Helsinki

Weather and climate change risks in Helsinki

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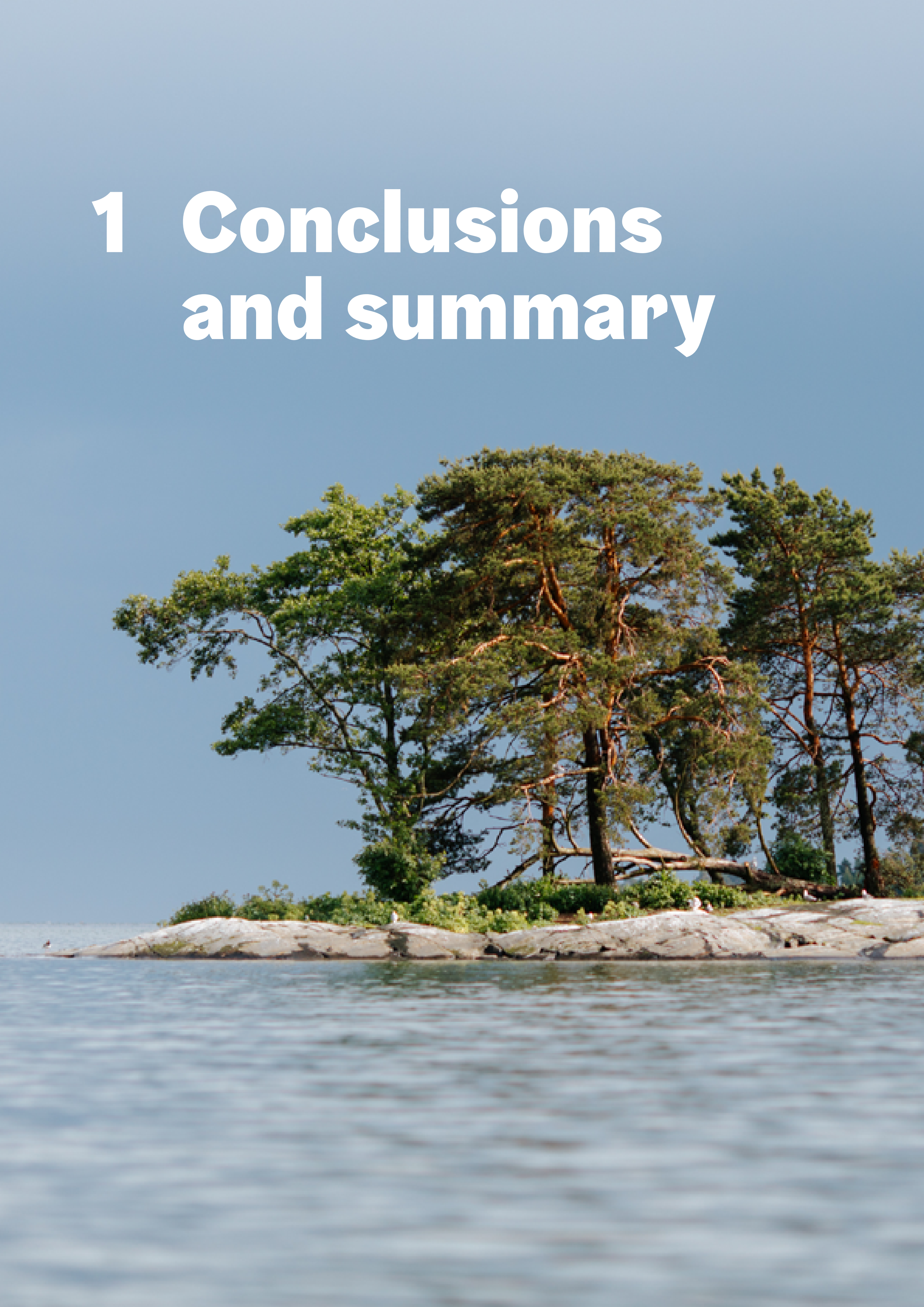

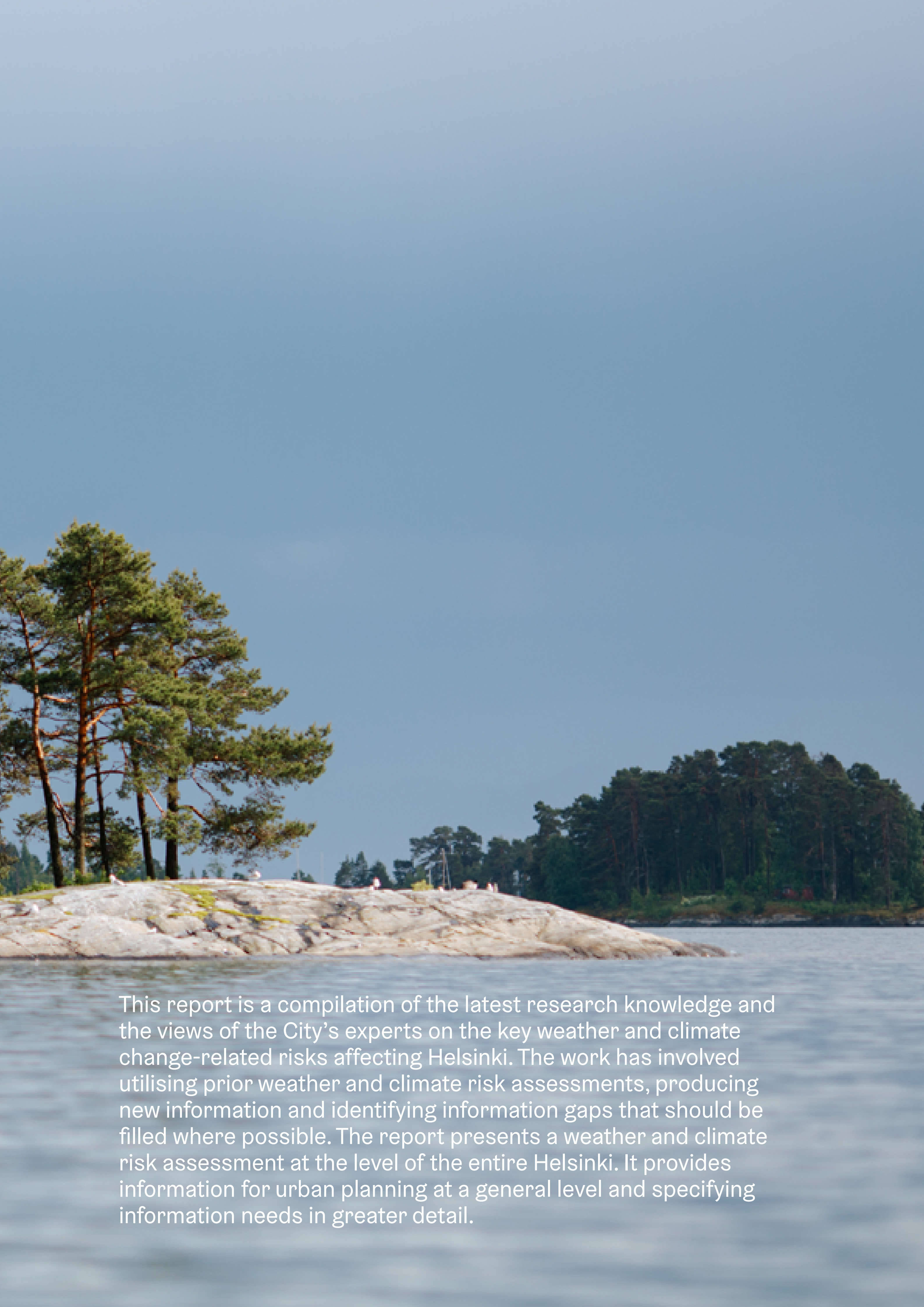

This report is a compilation of the latest research knowledge and the views of the City's experts on the key weather and climate change-related risks affecting Helsinki. The work has involved utilising prior weather and climate risk assessments, producing new information and identifying information gaps that should be filled where possible. The report presents a weather and climate risk assessment at the level of the entire Helsinki. It provides information for urban planning at a general level and specifying information needs in greater detail.

1. The impacts of weather and climate change must be taken into consideration in decision-making

Helsinki's vision is to be *the most functional city in the world*[1]. **A functional city must take the impacts of weather events and climate change into account** and strive to reduce them. The impacts have implications for society's functional capability, the economy, nature and people's everyday life. Weather and climate set many limitations to Helsinki's operations and have effects on the people and organisations operating in the city. The changing climate poses additional challenges. Compared to our current climate, mean temperatures are projected to increase in Helsinki by several degrees. Changes in extreme temperatures and their durations, as well as intensifying torrential rains, will have a wide variety of impacts on

[1] City of Helsinki, 2017 https://www.hel.fi/helsinki/en/administration/strategy/strategy/city-strategy/

society. Furthermore, the impacts of weather and climate variability and climate change occurring in other parts of Finland or outside Finland can be reflected in Helsinki and prove to be substantial.

The increasing climate risk should be integrated into all levels of relevant decision-making. Planning and construction play a significant role in risk reduction. Even though plenty of preparation and adaptation measures have been implemented in Helsinki already, reducing the risk of storm water flooding in built areas, and complementary construction in particular, should be examined in depth. The use of urban green and other permeable surfaces that infiltrate and delay torrential rains should be assessed carefully. The city districts' flood routes should also be planned so that flood waters are removed from the area in a controlled manner. Urban green spaces reduce the discomfort caused by heat waves as well. Heat wave risk in Helsinki is increasing due to a denser city structure and rising summer temperatures. The cost efficiency of different adaptation measures and their lifecycle costs should be surveyed before implementation.

Helsinki's most significant climatic hazards are probably floods and extreme winter conditions. In addition to these, the risks to nature are considerable, particularly because nature in Helsinki is already under notable pressure. The following section provides a summary of the climatic variables changing due to climate change that are presented in the report in greater detail, as well as a presentation of the risks they cause to Helsinki.

2. Increasing risk of floods

Based on the survey conducted in 2011, Helsinki does not have significant storm water flood risk areas. Due to a denser city structure and climate change, **the storm water flood risk will probably increase in Helsinki due to intensifying torrential rains**. As the City grows denser, its impermeable surface area increases, meaning that more attention must be paid to storm water management in all areas. The probability of a torrential rain flood causing massive damage is at its highest in city centre. The area has less water infiltration surface area, such as parks and other forms of urban green spaces, than other parts of the city, and its building density is the highest. Additionally, the risk of storm water floods is increased by extensive underground spaces and functions. If storm water enters the tunnels, many important functions, such as energy management, will be in danger. In the city centre, the economic, societal and health-related effects of extreme torrential rains may become very significant. However, the flood risk and the spreading of storm waters and torrential rains in the city centre requires more detailed modelling than was possible within the framework of this analysis. Even though the city centre is the most susceptible to storm water floods, people's vulnerability to the effects of storm water floods is at its highest in the city districts of southern Vuosaari, western Herttoniemi, Roihuvuori, Viikki, Vallila/eastern Pasila, Maunula-Suursuo and northern Meilahti. A more detailed and updated storm water flood assessment was carried out for Helsinki in 2018.

Winter climate to see the greatest changes

Great efforts have been made to manage the sea and river flood risk in Helsinki. The 2005 sea flood led to the development of a flood strategy. Furthermore, an investigation was made, based on which flood protection measures were carried out in risk locations. **The sea level rise due to climate change increases the risk of sea water flooding to a degree.** In new residential areas, the risk is taken into consideration in the construction phase, but in old seashore areas, the risk is greater. However, the risk has been reduced in a variety of ways. The sea flood risk areas are not heavily populated, so exposure is rather minor. The sea flood risk is significantly affected by properties' own risk reduction and preparedness measures. **River floods in Helsinki are caused by torrential rains and melting snow.** River Vantaa and small brooks are especially prone to flooding. In the past, river floods have flooded property, temporarily interrupted the recreational use of areas and increased the leaching of nutrients and other impurities into water bodies. **Climate change is estimated to increase the occurrence of river floods in winter as well.**

3. Winter climate to see the greatest changes

In Helsinki, winter is the season changed the most by climate change. In winter, temperatures rise the most, precipitation and cloudiness increase, and a growing proportion of the precipitation occurs in the form of water. For example, January and February will be approximately two degrees warmer in 2050 than in 1971–2000, and the mean temperature for March will rise above zero. Winters in Helsinki will become darker and more humid, extremely cold periods will become rarer and the thickness and area of the ice over the Gulf of Finland will diminish.

Slippery conditions cause a significant health risk and have economic effects. The risk of pedestrians having slipping accidents is multiplied when rain or snow falls onto an already icy pavement. Even though the winter season in Helsinki is becoming shorter due to climate change, slippery conditions in mid-winter may become more common in the coming decades as the temperature fluctuates above and below zero degrees. This increases the likelihood of accidents and the need to increase anti-skid treatment resources, and possibly the amounts of compensation paid to people who are injured due to falling. Slippery conditions must be taken into account in winter cycling as well, as the goal of Helsinki is to promote winter cycling and develop the winter maintenance of cycling routes.

Climate change makes the winter season shorter, but intense snowstorms must still be prepared for in traffic and maintenance. Snowfalls exceeding six centimetres in one day will become less common, but heavy snowfalls (more than 10 cm/day) may actually become slightly more frequent. Freezing rains, in which the water is supercooled, are very rare in the Finnish climate. The probability of freezing rains will increase somewhat due to climate change, which may make the conditions in Helsinki more slippery. Traffic technology is developing rapidly, and it is possible that most cars will be self-driving in 2050. Thus, the effects of the changing winter conditions on, for instance, accident risks are difficult to estimate.

Climate change reduces the amount of sunlight in the winter months, which may cause exacerbated winter depression. The symptoms of winter depression expose people to the risk of physical illnesses, such as metabolic syndrome, as well.

Rainfall in winter is expected to increase due to climate change. **Precipitation as water instead of snow may, for instance, cause storm water problems and increase the risk of slipping.** Nutrient load into water bodies will increase due to increasing rainfall in winter. In winter, the low evaporation level will increase the effects compared to summer conditions. Furthermore, slipping accidents and other traffic problems will increase if rain is followed by freezing temperatures.

4. Increasing risks caused by heat

Heat exacerbates the symptoms of many chronically ill people and increases the risk of premature death, especially among people aged 75 and over. High summertime temperatures will become more common at the same rate as the mean temperature. Thus, in the middle of the 21st century, 32 °C temperatures would be approximately as common as 30 °C temperatures in the late 20th century (provided that emissions follow the RCP4.5 scenario, i.e. the Paris climate change agreement is implemented moderately). **As the population ages and elderly care becomes increasingly focused on home care, it is expected that the health risk caused by heat waves will increase.** This risk can be reduced by preparing for the situation in healthcare and elderly care. **The health risk caused by cold temperatures will decrease due to climate change, but it will not be eliminated.** Risk groups must continue to prepare for extremely cold temperatures.

5. The risk caused by strong winds and storms will not change significantly

In Helsinki, unlike in many other regions in Finland, strong winds and storms rarely cause power outages, as the underground cabling degree of the Helsinki electricity network is 96% (managed by Helen Electricity Network Ltd) . However, storms have impacts on Helsinki's forest areas and parks. For example, a storm in the summer of 2017 felled or damaged approximately 10,000 individual trees, and some of the trees left upright are susceptible to new damage. Many large public outdoor events are also held in Helsinki in the summer, potentially exposed to dangerous situations during heavy storms. Boating is also sensitive to strong winds, and boaters may be caught unprepared.

The risk caused by strong winds and storms will not necessarily change significantly due to climate change. However, the decrease in ground frost during the winter months will make trees more exposed to strong winds. In Helsinki and its coastal areas, the mean wind speeds have slightly decreased over the past decades. Based on climate scenarios, the mean wind speeds will increase in Helsinki by a few percent. The frequency of strong winds and storms is estimated to increase somewhat in the future, but the changes will probably remain minor.

6. Tick-borne diseases will become more common

Weather and climate conditions affect the presence and activity of ticks. **Warming climate will probably increase the prevalence of ticks and tick-borne diseases as the growing season becomes longer.** In Helsinki, the risk of tick-borne diseases is at its highest in the archipelago. Ticks are found almost everywhere, but no exact figures of the proportion of ticks carrying disease agents exists. In Finland, 15–20% of ticks carry Lyme disease and approximately 1.5% carry TBE (tick-borne encephalitis). Several cases of Lyme disease are reported each year in Helsinki, and cases of TBE have been increasing in the Helsinki University Hospital HUS area since 2010. On the islands off the coast of Helsinki, ticks carry TBE, against which a vaccine is available. There is no vaccine against Lyme disease, but the disease can be treated with antibiotics. The transmission of these diseases to people is largely related to people's behaviour, especially free-time hobbies.

