Consequences
- Uncertainty

In addition, one other element is assessed:

- Steering ability: How manageable are the risk and vulnerability attached to the scenario? To what degree are there available measures which are likely to reduce risk and vulnerability?

Vulnerability in health services / rescue services / EKOM services is the analytical object in the model.

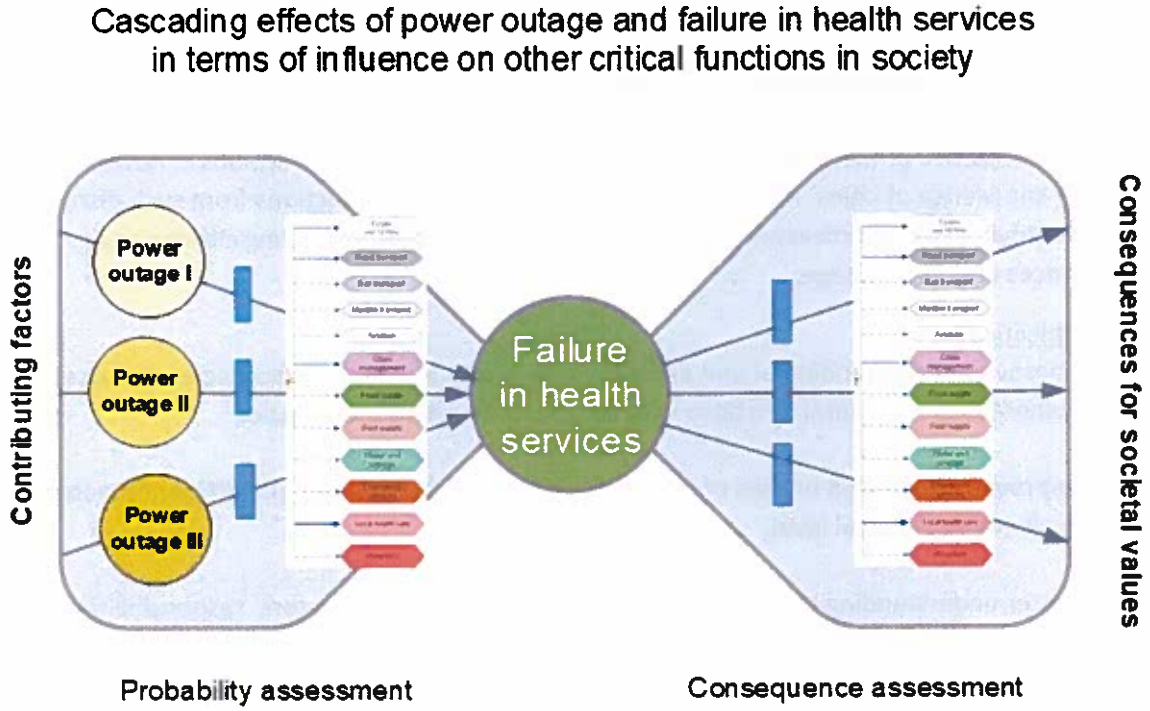


Figure 2. Risk and vulnerability assessment in four steps: 1) How do the scenarios affect other vital functions? 2) How does failure in such vital functions affect health services? 3) How does disruption in health services affect other vital societal functions (interdependencies) 4) What are the consequences for citizens and society?

Choice of scenarios

Describe the choice of scenarios of power outage

Assessment of probability – how likely is it that the scenario will occur?
The probability assessment builds on results and insights from earlier risk and vulnerability assessments and other available existing knowledge and data material.

The probability intervals used are:

- Very low probability: 0-10 per cent likely in 50 years
- Low probability: 10-40 per cent likely in 50 years
- Moderate probablity: 40-60 per cent likely in 50 years
- High probability: 60-90 per cent likely in 50 years
- Very high probability: 90-100 per cent likely in 50 years

How do the scenarios affect other vital functions?
In the assessments we are examining whether and how the scenarios affect other critical input factors of which health services are dependent on in order to function.

How are health services affected?
In the assessment we are describing how the different scenarios affect health services, either directly or indirectly, due to failure or disruption in one or several other critical input factors for health services.

Furthermore, an overall assessment is made of how health services are affected in total. The assessment is based on a five-part scale from very low to very high degree.

Cascading effects and consequences for other vital societal functions
By examining other vital societal functions` dependency on health services, we get an impression of vulnerability in society related to failure in health services.

Societal impact
In this assessment we have chosen to assess consequences for society and citizens by focusing on the following societal values / types of impact:

- Human impact / life and health
- Societal stability / social impacts

The impact type "life and health" is further divided into two consequence categories: 1) number of deaths expected deaths and 2) number of severly injured or ill people

The impact type "societal stability" is further divided into two consequence categories: 1) Social and psychological reactions and 2) Challenges in daily life

Uncertainty and steering ability
Assessment of degree of *uncertainty* is related to an evaluation of the quality of excisting knowledge used in the vulnerability assessment as well as an evaluation of to what degree the results are sensitive to changes in the conditions.

Degree of *steering ability* is evaluated by an assessment of whether efficient measures, of which can reduce the risk and vulnerability, exist and are well known. This is an important evaluation after the results of the risk and vulnerability assessment are ready and alternatives of measures are being adressed.

Annex 3 Participating organizations

Organization	Responsibility
BKK Nett	Utility provider electrical
BKK Energi	Utility provider district hot water heating
Bergen Vann	Municipal water and sewage treatment
Bergen kommune, Sykehjemsetaten	Dept. of nursing homes
Bergen kommune, Helsevernetaten	Dept. of public health
Bergen kommune, Legevakten	Municipal A&E
Bergen kommune, Etat for tjenester til utviklingshemmede	Dept. of services for the disabled
Bergen kommune, Etat for hjemmebaserte tjenester	Dept. of home based services/home nursing
Bergen kommune, Kommunal hjelpemiddelsentral	Municipal assistive aids central
Bergen kommune, Psykisk helse og rustjenester	Dept. of mental health and addiction services
Bergen kommune, Etat for digitale driftstjenester	Municipal ICT services
Haraldsplass Sykehus	Regional hospital
Helse Bergen/Haukeland sykehus	Regional hospital/ambulance services/medical assistive devices
Fylkesmannen	Office of the County governor
Statens Vegvesen	Public roads administration