7. Biodiversity is threatened by many factors

In Helsinki, the impacts of climate change on nature must be analysed in conjunction with urban development. As the city becomes denser, the amount of green areas is reduced, and their ecological quality is weakened. Cities' nature reserves are small and the green network is fragmented. **The rapid change in winter conditions changes the living conditions of many plant species. Consequently, there is a significant risk of certain species being unable to adapt to climate change and spread to new areas.** It is not yet known how the loss of species will affect habitats and the functioning of ecosystems.

Due to climate change, plant diseases and insect pests will be more likely to spread to urban trees. Climate change increases the risk of new plant diseases and pests spreading. This can be prevented by diversifying the range of species of park plants and urban trees to better suit the changing climate conditions. The impact of climate change on invasive species risk in Helsinki has not been researched in detail. Invasive species and combating them are causing, and will cause, significant costs in the City's maintenance operations.

Climate change affects the biodiversity of the Baltic Sea, and invasive species will settle in the Baltic Sea easier than before. The geographical distribution of organisms is also affected by the salinity of the Baltic Sea, which may decrease due to increasing rains. The decrease in salinity may threaten the so-called key species, whose existence several other species are dependent on. In turn, the increased carbon dioxide content of the atmosphere will expedite the dissolution of carbon into the sea water, causing the sea water to acidify. Acidic water dissolves calcium compounds and hinders the growth of organisms with a calcareous skeleton, which will affect food chains. Climatic warming may expedite eutrophication. In the Baltic Sea, this causes problems, such as the water becoming more turbid and lack of oxygen in the bottom/ bottom sediment. It also increases the occurrence of filamentous algae, which displace other species. In the Gulf of Finland, the temperature rise, increased layering of the sea water and release of phosphorus from the sea bottom can increase the occurrence of toxic blue-green algae blooms, unless the nutrient loading from land can be mitigated. **At the end of the 21st century, the majority of the Gulf of Finland will remain unfrozen over average winters, as the ice winters on the Baltic Sea will become shorter by an average of 1–3 months compared to the current situation. This affects both the organisms living in the Baltic Sea and ship traffic.**

8. Transboundary impacts will reach Helsinki

Transboundary impacts refer to the interaction chains between weather and climate variability and climate change, which begin outside of Finland but eventually extend to Finland. In Helsinki, transboundary impacts may also result from impacts originating from other regions of Finland, e.g. through agriculture. **Transboundary impacts occur especially through the availability and prices of raw materials and production factors, as well as demand in the export market.** Helsinki's security of supply (energy, food, etc.) is highly dependent on production and industry that take place elsewhere. The availability of goods and a sudden increase in prices due to, for instance, an extensive drought can have a significant effect on low-income residents of Helsinki. Imports in the energy sector also play a very significant role in Finland, and as transfer connections develop, the possibility of transboundary impacts will increase.

Migration caused solely due to climate change is difficult to assess, as there are usually other reasons, such as political and economic ones, in the background as well. However, long-term climate-change-induced migration can have various impacts on the population structure and culture in Helsinki. Health-related transboundary impacts can occur as diseases strengthened by climate change are transferred to Finland, or with climate-change-induced migration. International trade can also bring disease agents to Finland. **Tourism to Helsinki may increase, as Finland has been identified as a country whose attractiveness as a tourism destination may increase with climate change, or when the safety situation weakens elsewhere. Long-term economic transboundary impacts are difficult to estimate.** Climate change has been estimated to decrease the global gross domestic product, which will be reflected in Helsinki as well. This may have a variety of impacts on the city's operations. The international financial markets' reaction to the changing climate is difficult to estimate.

9. Better risk management requires information and adaptation measures

The risks caused by climate change must be considered at all decision-making levels in Helsinki. Many risk reduction and adaptation measures have already been implemented. However, there are still areas in which the adaptation to growing risks must be improved. In particular, management of storm water flood risk, health risk and of the impacts on nature should be developed.

Helsinki's **storm water flood risk** is the sum of many factors, of which increasing rainfall is only one. The growing storm water flood risk must be carefully modelled, especially for the city centre. Based on the modelling results, ways to reduce the risk should be developed. Furthermore, different stakeholders must be prepared for flood situations. The risk must also be considered in complementary construction. Storm water assessments should be carried out for new areas already in the planning phase. Additionally, the use of alternative storm water management methods, i.e. green structures for retention of storm water, should be surveyed and stakeholders should be encouraged to use them. Storm water management should have a clear implementation timeframe, responsible parties and budget. Flood risk maps should also be updated on a regular basis, and they should contain information such as catchment area boundaries and implemented adaptation measures. The storm water modelling could be carried out using the new, next generation 3D models of Helsinki. The modelling should take sewer floods and nature based storm water management into consideration.

The risks caused by high temperatures and heat waves have not been researched much in the City of Helsinki, and there is a great need for knowledge related to them. The functionality of buildings during heat waves should be studied in new construction and renovation alike. In particular cooling systems, their energy efficiency and their cost-effects should be researched. The preparedness level for heat waves in elderly care, especially when elderly people are at home care, should be assessed and procedures to be implemented during heat waves should be developed.

The urban heat island phenomenon has also not been researched much in Helsinki. The consequences of urban development and denser structure on the phenomenon should be assessed, and risk reduction measures surveyed. Urban green spaces are one example of a risk reduction measure, but its possibilities in cooling urban heat islands and reducing the impacts of climate change in Helsinki are yet to be assessed. Furthermore, the heat loss of buildings in winter and its effects on the urban heat island phenomenon should be researched. Changes to the phenomenon caused by climate change present a complex research topic, as the most significant reason behind the phenomenon is urban development. However, climate change can have indirect effects on urban heat islands. These indirect effects have not yet been researched much. Improved understanding of them could facilitate a better needs assessment for adaptation measures.

Compared to rest of Finland, **large traffic volumes in Helsinki affect the amount of traffic jams and car crashes in winter.** Another significant factor affecting the traffic during snowstorms is people's behaviour. Commuting to work by car increases the traffic volumes on roads and reckless driving, not considering the weather situation, increases the risk of crashes considerably. The potentially increasing share of rail traffic in public transport in Helsinki may increase the risk related to snow storms. Long-term impacts from the changing winter conditions may occur if, for example, rescue and healthcare services have insufficient resources in possible pile-up situations and people's access to care is delayed.

The risks caused to traffic by winter conditions can be reduced with the following measures:

1. Lowering speed limits. This should reduce pile-ups or consequential accidents.

2. Anti-skid treatment and snow clearing. In particular, clearing the snow from pavements and cycling lanes should be taken care of, so that pedestrians and cyclists do not need to use car lanes. Snow clearing in the city requires area reservations for snow, which should be considered in land-use planning. For example, green areas could be used for snow disposal in winter.

3. Weather warnings, real-time warnings and safety cars. These improve drivers' preparedness for the situation.

4. Providing information about public traffic services and the ways to use them.

5. Favouring remote working.

6. Examples of methods facilitated by smart traffic in the future include adjusting winter speed limits in urban areas and providing real-time information about the conditions, changing speed limits and exceptional traffic route situations.

Reducing **slipping risks** requires people's own preparedness. This can be influenced significantly through communication. Due to increasing immigration, information should also be provided in English and possibly in other languages as well. In addition to information provision, the City could also provide residents with non-slip devices and offer shoe studding services.

Ecological risks due to climate change, combined with changes in the urban structure, should be researched more in Helsinki. Generally speaking, adaptation to ecological risks can be improved by closely observing the changes occurring in nature and taking care of the species diversity. In combating invasive species, prevention is more cost-efficient and environmentally friendly than repairing damage that has already occurred, and combating species after they have already settled in Helsinki.

The risks related to transboundary impacts in Helsinki should be surveyed in detail. When examining these impacts, the impacts coming from outside of Finland, and Helsinki's dependence on operations susceptible to climate change in other parts of Finland, should be studied. It must be noted, that general preparedness for disruptions improves the preparedness for transboundary impacts of climate change as well.

The City of Helsinki plays an important role in **risk communications as well**, as it is of utmost importance that the residents and other stakeholders are prepared for disruptions. The most common hazards behind significant dangerous situations in Helsinki are slippery conditions and snowstorms, and residents are relatively well prepared for them. However, the preparedness for other disruptions caused by weather or climate variability is not necessarily at the same level. For example, preparedness for storm water flood risks should be increased and people should be given guidance regarding how to act in situations in which the basic and critical infrastructure are not working. The City of Helsinki has ways to communicate, such as the Flood Guide distributed to residents and the Helsinki Safety website (https://www.hel.fi/turva/fi/varautuminen/). Information regarding how residents can prepare for disruptions caused by weather should be added on this website as well.

The economic efficiency of risk management and adaptation measures should be an important criterion when selecting the measures. However, for instance cost-benefit analyses are not usually used in Helsinki when assessing adaptation measures. The need has been identified, however. Another key method is lifecycle cost analysis. This involves the assessment of investment and opportunity costs, which differ between implementation phases of various potential measures. For example, the initial investment and opportunity costs of a green area of a new residential area are in practice higher than those of storm water sewer pipes. However, in the long term, due to, for instance, increasing uncertainty due to climate change, the lifecycle costs of the green areas may be lower than those of redimensioning the storm water sewer pipes.

As the impacts of climate change increase, the different stakeholders of the City of Helsinki must pay more attention to reducing these impacts. For example, the growing flood and heat wave risk and increasing impacts on nature can cause significant economic, health-related and ecological effects. In addition to increasing floods and heat waves, it must be kept in mind that despite climate change, Helsinki will remain a wintry city for a long time. Slippery conditions and their prevention form an important part of Helsinki's climate risk management, as slipping accidents cause significant costs to society. This report discusses a wide variety of currently foreseeable potential impacts of weather and climate change, and features an assessment of which changing societal factors increase these risks in addition to climate change. The report also features an assessment of what measures can be taken to decrease these effects. All in all, proactive, cost-efficient risk reduction is the best way to make Helsinki the most functional city in the world regardless of weather and climate change.

2 Climate sets limitations for Helsinki's operations

In accordance with the Helsinki City Strategy 2017–2021, Helsinki's vision is to be the most functional city in the world[2]. **In a functional city, preparing for the impacts of weather events and climate change is of utmost importance.** The City should strive to mitigate the negative impacts of weather and climate change on society's operating capability, economy, nature and people's everyday lives.

This report is a compilation of the latest research information and the views of the City's experts on the key weather and climate change-related risks affecting Helsinki. **Weather and climate risk refers to potential consequences caused by weather and climate phenomena and their changes on the subject being examined, such as human activities and nature.** The risk consists of the probability of the event and the magnitude of the consequence. Preparing for weather and climate risks makes it possible to secure a safe and functional everyday life for the residents of Helsinki. Hereinafter, the report discusses the climate risks in short and focuses on the potential negative impacts caused by weather and climate change.

Climate sets many preconditions for the way people live and operate in Helsinki: livelihoods, housing, traffic and other societal functions have adapted to the local climate conditions. Current weather events, such as snow storms and heat waves, are already causing disturbances in society's functionality. On 3 February 2012, a heavy snow storm caused a serious pile-up of approximately 690 cars on the Finnish national highway 4 in Helsinki. In July 2010, a heat wave increased the number of deaths in the Hospital District of Helsinki and Uusimaa region by around 60 compared to a typical July. Every year, the City of Helsinki allocates approximately 20 million euros to the winter maintenance of roads and streets. Despite these efforts, there are occasional days when the numbers of slipping accidents increase considerably.

[2] City of Helsinki, 2017 https://www.hel.fi/helsinki/en/administration/strategy/strategy/city-strategy/

The changing climate increases climate risks. Compared to the current climate, the mean temperatures are projected to increase in Helsinki by several degrees. Finland's temperature will increase more than the global mean due to factors such as decreasing amounts of snow and ice in the Arctic region. For example, changes in extreme temperatures, as well as intensifying torrential rains, have a wide variety of impacts on society. Furthermore, the impacts of weather and climate variations and climate change occurring elsewhere in the world can have significant consequences for Helsinki as well.

Climate risk is always a combination of climatic, societal, economic and political factors. For example, building on flood risk areas can increase the risk, but the flood risk can be kept under control with appropriately designed adaptation measures. However, there is not always enough political will or financial resources for this. Furthermore, different groups of people are vulnerable to weather phenomena in different ways. Helsinki has many residential areas located in sea flood risk areas, but only less than 1% of residents live in them, and the average price of housing in these areas is considerably higher than elsewhere. Additionally, in new building sites, the recommended lowest safe building elevations are used, which prepare for sea level rise and increase in waving near the shore up to 2100[3].

Helsinki has numerous ways to reduce and prepare for climate risks. On the one hand, winter maintenance plays a key role in the traffic flow: how easy is it to get to work using public transport during a snow storm, or how safe is it to get around in icy zero-degree conditions? On the other hand, climate change will raise Finland's mean temperatures. The risks caused by heat waves to people's health is real, and it is important to prepare for high indoor temperatures. Increasing precipitation will pose challenges in a densely built environment, as the water does not infiltrate to the ground quickly enough. Green areas increase living comfort, and they reduce storm water damage. At worst, weather events and climate change can put a strain on the City's economy. Thus, planning and decision-making must focus on preventive measures that are cost-efficient or achieve goals set with minimal costs/resources. Additionally, the residents' own preparedness plays a significant role in risk reduction.

The starting point for the analysis was the monitoring list of the Global Covenant of Mayors commitment[4] concerning natural phenomena with potential adverse impacts. Helsinki joined the Compact of Mayors climate commitment (now called the Global Covenant of Mayors) in 2015. In accordance with the monitoring list of the Carbon*n* Climate Registry (CCR) reporting system[5], the member cities must report what kinds of risks natural hazards pose now and possibly in the future. In this report, the hazards are merged into natural categories, and the original list is provided in Appendix 2. Helsinki's climate risks have been studied in several previous projects and assessments. Several of them are listed in this report, and more detailed references are provided at the end of the report. Additionally, numerous climate studies concerning the entire Finland have been carried out, and based on them, the occurrence of different weather phenomena, as well as current and future impacts of climate change in Helsinki can be assessed. Two workshops were also organised during this risk assessment project, which were attended by Helsinki's risk and adaptation working groups' experts from different administrative divisions (Appendix 1).

[3] Kahma et al., 2016 https://www.hel.fi/static/kv/turvalliset-rakentamiskorkeudet.pdf (in Finnish)
[4] Global Covenant of Mayors -commitment https://www.globalcovenantofmayors.org/
[5] carbonn Climate Registry http://carbonn.org/

In this report, previous climate risk assessments have been utilised and information gaps were identified. These gaps should be filled where possible. This report presents a risk assessment at the level of the entire City and provides information for the general level city planning and specifying information needs in greater detail. The report discusses climatic factors that pose risks and their changes due to climate change. It also discusses societal factors that affect the formation of risks. Some thought is also given to future risk factors arising from societal changes. Furthermore, the report aims to identify how climate risks can be managed in city processes and recommends actions for the different processes. The assessment does not feature quantitative calculations regarding the magnitude of different risks facing Helsinki. Instead, the risk ordering used in the report is mainly based on the prioritisation established at a workshop held during the risk assessment. Arranging different climatic risks quantitatively in a priority order is difficult, as assessing the actual impacts is not accurate and prioritising different impacts (such as economic and health-related) is challenging.

The City of Helsinki has published[6] a document entitled *Helsingin ilmastonmuutokseen sopeutumisen linjaukset* 2019–2025[6] (Helsinki's climate change adaptation policies 2019–2025), and climate risk assessment has been established as one of the actions therein. This work was commissioned by the Environmental Services of Helsinki's Urban Environment Division, and it was directed by Jari Viinanen and Sonja-Maria Ignatius in co-operation with the climate risk working group. The members of the working group are listed in Appendix 1. The work was carried out by the Finnish Meteorological Institute between September 2017 and February 2018. The coordinator was Karoliina Pilli-Sihvola and experts involved were Riina Haavisto, Ulpu Leijala, Sanna Luhtala, Antti Mäkelä, Reija Ruuhela and Athanasios Votsis.

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[6] City of Helsinki 2019
https://www.hel.fi/static/kanslia/Julkaisut/2019/Ilmasto_Sopeutumislinjaukset.pdf

3 Climate risk is the sum of several factor

Risk is typically defined as the product of the probability and consequences of an event. Climate risk refers to the potential impacts of weather and climate and their progression on human activities and the nature. A risk often refers to adverse impacts, which is the focus of this report. Risk can also realise over a longer period of time. Climate risks are related to both weather phenomena (e.g. storms) and gradual long-term changes (e.g. shorter periods of ice cover on the sea).

When realised, climate risks involve impacts that can be both direct (e.g. property damage) and indirect (e.g. downtimes caused through supply chains). At their strongest, climate risks can, for instance, hinder the achievement of goals important to the city. At the national level, *transboundary impacts* refer to the interaction chains between weather and climate variations and climate change, which begin outside of Finland but eventually extend all the way to Finland.[7] From Helsinki's perspective, the chain of transboundary impacts can also begin inside Finland's borders and extend to Helsinki.

7 Gregow et al., 2016
http://tietokayttoon.fi/julkaisu?pubid=15406 (in Finnish)

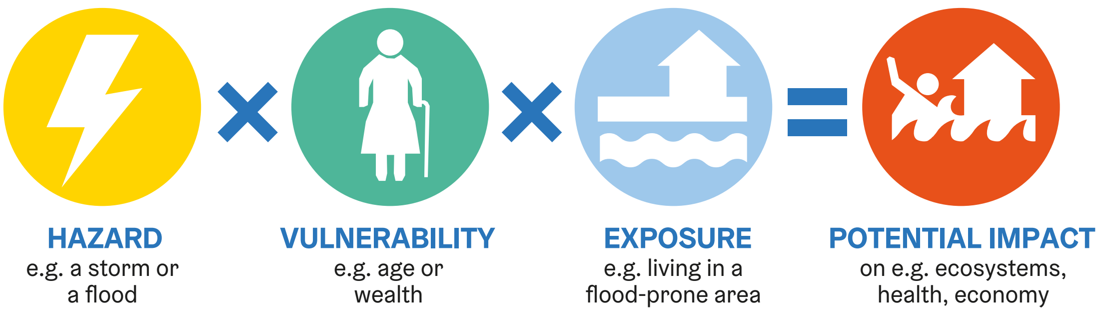
In addition to actual weather phenomena and climate change, weather and climate change risk always consists of interconnected societal and economic factors as shown in Figure 1.

In other words, the factors affecting the risk are the hazard itself, exposure to it and vulnerability, as well as the ability to manage risks.

- *Hazards* refer to potentially damaging or hazardous physical phenomena caused by nature or human activities and their development.
- *Exposure* refers to the location of people, livelihoods, ecosystems and natural resources, infrastructure or economic, societal or cultural capital in a place in which they are exposed to potential damage or danger.
- *Vulnerability* refers to sensitivity to potentially damaging or hazardous phenomena. The concept of vulnerability applies to infrastructure, individuals and societies.
- *Risk management capability* refers to organisations', communities' and societies' assets, characteristics and resources with which risks can be reduced and actual impacts reacted to and recovered from. **The risk management capability of different operators has a significant effect on the formation of the risk.**

The climate risk arises from so-called risk drivers. These include but are not limited to climate change that increases the hazard, land use planning that fails to take increasing exposure into account and political development that increases vulnerability[9].

Figure 1. Factors affecting weather and climate risk [8]



Every factor affecting climate risks changes constantly. Hazards change as the climate or the state of the environment changes. In turn, vulnerability is affected by socio-economic development. Exposure can be influenced by, for instance, land use planning, regardless of whether it has to do with conscious choices or not. Thus, climate risk is constantly changing, which must be taken into consideration when planning actions to mitigate risks and prepare for them. The most difficult aspect of creating a long-term climate risk assessment is estimating the development of society and technology. In 2050, the world may be vastly different in terms of, for instance, traffic and communication technologies.

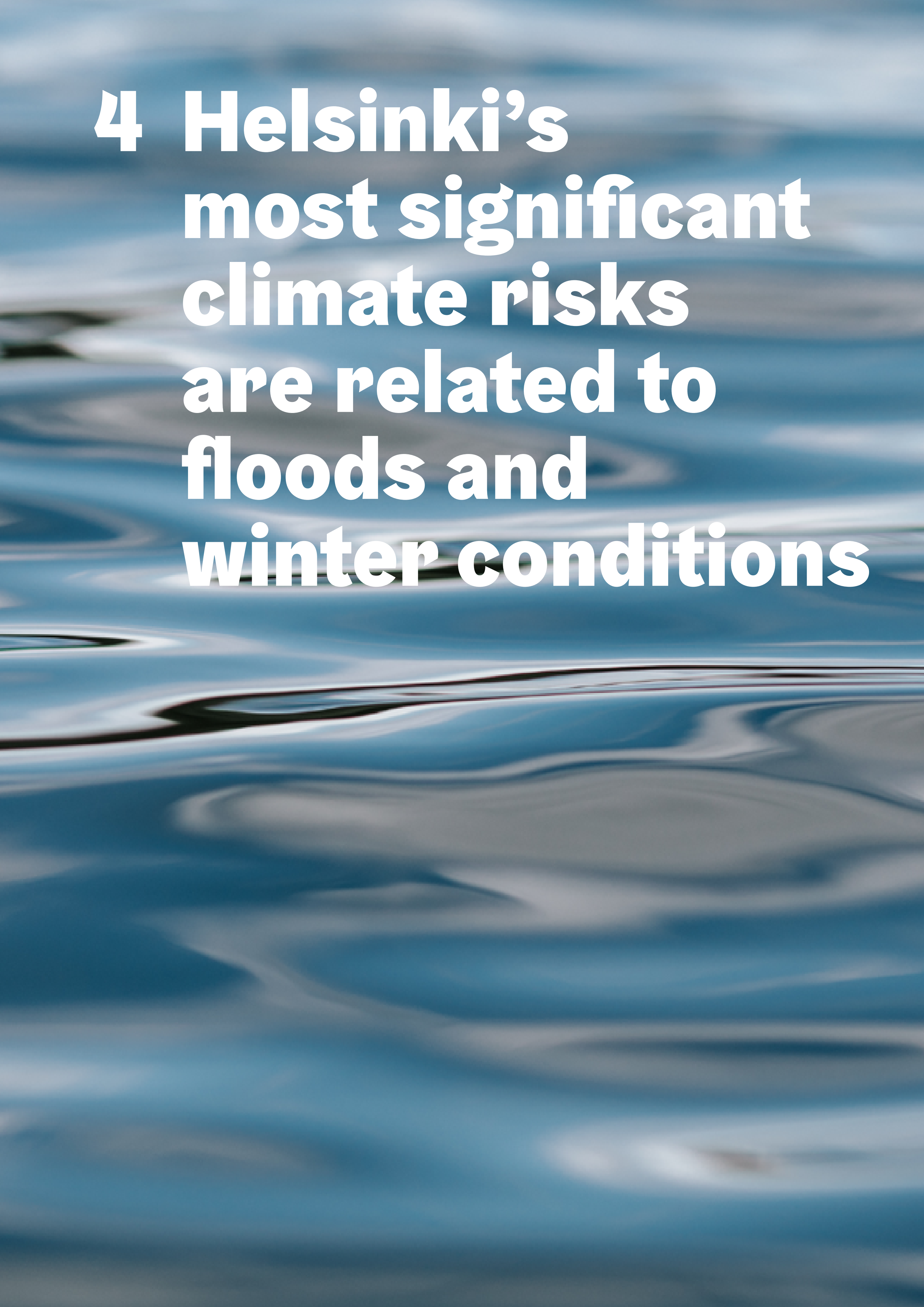
Climate risk is reduced with different measures. Figure 2 presents a classification of these measures[10]. Climate change mitigation reduces the hazard. The goals of the Helsinki City Strategy 2017 include making Helsinki carbon-neutral by 2035 and reducing greenhouse gas emissions by 60% between 1990 and 2030[11]. The City of Helsinki has implemented many risk management and adaptation measures that are not related to climate change mitigation, but to other factors affecting the weather and climate risk. Insofar adaptation measures in this report are measures related to vulnerability and exposure. These include but are not limited to land use planning, insurance policies, communication campaigns and the use of early warning systems. In climate risk management, nature-based solutions that utilise ecosystem services have also become more important.

Risk reduction, management and climate change adaptation measures that affect societal factors are primarily implemented locally. Unlike with climate change mitigation measures, their costs and benefits are primarily local.

Figure 2. Classification of climate risk reduction and management methods.

8 An adaptation of original figure by Pilli-Sihvola et al., 2016 http://tietokayttoon.fi/julkaisu?pubid=15404 (in Finnish)
9 Safaie et al., 2017 http://www.unisdr.org/we/inform/publications/52828
10 Pilli-Sihvola et al., 2016 http://tietokayttoon.fi/julkaisu?pubid=15404 (in Finnish)
11 City of Helsinki .2017 https://www.hel.fi/helsinki/en/administration/strategy/strategy/city-strategy/

4 Helsinki's most significant climate risks are related to floods and winter conditions



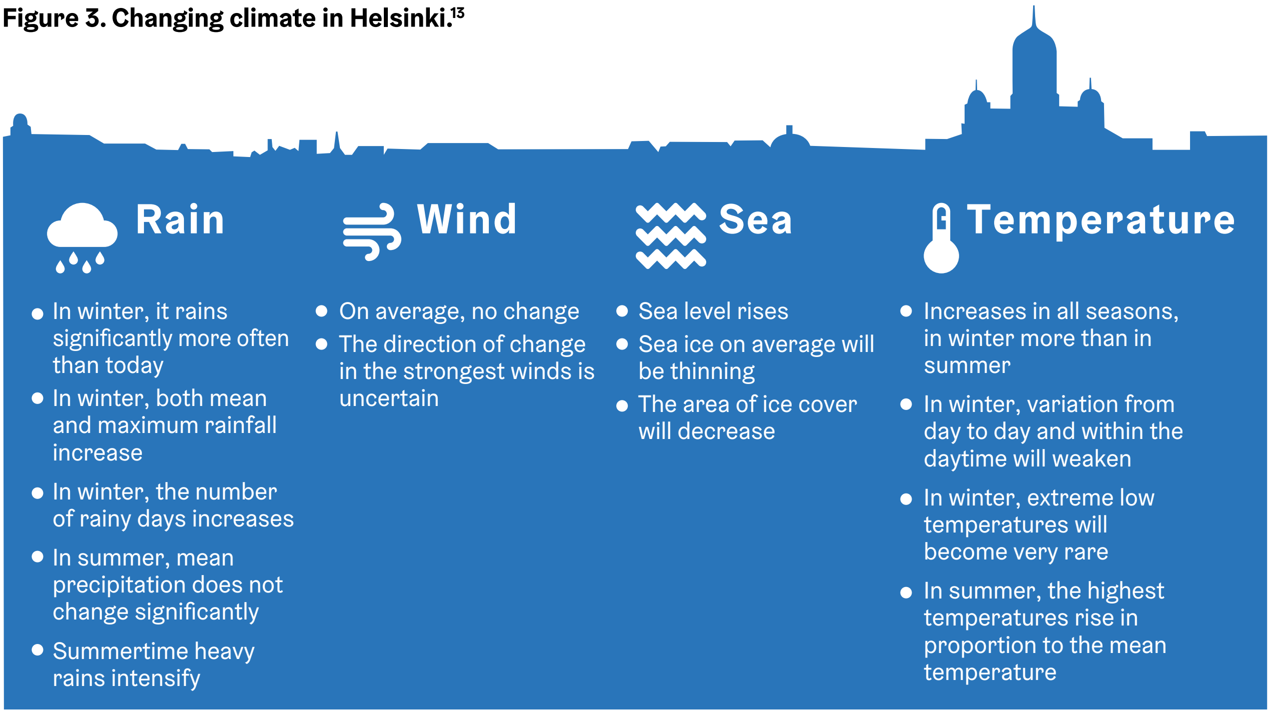
Helsinki's most significant climatic hazards posing a risk are probably floods and extreme winter conditions[12]. This report discusses all of the hazards listed in the so-called cCR listing (Carbonn Climate Registry) of the Compact of Mayors climate commitment (original listing provided in Appendix 3) that are relevant in Helsinki based on an expert assessment. The hazards have been combined into appropriate categories. The significance of the hazards in Helsinki was discussed and assessed at a workshop (Participants' list in Appendix 1). Prioritising the risks caused by different hazards quantitatively would require analyses of the probabilities and potential impacts of different weather phenomena that go into greater depth than was possible in this report. The methods used in the assessement are listed in Appendix 2.

Future climatic changes in Helsinki are compiled into Figure 3.

Helsinki has allocated plenty of resources to assessing sea floods and their risks since a flood that occurred in 2005. Storm water floods became another focus area some time later. Helsinki has already prepared for coastal floods by building floodbanks, but preparing for storm water floods is more complex. Floods were raised among the most significant hazards at the workshop as well, and they are discussed first in the report.

Due to its location, Helsinki will remain a wintry city even when the climate changes. Money is budgeted every year for the winter maintenance of roads and pedestrian and bicycle lanes, snow storms cause accidents and slow down traffic, and winter depression (Seasonal affective disorder) reduces people's well-being. Extreme winter conditions were also brought up at the workshop among the most significant hazards.

Figure 3. Changing climate in Helsinki.[13]



[12] The listing is based on the cCR monitoring listing of the Compact of Mayors agreement, which the cities that have signed the agreement report annually: http://carbonn.org
[13] Mäkelä et al., 2016 http://hdl.handle.net/10138/170155 (in Finnish)

In addition to floods and extreme winter conditions, **the report discusses risks caused by high and low temperatures, as well as strong winds and storms**. The risk caused by heat waves increasing due to rising temperatures has recently received attention globally, and at the workshop, it was considered an interesting, yet lesser known, topic.

The ecological impacts can become substantial, as in addition to individual species, climate change affects the functioning of entire ecosystems. As the climate changes, some species adapt, but others do not. Especially sensitive species that have adapted to a certain habitat and species with a poor migration capacity are in danger of disappearing, at least locally.

Transboundary impacts, i.e. impact chains originating from weather and climate variability and change occurring elsewhere and extending to Helsinki, are not in the cCr listing. However, they were brought up at the workshop, with climate-induced human migration mentioned as an example. Transboundary impacts are discussed at the end of the report.

The mean temperatures are expected to rise in Helsinki by 2.3–3.4 °C by 2050 depending on the climate scenario, i.e. the development of greenhouse gas emissions. The mean of 1971–2000 is used as the reference point (Figure 4)[14]. In 2030, the temperature will be 2 °C higher on average when compared to 1971–2000. It is important to note that the temperature increase in Finland will be higher than the global mean. This is caused by, for example, decreasing amounts of snow and ice in the Arctic region. The temperature increase caused by climate change is often depicted in comparison with the past climate, e.g. the pre-industrial era (as is the case in the Paris climate

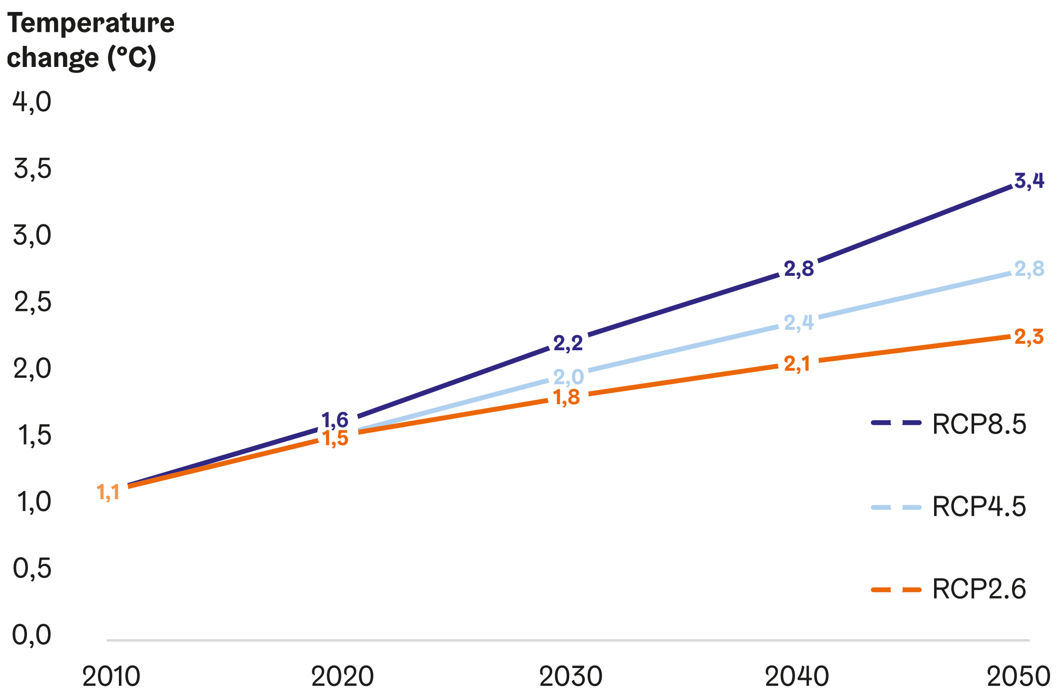


Figure 4. Change in Helsinki's mean temperature by 2050 compared to the period of 1971–2000 in accordance with different climate scenarios. The RCP8.5 scenario represents major greenhouse gas emissions, RCP4.5 represents emissions complying with moderately successful climate policies, and RCP2.6 represents very minor emissions.
Image: Finnish Meteorological Institute

[14] Mäkelä et al., 2016 http://hdl.handle.net/10138/17015 (in Finnish)

change agreement) or virtually any period that is meaningful from the climate perspective, i.e. is long enough (usually 30 years). In Finland, usually a climatic reference period of 30 years is used.

In Helsinki, winter is the season chaning the most by climate change. In winter, temperatures rise the most, precipitation and cloudiness increase and a growing proportion of the precipitation occurs in the form of water. For example, January and February will be approximately two degrees warmer in 2050 than in 1971–2000, and the March mean temperature will rise above zero. Winters in Helsinki will become darker and more humid, extremely cold periods will become rarer and the thickness and area of the sea ice over the Gulf of Finland will diminish. However, in certain weather conditions, the open sea can produce heavy snowfalls near the coast, which can be detrimental to traffic in particular[15].

While the lowest temperatures will become rarer, high summertime temperatures will become more common at the same rate as the mean temperature. As such, in the middle of the current century, 32 °C temperatures would be approximately as common as 30 °C temperatures in the late 20th century (provided that emissions follow the RCP4.5 scenario, i.e. the Paris climate change agreement is implemented moderately)[16]. Heat waves with significant health effects have occurred in Helsinki in the 21st century in 2003, 2010 and 2014.

The average changes in Helsinki's precipitation amounts are presented in Figure 5. In 2050, precipitation will occur increasingly in the form of water, but snowfall situations will not disappear. The mean precipitation amount will increase by 6.9–11% compared to 1971–2000. It should be noted that the variation from year to year will remain as high as in the current climate.

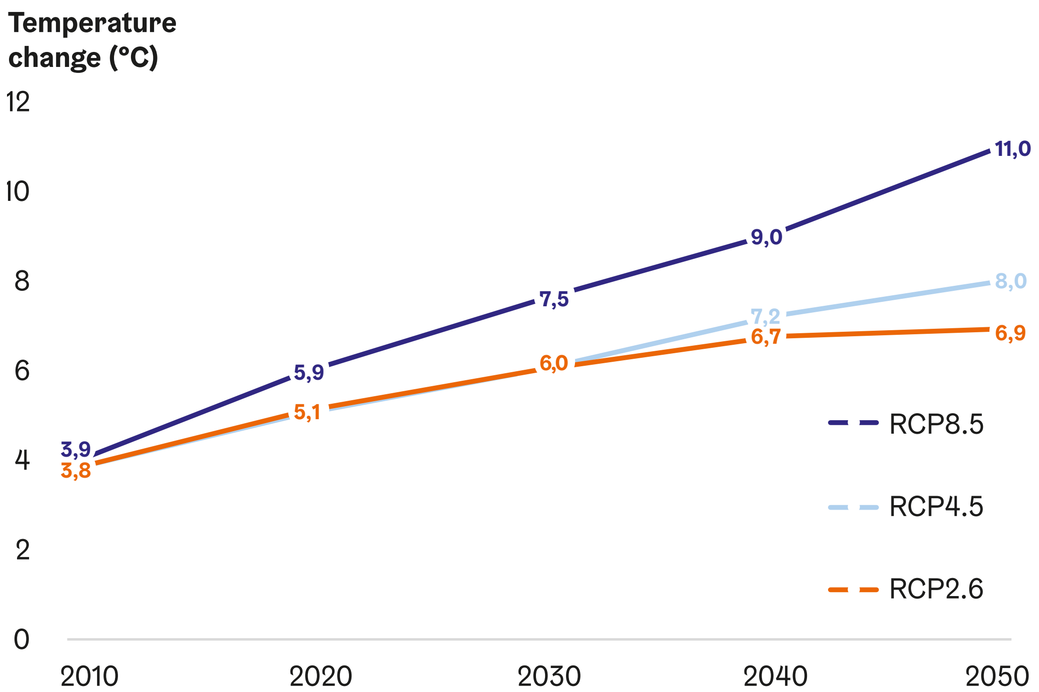
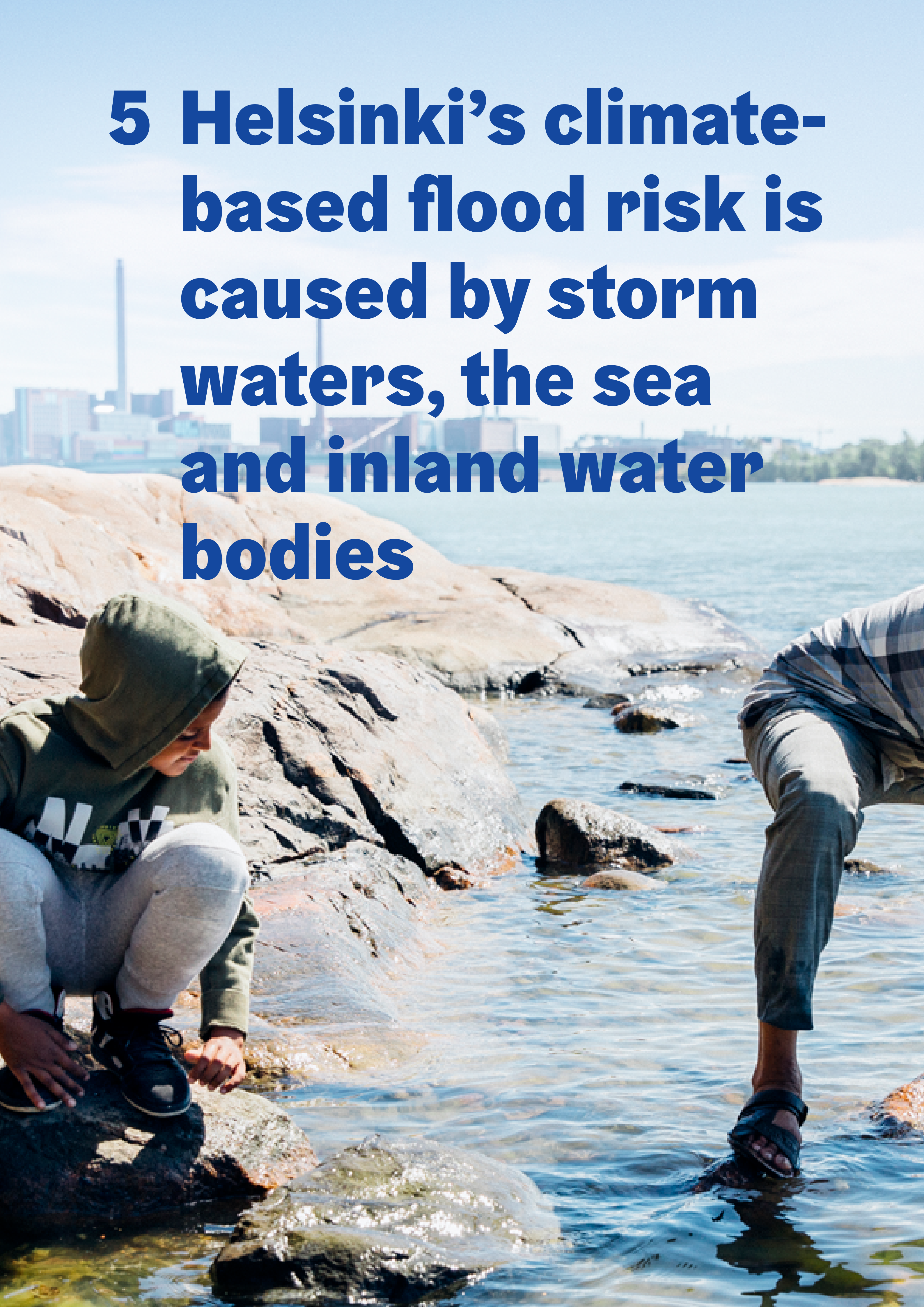


Figure 5. Change in Helsinki's mean precipitation by 2050 compared to the period of 1971–2000 in accordance with different climate scenarios. The RCP8.5 scenario represents major greenhouse gas emissions, RCP4.5 represents emissions complying with moderately successful climate policies, and RCP2.6 represents very minor emissions. Image: Finnish Meteorological Institute

[15] Mäkelä et al., 2016 http://hdl.handle.net/10138/17015 (in Finnish)
[16] Ruosteenoja et al., 2016 http://www.geophysica.fi/pdf/geophysica_2016_51_1-2_017_ruosteenoja.pdf

5 Helsinki's climate-based flood risk is caused by storm waters, the sea and inland water bodies



In Helsinki, three climate-based flood types cause a risk: storm water, sea and river floods. The City of Helsinki has made great efforts to manage the flood risk in the city. The 2005 sea flood led to the development of flood strategy[17]. Futhermore, an investigation was made, based on which flood protection measures were carried out in risk locations. Helsinki has several storm water management pilot locations, such as city districts of Eko Viikki and Kuninkaantammi.

However, the flood risk continues to exist in Helsinki, and due to increasing torrential rains and a denser urban structure, the storm water flood risk in Helsinki is likely to increase. In accordance with the Water Services Act[18], storm water refers to rainwater or melt water accumulating on the ground surface, building roofs or other surfaces. Storm waters cause floods if they temporarily accumulate on the ground surface for one reason or another (Flood Risk Management Act[19] Section 2(1)). As the city grows denser, its impermeable surface area increases, meaning that more attention must be paid to storm water management.

5.1 Storm water floods in Helsinki are caused primarily by torrential rains

The Flood Risk Management Act (620/2010) provides that municipalities must carry out preliminary storm water flood risk assessements and identify significant storm water flood risk areas [20]. According to the Act, the first assessment was to be carried out in 2011. In the second round, the assessments are to be reviewed by 22 December 2018. When assessing the significance of a flood risk, the likelihood of a flood event and the following adverse consequences from the general

[17] Valkeapää et al., 2008 https://www.hel.fi/hel2/ksv/julkaisut/yos_2010-1.pdf (in Finnish)
[18] Water Services Act 119/2001 https://www.finlex.fi/en/laki/kaannokset/2001/en20010119
[19] Flood Risk Management Act 620/2010 https://www.finlex.fi/en/laki/kaannokset/2010/en20100620
[20] Flood Risk Management Act 620/2010 https://www.finlex.fi/en/laki/kaannokset/2010/en20100620

perspective caused by the flood are to be taken into consideration (Flood Risk Management Act, Section 8):

1) adverse consequence to human health or safety;

2) long-term interruption of indispensable services, such as water management, energy management, telecommunications, road traffic or other similar functions;

3) long-term interruption of economic activities which ensure vital societal functions;

4) long-term or extensive adverse consequence to the environment; or

5) irreparable adverse consequence to cultural heritage.

Additionally, regional and local conditions are to be taken into consideration when assessing the significance of flood risk.

The City of Helsinki assessed its significant storm water flood risk areas in late 2011. The storm water flood information for the report was collected from different databases and through an online survey. Based on the various materials, a total of approximately 240 flood locations were identified, approximately 170 of which were in clearly separate areas. Furthermore, more than 50 new storm water flood locations were identified based on people's feedback.

Based on the 2011 report, none of the storm water flood locations exceeded the significance threshold prescribed in the Flood Risk Management Act.[21] However, based on the assessment it was concluded that Helsinki has many storm water flood prone areas in which potential storm water floods could cause substantial damage to the City's operations or property. An updated storm water flood report was completed in 2018.

5.1.1 Long-term torrential rains cause the most damage

Torrential rains that cause flooding occur in Finland mostly from spring to autumn. The Finnish Meteorological Institute's rain warnings feature three hazard levels for both short and long-term rains:

- A a short-term torrential rain warning is issued in accordance with the following hazard levels:
- 20 mm per hour (yellow)
- 30 mm per hour (orange)
- 45 mm per hour (red).
- A a long-term heavy rain warning is issued in accordance with the following hazard levels:
- 50 mm per day (yellow)
- 70 mm per day (orange)
- 120 mm per day (red).

The Flood Centre[22] warns the general public of torrential rains in the Uusimaa region a few times a year. A rain warning was issued for the Uusimaa region in five different situations in 2015, ten in 2016 and three in 2017.

From the climate perspective, the damage caused by torrential rains depends on overall rain amounts and over what period of time the rain occurs, i.e. the intensity of the rain. If it rains heavily and for a long time, the flood damage risk increases. The rarity of rain events with different intensity levels is depicted with their frequency, i.e. the statistical average of how many years pass between events. The annual probability of a phenomenon that occurs once a century is 1%. The torrential rain climate of the Helsinki metropolitan area is illustrated in Figure 7, which presents the intensity and local frequency of short-term rains in Finland. The image can be applied to estimating the probability of torrential rain occurring at one point. Frequencies of at least 30 years are *exceptional*. A tool based on the image, entitled 'Intensity and frequency of short-duration rainfall in Finland' can be found on the Climate Guide website at http://ilmasto-opas.fi/en/ilmastonmuutos/videot-ja-visualisoinnit/-/artikkeli/b4df9633-7e1f-4389-9dd0-a0539588f211/visualisoinnit.html#rankkasateiden-toistuvuus

In Finland, the highest recorded 60-minute rainfall amount is 59.3 mm, recorded in city of Oulu, Oulunsalo weather station on 18 July 2014. 50 mm of the rain fell over a period of 30 minutes. **In Helsinki, the highest recorded 60-minute rainfall amount is 39.5 mm, recorded at the Kaisaniemi park weather station on 22 August 2011. At Helsinki-Vantaa Airport, which is more representative of northern Helsinki, 27.2 mm of rainfall in 60 minutes was recorded on 14 August 2016.** According to the calculator tool, the frequency of such heavy rains is lower than once every 100 years. By the middle of the century, the probability of a corresponding event is approximately once every 60–70 years[23]. However, the statistics are based on a fairly short time series. A few individual stations already had short-term rainfall measurements in early 2000s, but most stations began their measurements around 2006–2008.

Intensity and frequency of short-duration rainfall in Finland

The intensity and local frequency (recurrence interval) of short-duration summer rainfall in Finland is represented in the following graph. The graph can be applied to estimate the probability of heavy rainfall event in a single place. For example, if the rainfall in 15 minutes is 10 mm, the probability for a similar rainfall event in the same place is 25% or, on average, once in every 4 years.

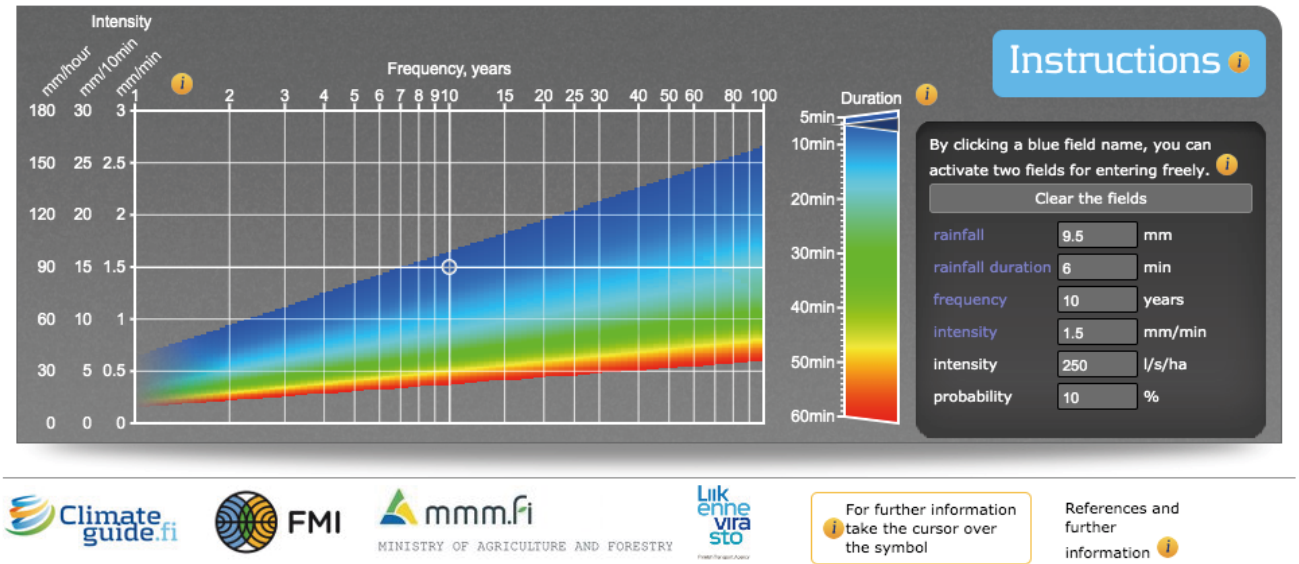


Figure 7. Tool depicting the intensity and frequency of heavy rainfall on the Climate Guide website.

21 Hyöty et al., 2012 https://dev.hel.fi/paatokset/media/att/07/0777e29427a10a61b9c9350fc53132e0965ff257.pdf (in Finnish)
22 The Flood Centre is a joint service provided by the Finnish Meteorological Institute and the Finnish Environment Institute based on close co-operation with Centres for Economic Development, Transport and the Environment and rescue departments. It forecasts and warns of all types of floods and maintains a continuous situational picture related to them: http://ilmatieteenlaitos.fi/tulvakeskus (in Finnish)
23 Mäkelä et al, 2016 http://hdl.handle.net/10138/170155 (in Finnish)

5.1.2 Climate change intensifies torrential rains

On the one hand, climate change is not expected to significantly affect the mean precipitation in summer. The direction of the yearly mean change is somewhat uncertain, but the most likely scenario is that the precipitation amounts will increase somewhat. **On the other hand, torrential rains are estimated to intensify by 7–11% by 2050 (compared to 1971–2000).** However, due to the great fluctuations and random nature of precipitation amounts, depictions of even the current climate are marred by inaccuracies. Future estimates are even more uncertain, as the climate models have problems with covering short, intense rain events lasting less than one day. However, it is important to note that as the atmosphere grows warmer, it is able to contain more water vapour, whereby in certain weather situations, a single torrential rain event may produce a greater accumulation of precipitation.

Additionally, the torrential rain frequencies will change. Torrential rains that occur approximately once every hundred years in the current climate will occur approximately once every 60–70 years by the middle of the century and once every 30 years at the end of the century[24].

5.1.3 The storm water flood risk pertains especially in the city centre

The storm water flood risk depends on many other factors than rain intensity and duration. The first phase of determining the storm water flood risk is calculating flood hazard maps. Flood hazard maps present areas that will remain under water, as well as the water level and depth during a flood taken into account the local conditions and rain probabilities appropriate for examining storm water floods (Government Decree on Flood Risk Management[25] Section 2). **The next phase is creating actual risk maps.** The risk maps take the locations' vulnerability and critical areas into consideration. These include but are not limited to the number of residents; energy production, transmission and distribution systems; and water management, as well as road infrastructure, significant economic activities, sites contaminating the environment, nature reserves and cultural heritage sites.[26] More information about calculating the storm water flood risk is provided in the Finnish Environment Institute's materials.[27]

In Helsinki, the probability of a torrential rain flood causing major damage is at its highest in the city centre. The area has less permeable surfaces, such as parks and other forms of urban green space, than other parts of the city, and its building density is the highest (Figure 8).

The exposure of the city centre to the flood risk is also discussed in the Analysis of social vulnerability to climate change in the Helsinki metropolitan area (HSY 2015)[28], in which the small amount of green areas translates to a high exposure rate (Figure 9).

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24 Mäkelä et al., 2016 http://hdl.handle.net/10138/170155
25 Coundcil of State Decree on Flood Risk Management 659/2010 http://www.finlex.fi/fi/laki/alkup/2010/20100659 (in Finnish)
26 Parjanne, 6.10.2017 http://www.ymparisto.fi/download/noname/%7B372C52CE-74C8-41D8-93F8-C81AB590C633%7D/131445 (in Finnish)
27 Suomen ympäristökeskus SYKE. 16.10.2017 http://www.ymparisto.fi/fi-FI/Vesi/Tulviin_varautuminen/Tulvariskien_hallinta/Tulvariskien_hallinnan_suunnittelu/Tulvariskien_alustava_arviointi_2_suunni(44789) (in Finnish)
28 Kazmierczak, 2016 https://www.hsy.fi/sites/Esitteet/EsitteetKatalogi/Raportit/Social-vulnerability-to-climate-change-Helsinki-metropolitan-area_2.pdf
29 Kazmierczak, 2016 https://www.hsy.fi/sites/Esitteet/EsitteetKatalogi/Raportit/Social-vulnerability-to-climate-change-Helsinki-metropolitan-area_2.pdf

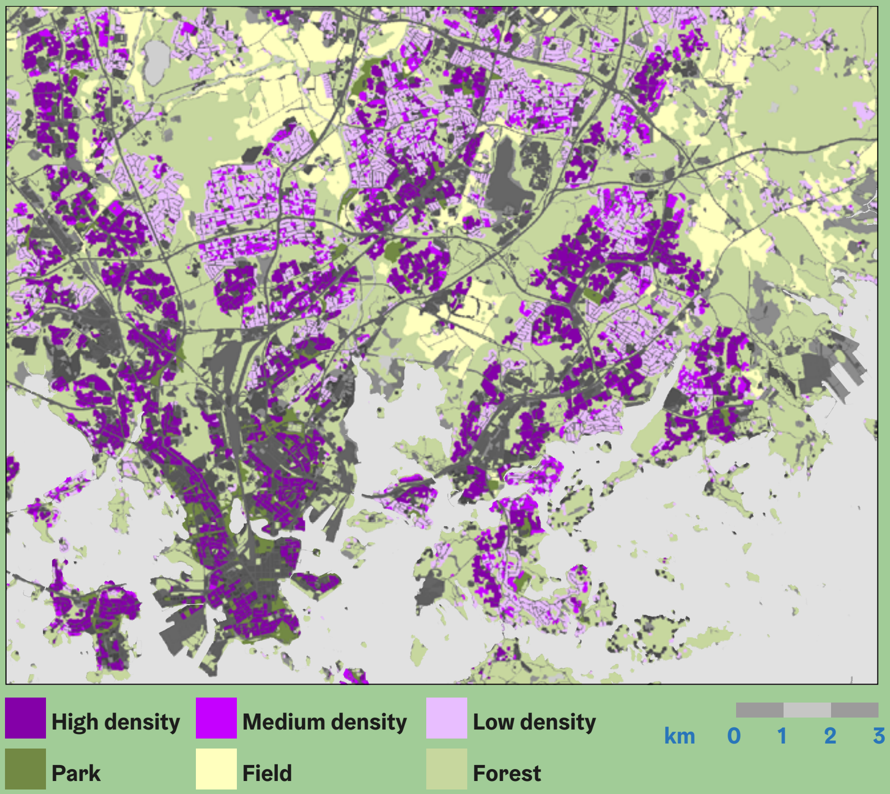

Figure 8. The map depicts Helsinki's building density and urban green locations. High density (dark purple colour) indicates an apartment building area, average density (bright purple) indicates an area of terraced houses and semi-detached houses, while low density (light purple) indicates detached houses. The map also indicates parks (dark green), open meadows (yellow) and forests (light green). Materials: National Land Survey of Finland. Map: Athanasios Votsis.

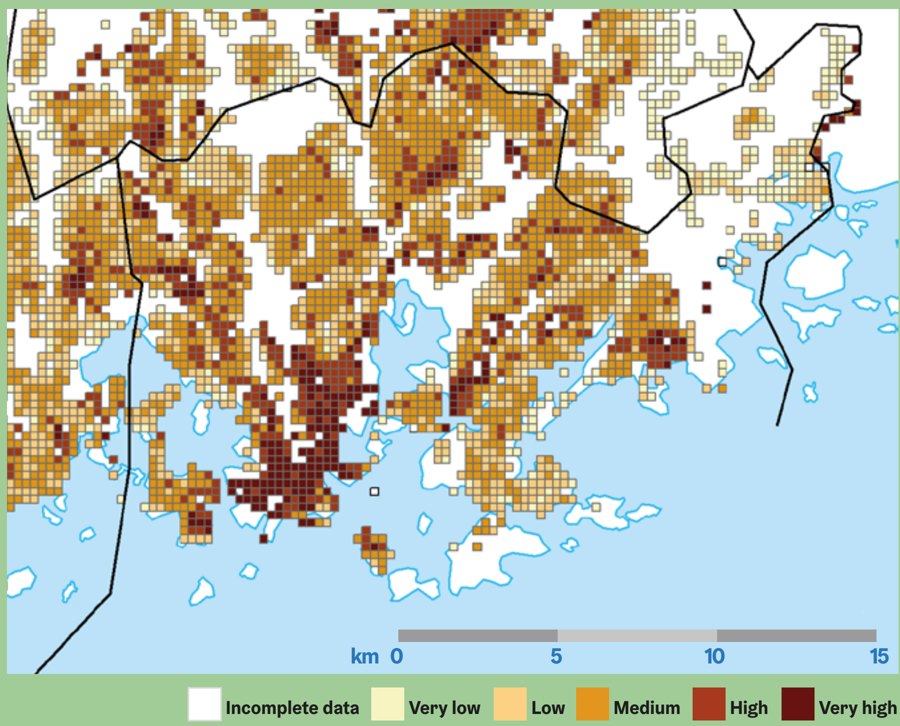

Figure 9. Enhanced exposure to floods in Helsinki.[29] The dark colours indicate a high exposure rate, while light colour indicate a low exposure rate. White indicates that not enough data was available for the assessment.

Based on the indicator value calculated into the City Biodiversity Index (CBI), the amount of permeable surfaces in Helsinki is moderate. The amount of permeable surfaces is described on a scale of 1–4, in which the city is given 0 points if permeable surfaces make up less than 33.1% of the overall surface area. The scale continues as follows: 1 point: 33.1–39.7%; 2 points: 39.8–64.2%; 3 points: 64.3–75.0% and 4 points: >75.0%. **Helsinki's score was 2.** The map in Figure 10 depicts Helsinki's permeable surfaces based on materials from 2014[30], which were used to calculate Helsinki's CBI for the first time. The results were updated internally in 2016, and the result is largely consistent with the situation depicted on the map. The City aims to update the indicator every two years. The proportion of permeable surfaces could be used as additional material for example in the exposure assessment presented in Figure 8.

The properties in the city centre are exposed to storm water floods that can cause significant financial damage. The city centre features several sites covered by the cultural property listing of the Hague Convention[32], as well as many other culturally and historically valuable properties. It also features plenty of the City's own properties and other economic activities. Storm water

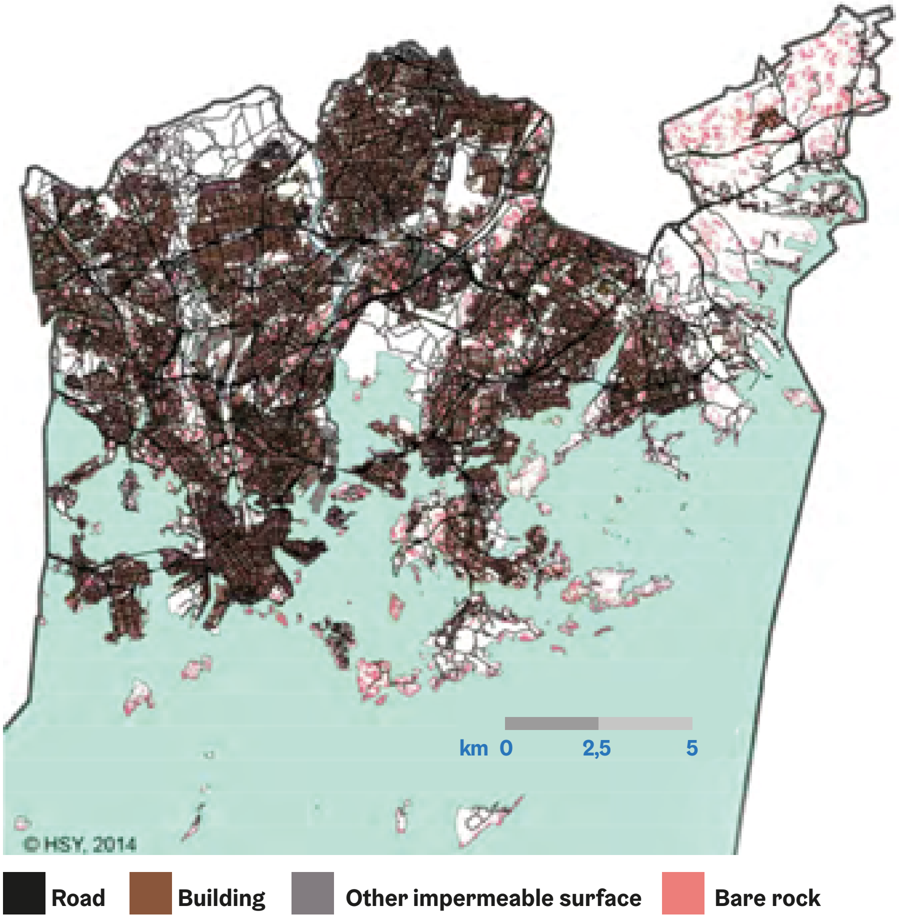

Figure 10. Map of Helsinki's permeable and impermeable surfaces. The white areas on the map indicate permeable surfaces, while the other colours indicate impermeable surfaces. (Image: Niina Salojärvi 2015)[31]

30 Heikkinen 2/2015 https://www.hel.fi/static/ymk/indikaattorit/cbi-pinnat.pdf (in Finnish)
31 Heikkinen 2/2015 https://www.hel.fi/static/ymk/indikaattorit/cbi-pinnat.pdf
32 The Hague Convention from 1954 is a humanitarian convention under UNESCO that aims to protect cultural property under conditions of armed conflict. The Hague inventory list is an official report that is intended primarily to be used by authorities for preparedness planning concerning exceptional conditions and risk management under normal conditions: Finnish heritage Agency https://www.museovirasto.fi/en/about-us/international-activities
36 Kazmierczak, 2016 https://www.hsy.fi/sites/Esitteet/EsitteetKatalogi/Raportit/Social-vulnerability-to-climate-change-Helsinki-metropolitan-area_2.pdf

floods will also make commuting more difficult, and offices may have to be closed temporarily. The direct economic impacts of floods are relatively easy to estimate, but estimating the overall economic effects is more difficult.

When assessing the storm water flood risk, sites that are critical to infrastructure and societal functionality must be taken into consideration. The city centre features plenty of electricity, water and heat production, distribution and transmission systems, some of which are in underground facilities and thus particularly exposed to flood waters. Sites that are critical to healthcare include healthcare centres and hospitals, and the continuity of rescue operations during a flood situation is important in reducing the danger to people. However, rescue operations in the city are likely to become more difficult if the streets are heavily flooded. The Erottaja and Kallio rescue stations in Helsinki are probably safe from flood waters, as they are both located on hill tops. The city centre also serves as a traffic hub, and the train and bus stations, as well as the metro system, are exposed to storm water floods. Furthermore, the administration of the City and the state adminsitration of Finland are located mainly in the city centre, and their operations can also be disrupted during heavy floods. Special attention should be paid to protecting critical sites from floods wherever allowed by the City's resources. However, many of the sites are obligated to carry out preparatory measures themselves.

The detailed storm water flood risk assessment must consider underground facilities and functions, such as public transport, energy management and civil protection. One of Helsinki's special characteristics is an extensive underground city that serves as the location of many functions and especially various critical public transport, energy management and civil protection infrastructure. Helsinki's first underground

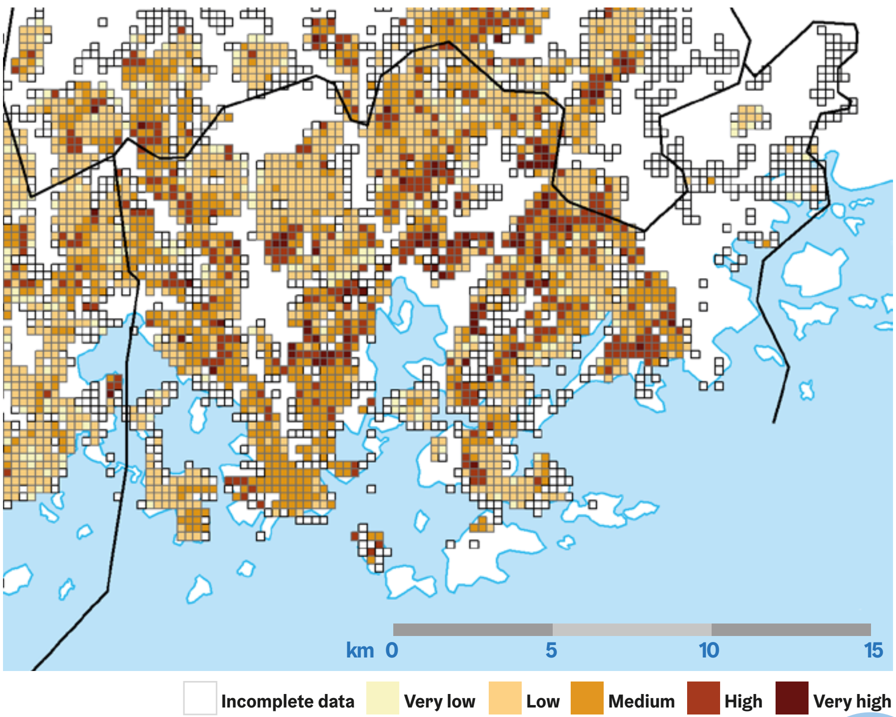

Figure 11. Helsinki's social vulnerability to floods.[36] The dark colours indicate high vulnerability, while the light colours indicate low vulnerability. White indicates that not enough data was available for the assessment.

master plan entered into force in 2011[33], and preparatory work for a new underground master plan began in 2017. The first underground master plan involved a general safety report[34], in which the flood risk caused by natural events (as opposed to a water pipe breakage) was considered, but not assessed systematically. A potential flood was assessed to affect underground fire and rescue safety, as well as risks related to public utilities during operation.

Although the city centre is most exposed to storm water floods, a Helsinki metropolitan area level analysis indicates that social vulnerability is at its highest in city districts of southern Vuosaari, western Herttoniemi, Roihuvuori, Viikki, Vallila/eastern Pasila, Maunula-Suursuo and northern Meilahti (Figure 11). In the analysis, *social vulnerability* refers to a combination of sensitivity, enhanced exposure and adaptive capacity: "Adaptive capacity refers to the ability of people to prepare for, respond to and recover after flooding or heat wave, related mainly to their social and material situation. Enhanced exposure refers to the aspects of the physical environment, such as housing and presence of permeable surfaces, as well as the amount and quality of green areas in the living environment."[35]

The social vulnerability analysis is based on the following indicators:

- Location within one kilometre from the railway station
- Accessibility zone
- Percentage of households without a car
- Accessibility in an emergency situation
- Percentage of people who have completed basic education
- Percentage of children aged 6 or younger
- Percentage of elderly people aged over 75
- Percentage of unemployed labour force members
- Percentage of economically inactive people in the population
- Percentage of long-term unemployed labour force members
- Median income of households
- Occupancy rate
- Percentage of households with more than 7 people
- Percentage of students
- Percentage of single-person households
- Percentage school-aged children account for of the population
- Percentage of households with leased housing
- Percentage of dwellings leased from Housing Finance and Development Centre of Finland ARA
- Percentage of total green space in land area

[33] ilaakso et al., 17.12.2009 https://www.hel.fi/hel2/ksv/Aineistot/maanalainen/Maanalaisen_yleiskaavan_selostus.pdf (in Finnish)
[34] Kivilaakso et al. 2006 https://www.hel.fi/hel2/ksv/Aineistot/maanalainen/Maanalaisten_toimintojen_yleinen_turvallisuusselvitys.pdf (in Finnish)
[35] Kazmierczak, 2016 https://www.hsy.fi/sites/Esitteet/EsitteetKatalogi/Raportit/Social-vulnerability-to-climate-change-Helsinki-metropolitan-area_2.pdf

In addition to these indicators, flood insurance for housing companies and residents, its availability and coverage in a flood situation, should be taken into consideration when examining social vulnerability. In areas with the highest vulnerability to floods, most dwellings are located in apartment buildings (Table 1).

Residential area in Helsinki	Proportion of apartment buildings 2015
00270 northern Meilahti	*99*
00630 Maunula-Suursuo	*87*
00510 Etu-Vallila – Alppila	*99*
00520 eastern Pasila	*100*
00790 Viikki	*91*
00820 Roihuvuori	*100*
00800 western Herttoniemi	*89*
00980 southern Vuosaari	*87*

Table 1. Proportion of apartment buildings in Helsinki's residential areas with the highest social vulnerability to floods.

In apartment buildings, the housing company plays a major role in covering damage. In the case of rental apartment buildings, the role falls upon apartment building owners and their insurance policies. However, insurance coverage policies in a flood situation must be examined carefully. Usually, insurance policies only cover damage in *exceptional* flood situations, which are defined in the insurance terms[38].

The increasing density of the urban structure and the resulting increase in impermeable surfaces is a significant factor increasing the storm water flood risk in Helsinki. Such surfaces are created when buildings are built and areas are paved. At the City of Helsinki's expert workshop, several factors were assessed as affecting the formation of the storm water flood risk and its impacts. Additionally, City's Environmental Services have assessed the inclusion of climate change adaptation in Helsinki's urban planning[39]. The publication also features an assessment of barriers to storm water management, the most significant of which is the **lack of integrated**

[37] Statistics Finland
http://pxnet2.stat.fi/PXWeb/pxweb/fi/Postinumeroalueittainen_avoin_tieto/Postinumeroalueittainen_avoin_tieto__2017/paavo_6_ra_2017.px/?rxid=053ff272-26c0-467d-8071-622c786f660d (in Finnish)
[38] Suomen ympäristökeskus SYKE, 20.10.2017
http://www.ymparisto.fi/fi-FI/Vesi/Tulviin_varautuminen/Tulvariskien_hallinta/
[39] Haapala, 2017 https://www.hel.fi/static/ymk/julkaisut/julkaisu-03-17.pdf (in Finnish)

storm water management in urban planning. Based on this publication and the risk analysis work, the following factors were assessed as affecting the lack of integrated management:

1. Sewer pipes are already dimensioned carefully in the current situation. However, in old built areas, storm water management in areas such as courtyards can be inadequate, as they are often paved, and the storm water systems can be undersized. Additionally, properties' maintenance resources can be undersized, increasing the flood risk. The growing storm water flood risk must also be taken into consideration in complementary construction.

2. However, the use of alternative storm water management methods, i.e. green structures infiltrating storm water, is currently insufficient. Permeable surfaces can be used in the city to significantly reduce the storm water flood risk.

3. In the planning phase of new residential areas, storm water examinations are only carried out in a few cases (e.g. Kuninkaantammi). If carried out, the entire area should be examined as a whole instead of one block area. In many areas flood routes are currently planned inadequately, thus storm waters are not removed from the area in a controlled manner.

4. Storm water management is for the most part already a routine part of any larger-scale planning projects. However, the planning process does not yet feature clear provisions or policies for integrating climate change adaptation and storm water management into the plans (except for the method selection of the City Planning Department's environmental programme[40]). In many cases, the planning of adaptation and storm water management can depend largely on the planner. However, there has been improvement in planning co-operation in recent years. One planner brought up the problem that storm water dimensioning calculations are difficult to carry out when all the plans for the area, such as the yard plan, are not yet known at the time of planning.[41]

5. Helsinki lacks jointly agreed clear implementation timeframes, implementer or budget for storm water management.

6. In flood situations, the capacity of the sewer pipes is also affected by temporary problems that can be structural in some cases. If the storm water pipes are clogged during a torrential rain by tree leaves, for example, the amount of storm water accumulating on the streets increases considerably. Potential procedures must be prepared for in advance in case of major torrential rain situations. Another risk factor during the situation can be the preparedness level of the rescue and healthcare services if the situation has not been anticipated or there are no resources to be used during the situation. This is probably not a problem currently, but resourcing must be taken care of in case of highly exceptional situations.

7. Adverse impacts are created when contaminated storm waters are conveyed into water bodies and the Gulf of Finland without purification.

5.1.4 Storm waters already cause damage in the current climate

Helsinki has not yet suffered any storm water floods causing major damage, such as those in Pori in 2008, in Copenhagen in 2011 and 2014 and in Malmö in 2014. In Pori, the costs amounted to more than 20 million euros. However, torrential rains have caused basements to be flooded and contaminated waters to be sluiced at the water treatment plant.

5.1.5 The storm water risk increases as the climate changes

The Act provides that preliminary flood risk assessments are to be carried out based on floods that have occurred, by taking long-term climate change into consideration and based on available information concerning the development of the water conditions. As regards potential future storm water floods, the Act requests that risk assessments be based on a storm water flood caused by a torrential rain that is based on historical observations and recurs approximately once a century. The Climate Guide web tool indicates that the hourly precipitation amount of such a torrential rain is currently approximately 36.6 mm.

Even though the study carried out in 2011 indicates that Helsinki does not have significant storm water flood risk areas, there have been examples in which exceptional torrential rains have caused sizeable damage in locations in other Nordic countries, such as Copenhagen:

In the evening of 2 June 2011, torrential rain occurring in the Copenhagen city centre caused a sizeable storm water flood and major damage. 90–135 mm of rain fell in less than two hours. The rain was also accompanied by hail and lightning. The financial value of the damage covered by insurance was approximately one billion euros, making the case the most expensive disaster triggered by a natural phenomenon in Europe in 2011. There were approximately 90,000 individual damage cases. The flood was so extensive that it caused significant problems to the infrastructure: for example, Copenhagen University Hospital was flooded and its operations had to be transferred elsewhere, 10,000 households suffered from power outages, 50,000 people's district heating and hot water distribution were disrupted for a week and the communication and computer systems of one prison, the police and the emergency centre were damaged. It was estimated that 70% of the critical IT systems of the City of Copenhagen were close to crashing. The flooding of the emergency centre's machine room caused a risk of the emergency system breaking down completely, but this was avoided and the emergency phone number remained operational throughout the entire situation. The flood water also hindered ambulances. Offices had to be closed and kept closed for several days in some cases. The flood in Copenhagen also had impacts on people's health. The flood did not cause casualties, but five cases of leptospirosis[42] were reported later, one of which was fatal. Workers who were in contact with the rainwater fell ill, the flood water caused traffic accidents and scalding hot steam coming from wells caused burns to nine people.[43]

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40 Helsingin kaupunkisuunnitteluvirasto, 2015 https://www.hel.fi/static/public/hela/Kaupunkisuunnittelulautakunta/Suomi/Paatostiedote/2015/Ksv_2015-10-20_Kslk_23_Pt/6AED9EBF-0056-4ACC-A72F-8458086749D0/Liite.pdf (in Finnish)

41 Haapala, 2017 https://www.hel.fi/static/ymk/julkaisut/julkaisu-03-17.pdf (in Finnish)

42 Leptospirosis is a fever caused by the Leptospira genus of bacteria.

43 The Danish Emergency Management Agency (DEMA), 2013 https://brs.dk/viden/publikationer/Documents/National_Risk_Profile_(NRP)_-_English-language_version.pdf

Although torrential rains like the one in Copenhagen have not yet been recorded in Finland, they are possible in Helsinki already in the current climate. Their annual probability in the current climate is very low, considerably less than 1%, but the probability will increase due to climate change. Copenhagen's example shows that in the city centre of Helsinki, the economic, societal and health-related effects of extreme torrential rains may become very significant. However, the effects in Helsinki cannot be directly estimated based on the case in Copenhagen, as the urban and natural structures (amount of parks and other urban green areas, the dimensioning of the storm water pipes, topography, etc.) are different. The storm water flood risk caused by a corresponding amount of precipitation, however, is considerable in the city centre. However, the storm water flood risk and the spreading of the torrential rains in the city centre requires more detailed modelling than was possible within the framework of this risk assessement.

5.1.6 Reducing the risk of storm water floods requires green areas that retain rain waters and communication

To improve storm water management, the City of Helsinki's Storm Water Management Programme[44] was created in 2017–2018, replacing the Storm Water Strategy approved in 2008[45]. The Storm Water Management Programme features updated storm water management measures and responsibilities (who is responsible for the implementation and costs of the measures). The Programme presents the principles and procedures with which the City's services reduce storm water flood risks in Helsinki. The actions are implemented and developed as part of the City's planning and construction and various related processes. Furthermore, Helsinki will carry out a legally prescribed **storm water flood risk** study in 2018, which will involve identifying Helsinki's storm water flood risk locations and locations sensitive to storm water flooding. The significance of the flood risk locations will be assessed, and if significant flood risk locations are found, separate flood risk management plans will be created for them.

The primary means of storm water management will be the use of infiltration, delaying and retention structures, such as green areas. According to the City Budget 2018, "a significant portion of future storm water processing will take place in green areas, which requires allocating resources to planning green areas and making the implementation and maintenance process clearer and more fluent"[46]. According to a study conducted by the Finnish Meteorological Institute, **the differences between city districts must be taken into consideration when planning urban green areas**. A wrong kind of green area can affect the housing price development in the area. In Helsinki city centre, the value of apartments is increased by close proximity to an urban park. In suburbs, such parks are not as significant in the formation of the apartment prices, but open meadows and forests are.[47]

Structural changes will be made as well. In the most densely built areas, separate sewer systems will be built to reduce the amount of storm waters in the sewer network. The goal of this is to reduce the environmental impacts occurring during torrential rains, because if the combined sewer system capacity is not sufficient, waste

[44] City of Helsinki, 2018 https://www.hel.fi/static/liitteet/kaupunkiymparisto/julkaisut/julkaisut/julkaisu-03-18-en.pdf
[45] Nurmi et al., 2008 https://www.hel.fi/static/hkr/julkaisut/2008/hulevesistrategia_2008_9.pdf (in Finnish)
[46] Helsingin kaupunki, Kaupunginkanslia, 2017 https://www.hel.fi/static/kanslia/Julkaisut/2017/HKI_TA_2018_web.pdf (in Finnish)
[47] Votsis, A. 2017a http://doi.org/10.1016/j.ecolecon.2016.09.029

water will have to be sluiced directly into water bodies without purification. However, the capacity of the current combined sewer network is for the most part greater than that of the potential new separate storm water sewer, which is typically dimensioned for rains occurring once every 3–4 years. Thus, the significance of local storm water solutions, such as infiltration, delaying and retention structures, in storm water management increases.

Storm water assessement should be carried out for new areas in the planning phase. If carried out, the entire area should be examined instead of one block. The flood routes of the areas should be planned carefully, so that storm waters can be removed from the area in a controlled manner. For example, in Copenhagen, water is allowed to rise temporarily on the streets in order to protect other infrastructure. Storm water management plans should also be created for smaller areas, and catchment areas should be examined as wholes.

Due to changes to the Land Use and Building Act and the Water Services Act, the responsibilities for the costs of storm water sewerage will change. In accordance with the Water Services Act, the City of Helsinki will begin to pay a fee to the water management utility for storm water sewerage in public areas. The City of Helsinki and Helsinki Region Environmental Services Authority HSY, which is the water management utility, signed an agreement on storm water sewerage in 2018. The City may choose to charge the properties within its area the costs caused by storm waters.[48]

Helsinki uses the green factor as a planning tool. The factor is the ratio between a plot's weighted green area to total area. The weighted green area consists of the combined weighted areas of various green factor elements (e.g. grass, green roof, planted tree). The element weightings used in the calculations are determined from the perspectives of ecology, functionality, landscaping and maintenance, taking the views of the City's land use experts into consideration[49].

At the workshop organised during this risk assessement process, several storm water flood-related adaptation measures were highlighted, some of which are already in use in Helsinki at some level. In land use planning, green structures are used to increase the amount of permeable surfaces. For example, one of the goals of Helsinki's green roof policy[50] is improved storm water management. Permeable surfaces should also be used and favoured in areas other than dedicated green areas, such as street embankments and parking areas. Special attention should be paid to this in complementary construction.

In the UK, properties' own flood protection with different flood levels has been studied. Techniques for own flood protection, such as quick-install flood walls, have been developed. The impacts can also be reduced by informing the residents of pre-flood actions. This can be done when an early warning of a potentially damaging torrential rain is issued, for example. **The City of Helsinki also plays an important role in risk communications, as it is of utmost importance that the residents and other actors prepare**

[48] Helsingin kaupunki, Kaupunginkanslia, 2017 https://www.hel.fi/static/kanslia/Julkaisut/2017/HKI_TA_2018_web.pdf (in Finnish)
[49] Climate Proof City https://ilmastotyokalut.fi/en/ http://ilmastotyokalut.fi/tyokalut/viherkerroin/
[50] Helsingin kaupunki, 2016 https://dev.hel.fi/paatokset/media/att/08/08ad9d722e708c4e5ff9aeb3a8c291137aeeab6f.pdf (in Finnish)

for exceptional conditions. With the exception of slippery winter conditions and snow storms, weather does not cause significant hazards in Helsinki, so the residents' preparedness for other exceptional situations caused by weather or climate variability is not necessarily at the best possible level. **Therefore, preparedness for storm water floods should be increased and people should be given guidance regarding how to act in a situation in which the basic infrastructure and vital functions are not working.** For communication, Helsinki has for example the Flood Guide distributed to residents[51] and the Helsinki Safety web pages[52], to which information should be added regarding how residents can prepare for exceptional situations caused by weather.

From the Rescue Department's perspective, one procedure is increasing co-operation in predicting extreme weather conditions and utilising early warnings in preparing for situations.

5.2 Climate change increases the sea water and river flood risks

The coast of Helsinki is a significant sea flood risk area

Together with Espoo, the coast of Helsinki is one of Finland's 21 significant flood risk areas that have been determined as required by the EU Floods Directive[53]. A total of 15 flood sites have been defined in the coastal area of Helsinki[54]. Floods on the coast of Finland usually result from the combined impacts of several factors, primarily by strong winds and differences in barometric pressure, changes in the total water amount of the Baltic Sea and the inherent back-and-forth oscillations of the sea level in the Baltic basin. When winds blow in a certain direction in the Danish straits, they can keep the water level of the Baltic Sea higher than the Atlantic ocean for several weeks.

5.2.2 Climate change raises the sea level in Helsinki

With climate change, sea level is affected by the thermal expansion of the oceans and the melting of glaciers. In the current situation, these factors are largely equally significant. In the future, the most significant potential source of sea level rise is the melting of continental glaciers. Furthermore, climate change can affect the total water amount of the Baltic Sea (water exchange through the Danish straits) and thus the water level on the Finnish coast. Besides climate change, the sea level is affected by land uplift and the tides. Depending on the location, the earth's crust is rebounding from its compression during the ice age by approximately 4–10 mm annually, and **in Helsinki, the annual land uplift rate is approximately 4 mm[55]**. Compared to other coastal areas around the world, the tidal range is small on the Finnish coast: the tides change the sea level from a few centimetres to 10–15 centimetres, and the greatest fluctuations are observed at the far ends of bays.

[51] City of Helsinki, 2013 https://www.hel.fi/static/helsinki/julkaisut/Tulvaohje_eng_17062013.pdf
[52] City of Helsinki: Preparedness https://www.hel.fi/turva/en/preparedness/
[53] Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:288:0027:0034:FI:PDF
[54] Jaakonaho et al., 2015 http://www.ymparisto.fi/fi-FI/Vesi/Tulviin_varautuminen/Tulvariskien_hallinta/Tulvariskien_hallinnan_suunnittelu/Tulvariskien_hallintasuunnitelmat/Helsingin_ja_Espoon_rannikkoalueen_tulva%2829184%29 (in Finnsih)
[55] Johansson et al., 2014 https://doi.org/10.1016/j.jmarsys.2012.08.007

Despite the land uplift phenomenon, the average sea level on the coast of Helsinki is likely to rise by tens of centimetres towards the end of the century. This is caused primarily by the thermal expansion of the ocean water and the melting of glaciers. According to current estimates, the mean sea level rise in the Gulf of Finland will be approximately 30 cm in 2000–2100, with the highest estimate being approximately 90 cm (Figure 12). The difference between the mean and highest estimate is caused by the fact that the scenarios extending to the end of the century still have many uncertainties: it is particularly difficult to predict how the Greenland and West Antarctica ice sheets will behave in future climate. Due to land uplift, the mean sea level rise on the coast of Finland will remain smaller than without it.[56]

The increasing sea flood risk in Helsinki can, for example, be illustrated as follows: according to the current estimate, the height of a sea flood occurring on average once a century will be +2.00 m in 2050 and +2.57 m in 2100 in relation to the N2000[57]. To date, the highest sea flood measured in Helsinki is +1.7 m (N2000). The flood occurred in connection with storm Gudrun in 2005. N2000 is a geodetic vertical coordinate reference system bound to the bedrock, the zero level of which in Helsinki is approximately 20 cm below the current mean water level. The flood heights are provided in the N2000 system because its level remains constant in relation to the ground and structures, while the mean water level changes over time.

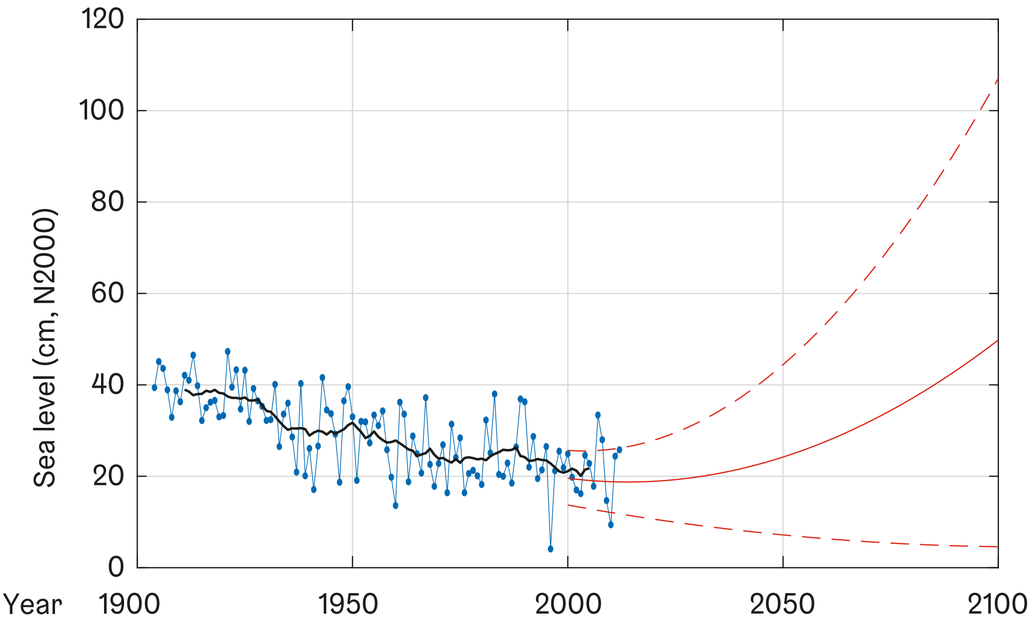


Figure 12. Mean sea water level in Helsinki[58]. The blue line represents the observed annual average water levels, the black line represents the long-term mean calculated based on the observations, and the red lines represent the future average sea level scenario with a 5–95% uncertainty threshold (dashed lines). The scenario was calculated by combining several latest forecasts of the rise in ocean levels (taking regional deviations from the global average into account), land elevation and an estimate of the effect of the changing wind climate on the sea levels on the Finnish coast. The most significant uncertainty has to do with how the West Antarctica continental glacier reacts to the warming of the climate.

[56] Kahma et al., 2014 https://helda.helsinki.fi/handle/10138/135226
[57] Johansson et al. 2014 https://doi.org/10.1016/j.jmarsys.2012.08.007
[58] Kahma et al., 2014 https://helda.helsinki.fi/handle/10138/135226

The difference between land areas flooded in statistically extremely rare and less rare floods occurring on the coast of Helsinki and its inland water bodies is relatively small (Figure 13). However, the height of a flood occurring once every 50 years on average is 50 cm lower than that of a flood with a 1/1000 frequency[59].

5.2.3 The sea water flood in the winter of 2005 flooded the Market Square and cut off roads

In January 2005, Helsinki experienced its most significant sea flood in modern history. Among other places, the flood water rose onto the Market Square, where it was dealt with by pumping water from the sewer network into the sea to prevent it from entering

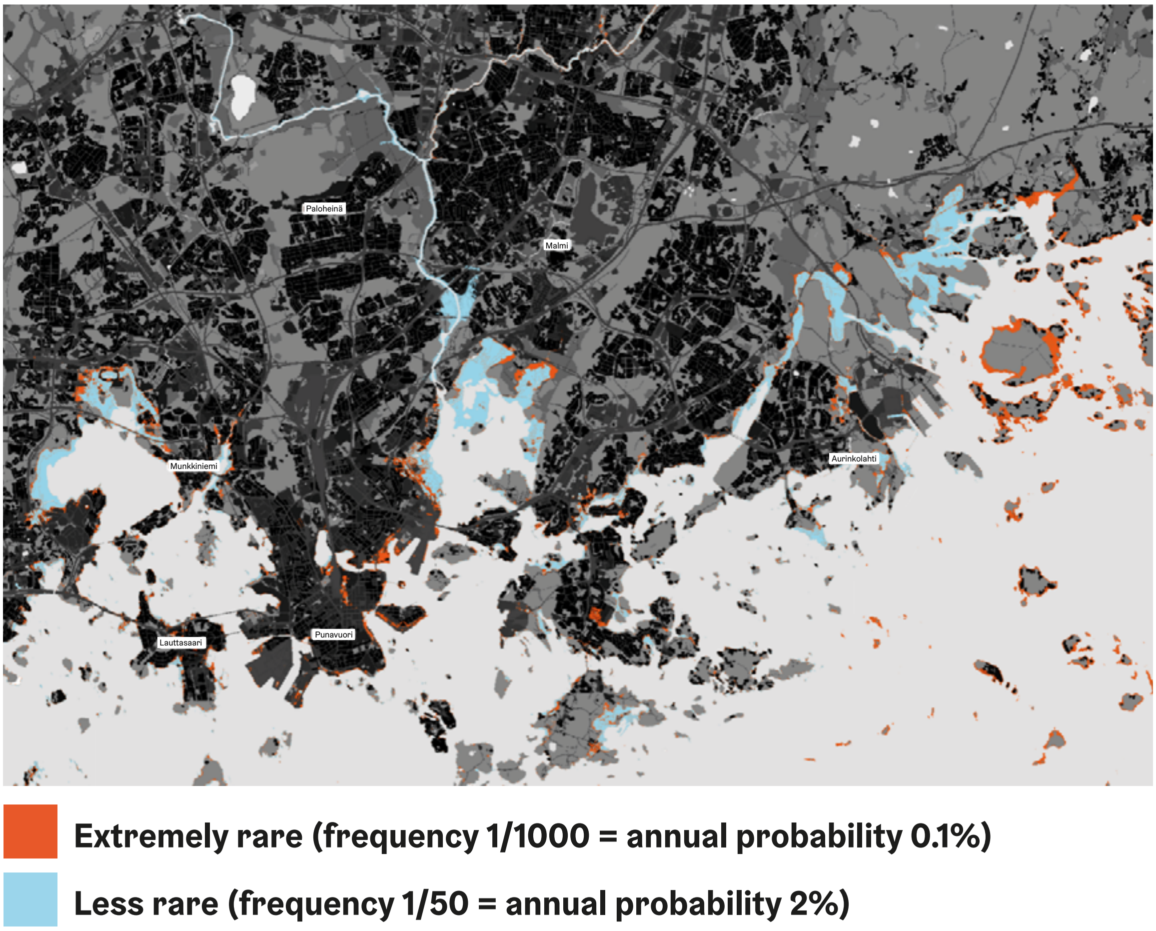


Figure 13. Flood hazard areas for an extremely rare (frequency 1/1000 = annual probability 0.1%) sea and river flood and a less rare (frequency 1/50 = annual probability 2%) flood. (Source: Flood map materials of the Finnish Environment Institute. Map: Athanasios Votsis) The difference between areas of land flooded in floods occurring statistically once every 50 years and once every 1,000 years is relatively small (indicated on the map with red). The flood heights represent floods in the current situation, and they do not take the effects of climate change into account.

59 Kahma et al., 2014 https://helda.helsinki.fi/handle/10138/135226
60 Myrskyvaroitus portaali (Storm alert portal) http://www.myrskyvaroitus.com/ (in Finnish)
61 Vähäkäkelä et al., 2010 http://www.ymparisto.fi/download/Turina_su_Uusimaa_meritulvapdf/d3b7b2d0-6f50-41a6-b0ba-4511bbc09eae/52201 (in Finnish)
62 Helsingin Sanomat, 10.1.2005 https://www.hs.fi/kotimaa/art-2000004279516.html (in Finnish)
63 Hallituksen esitys Eduskunnalle laiksi tulvariskien hallinnasta ja eräiksi siihen liittyviksi laeiksi HE 30/2010 http://www.finlex.fi/fi/esitykset/he/2010/20100030 (in Finnish)
64 Vähäkäkelä et al., 2007 https://www.hel.fi/static/hkr/julkaisut/tulvakohteet/tulvakohteet_esiselvitys.pdf (in Finnish)

basements in the city centre via the sewers. The flood invaded dozens of houses and property basements, cut off several roads and disrupted the Suomenlinna ferry traffic as the piers disappeared underwater. (Myrskyvaroitus storm warning portal[60]). The Kompassitori market square in the Kaivopuisto park was completely flooded, and on street of Ehrenströmintie, cars were floating through water until the street was closed in the early afternoon. Sizeable damage was avoided with the use of temporary flood protection structures. At Sörnäinen Harbour, 400–500 imported cars suffered water damage when the protective embankment made of sand and gravel to protect them broke during the night. On the island of Suomenlinna, the flood caused shore erosion and local landslides.[61] The flood water also cut off traffic in the city area of Pohjoisranta and on the Northern Esplande[62]. Elsewhere in the Helsinki metropolitan area, the flood partially cut off Ring road I in the city district of Otaniemi in the City of Espoo, and the Ring road III and the motorway Itäväylä junction area was also partially cut off. The flood was the highest flood measured on eastern Gulf of Finland, and it has been estimated to have caused a total of approximately 12 million euros worth of damage in Finland[63]. There is no estimate of the economic damage caused to Helsinki.

5.2.4 The sea flood risk area of Helsinki is scarcely populated and the property value is high

The food risk depends on how flood risk areas are planned and built. Helsinki has many old seashore districts, and new seashore districts have also been planned in recent years, such as Arabianranta, with Kalasatama and Jätkäsaari as the most recent examples. According to the flood location definition carried out in 2007[64], the largest unified flood hazard areas are located in the districts of Munkkiniemi, Tammisalo, Laajasalo, Vartiokylä and Vuosaari. The same document identified (in the N2000 vertical coordinate reference system) sea flood risk locations for a +1.10 m and NN +2.00 m sea level rise.

In 2014, the sea flood risk areas of Helsinki were scarcely populated (Table 2). Based on the social vulnerability analysis of HSY in 2015, the sea flood risk areas are not the most socially vulnerable, and not many people who are vulnerable to sea floods were found in the area. Furthermore, the apartments and properties located in the area are well protected against floods.

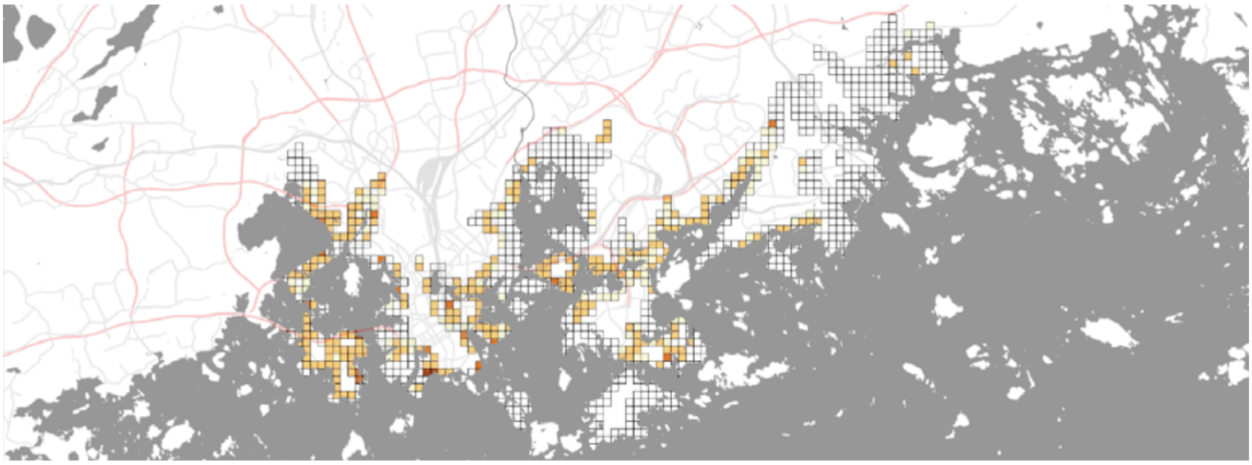
Frequency and annual probability of a flood	Population in the flood risk areas in 2014
1:2 = 50%	***310***
1:5 = 20%	***911***
1:10 = 10%	***1,350***
1:20 = 5%	***1,631***
1:50 = 2%	***2,051***
1:100 = 1%	***2,465***
1:250 = 0.25%	***3,461***
1:1000 = 0.1%	***6,345***

Table 2. Population in Helsinki's sea flood risk areas in 2014.

The value of properties in flood risk areas is an indicator of the economic effects of floods. The average price per square metre of dwellings in the sea flood hazard areas of Helsinki is presented in Figure 14.

The property values are presented more accurately in Table 3.

In a sea flood situation, the risk of economic impacts increases especially if residential buildings have basements below street level and the lowest foundation level is below the safe building elevation. Any crawl spaces under the lowest floor are also susceptible to flood damage. Similarly, if the lowest floors are unsupported, there is a



no housing market observations in 2000-2011

0 - 2.5 | 2.5 - 5.0 | 5.0 - 7.5 | 7.5 - 10.0

Real price of m² (€1000 / m²), mean of 11 years (2000-2011; 2011 pricess)

Figure 14. The long-term (2000–2011) average market price of detached and terraced houses (€1,000/m²) in areas located in a 1/1000 flood risk area. The dark colours indicate higher average dwelling prices and the light colours indicate lower prices. The materials are based on an extensive sample produced by real estate agents (N = 57693) from property purchases. The materials are compiled by the VTT Technical Research Centre of Finland. Map: Athanasios Votsis

Frequency and annual probability of a flood	Value of residential properties per m² (2000–2011 mean) €1,000	Mean total market value of residential properties in 2000–2011 €1,000	Total value of residential property purchases in flood risk areas in 2011 €1,000
1:2 = 50%	3,535	278,223	0
1:5 = 20%	2,670	261,554	1001
1:10 = 10%	2,800	297,074	1001
1:20 = 5%	3,242	483,726	1001
1:50 = 2%	3,453	376,469	3081
1:100 = 1%	3,821	389,001	5047
1:250 = 0.25%	3,864	309,669	8088
1:1000 = 0.1%	3,609	254,448	21968

Table 3. The value of residential properties (mean and total value in 2000–2011 and the total value of property purchases in 2011).

Sites causing an environmental hazard	Amount (pcs)
Contaminated soil, composting fields and sites causing nutrient loading	*12*
Old landfill sites	*4*
Harbours, shipyards and winter storage areas	*27*
Waste management	*2*
Fuel and chemical storage facilities	*21*

Table 4. Sites located in the sea flood risk area, in which the sea level will rise 2 metres from the mean water level in a flood situation that cause an environmental contamination risk.

greater risk of a capillary moisture rise occurring. In new potential risk areas, the flood impacts can be reduced by following the instructions regarding safe building elevations and building materials. High-quality, dense concrete with few seams can temporarily withstand moisture. Conversely, poorly compacted or poor-quality concrete is very sensitive to humidity damage in a flood situation. A layer of paint over the concrete does not repel moisture, but it forms a non-breathable film on the wall surface. Any belongings kept in basements are also in danger of being submerged in flood situations.

Helsinki has several sites located in the sea flood risk area that cause an environmental contamination risk (Table 4). They were surveyed in 2010[65].

Additionally, sea floods put the sewer network to test. Water bodies flooding into the sewer network is a known phenomenon, and it is tackled by installing backflow prevention devices at the identified problem points. For example, as a result of the sea water flood in January 2005, the overflow points of the sewer system were equipped with hatches.

5.2.5 The sea and river flood risks will increase to a degree

The sea level rise due to climate change increases the risk of sea water flooding to a degree. In new residential areas, the risk is taken into consideration in the construction phase, but in old seashore areas, the risk is greater. However, the risk has been reduced in Helsinki in a variety of ways. The sea flood risk areas of Helsinki are not heavily populated, so the susceptibility is rather low. Properties' own preparation measures are a significant factor affecting the sea flood risk.

65 Vaitomaa et al., 2010 https://www.hel.fi/static/ymk/julkaisut/julkaisu-09-10.pdf (in Finnish)

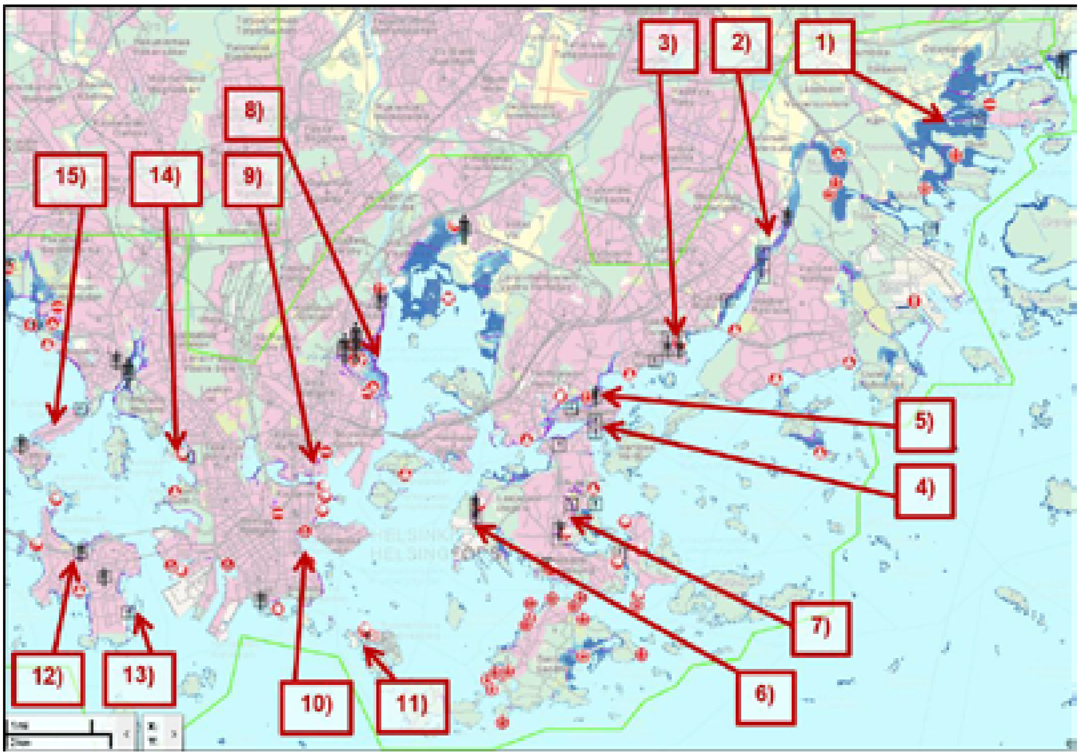


Figure 15. Sea flood risk areas in Helsinki[66]. The situation shown on the map is likely to change as climate changes.

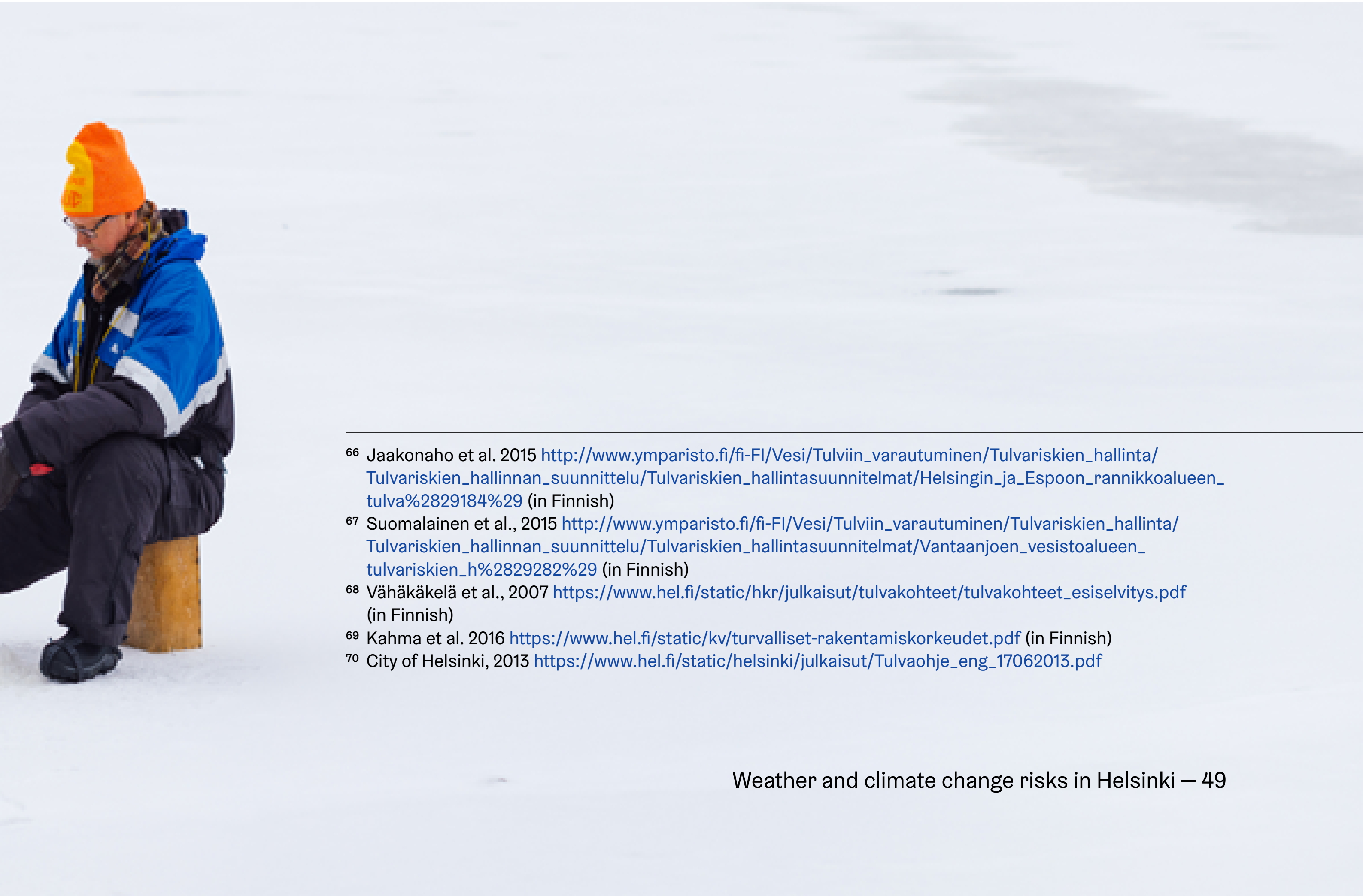
The current sea flood risk areas in Helsinki are presented on the map in Figure 15.

In Helsinki, river floods are caused by torrential rains and snow melting. The River Vantaanjoki and small brooks are especially prone to flooding. River floods have flooded property, temporarily interrupted the recreational use of areas and increased the leaching of nutrients and other impurities into water bodies. **Climate change is estimated to increase the occurrence of river floods in winter as well.** The Savela residential area and the Oulunkylä allotment garden area are particular flood risk areas by the River Vantaanjoki.[67]

5.2.6 Preventive measures to reduce the impacts of sea and river floods

The main focus in managing the sea and river flood risk in Helsinki has been on activities that aim to prevent the flood risk and reduce the impacts. Efforts have been made to reduce sea flood risk by for instance land use planning, flood risk assessements[68] and structural flood protection measures. In new residential areas, attempts to reduce flood risk include but are not limited to regulating the lowest safe building elevations for residential buildings to correspond with the recommendations in effect at the time of planning and by zoning the activities essential to the functioning of society outside flood risk areas. In 2016, location-specific lowest safe building elevations were defined for the coast of Helsinki for 2020, 2050 and 2100 by taking the combined impacts of the sea level and waving into consideration[69]. The study involved measuring waves, winds and water levels. The information was used to estimate how high a solid water mass can rise on a steep shore. The information is utilised in building projects located in coastal areas. Additionally, the City of Helsinki has created a Flood Guide for flood area residents that discusses how they can protect their property[70].

The current flood risk and the increasing sea flood risk due to climate change have been taken into consideration in new city



66 Jaakonaho et al. 2015 http://www.ymparisto.fi/fi-FI/Vesi/Tulviin_varautuminen/Tulvariskien_hallinta/Tulvariskien_hallinnan_suunnittelu/Tulvariskien_hallintasuunnitelmat/Helsingin_ja_Espoon_rannikkoalueen_tulva%2829184%29 (in Finnish)
67 Suomalainen et al., 2015 http://www.ymparisto.fi/fi-FI/Vesi/Tulviin_varautuminen/Tulvariskien_hallinta/Tulvariskien_hallinnan_suunnittelu/Tulvariskien_hallintasuunnitelmat/Vantaanjoen_vesistoalueen_tulvariskien_h%2829282%29 (in Finnish)
68 Vähäkäkelä et al., 2007 https://www.hel.fi/static/hkr/julkaisut/tulvakohteet/tulvakohteet_esiselvitys.pdf (in Finnish)
69 Kahma et al. 2016 https://www.hel.fi/static/kv/turvalliset-rakentamiskorkeudet.pdf (in Finnish)
70 City of Helsinki, 2013 https://www.hel.fi/static/helsinki/julkaisut/Tulvaohje_eng_17062013.pdf

districts. New residential areas use the lowest foundation levels prescribed in the 'Safe building elevations' report[71]. For example, the district of Jätkäsaari has prepared for a one-metre sea level rise by elevating the ground level by more than a metre from the ground level of the harbour that was previously located in the area. The lowest permitted floor height in the area is 3.5 m from sea level.[72] In many places, the surface level of streets and yards has been raised from the previous harbour level by several metres. The safe building elevations prepare for an increase in the sea level and wave heights. Up-to-date information about the local sea levels and waves in Helsinki is provided at http://meri.hel.fi. Other flood protection measures will have to be assessed separately for every new city district.

Older flood risk locations will use either fixed, built protective structures or, when the sea level rises, temporary flood protection measures. In many cases, property-specific measures fall under the responsibility of the property owners.

The Public Works Department's preliminary study[73] features a district-by-district review of flood risk locations in which a sea water flood could have adverse or damaging effects on properties, buildings and other structures located on the shore. The preliminary study serves as starting material for further plans. Already completed protection measures are: raising the Kaitalahti bay floodbank (2009), protecting the southern part of Sarvasto residential area from floods (2010), the district of Marjaniemi flood protection project (2011) and protecting the northern part of Sarvasto (2011) and Aittasaari residential areas from floods (2011). A flood protection plan and an implementation plan have been created for Vartiokylänlahti bay area. A flood pumping station for improving flood protection in the current Savela area was completed in the autumn of 2014. The 720-metre floodbank of the Oulunkylä allotment garden was completed in the autumn of 2016.

The flood risk management plan for the Helsinki and Espoo coastal area for 2016–2021 was completed in 2015[74]. The plan proposes measures for preventing and reducing the flood damages. State and municipal authorities, as well as the regional development authority, must take the plan and the proposed measures into consideration in their operations. More detailed planning work began after the plan was approved. The plan covers two of the Public Works Department's sites in the city district of Tammisalo. The significance of the flood risks will be assessed next in 2018, and the management plans will be updated where necessary by 2021.

The City Survey Division of the Real Estate Department created a terrain model that covers the entire city for assessing the impacts and risks of flood water[75][76]. The terrain model was completed in 2009. The materials are being updated constantly.[77]

According to a study conducted by the Finnish Meteorological Institute, **the provision of information describing the risks guides residents' behaviour and the real estate market to take the climate risks better into consideration**. The study discovered that the real estate market is efficient in putting well-planned adaptation measures into practice by changing the market prices that guide many factors in urban processes. Publishing detailed flood maps[78] guided the market of Helsinki's seashore properties so that the flood risks of different magnitudes had an effect on the prices of detached and terraced houses. The price development of houses located in the flood risk area was slower than that of dwellings located in the same residential area outside the flood risk areas.[79] Seaside construction should not be prohibited, as shore areas are highly sought after and valuable places of residence[80].

Seashore plots can be put into efficient use by taking care of flood protection. Hence, it is important to publishand regularly update flood risk maps and ensure that they take both the latest climate scenarios and implemented flood protection measures into account. Additionally, the impacts of sea and river floods can be reduced with the use of early warning systems and by planning measures for highly exceptional situations.

5.3 Needs for flood-related follow-up studies

As regards flood risks, the following needs for a follow-up study were brought up during the risk assessment:

1. The flood risk maps should contain the following information:

- the cost-benefit aspect of flood protection
- uncertainties and errors in the maps
- implemented adaptation measures
- taking the population density and age structure into consideration in flood risk analyses

2. Catchment area limits.
3. Storm water modelling should be carried out using Helsinki's 3D model. The model should take sewer floods and nature based storm water management into consideration.
4. Survey on whether for example the vulnerability of important facilities in housing companies' bottom floors/ basements is taken into consideration in planning or construction.
5. Storm water management information systems should be developed. The systems should contain information such as detailed, constantly updated geographical information data, modelling results, records of new measures and maintenance procedures and a compilation of damage information.

Potential changes to EU and national legislation are as regards flood risk legislation and how they could be prepared for in advance should be assessed . This also applies to other legislation related to weather and climate risks and their management.

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71 Kahma et al., 2016 https://www.hel.fi/static/kv/Geo/Vesi/Poijut.html (in Finnish)
72 Helsinki kaupunkiympäristö, 12.10.2017: Urban legends, part 1 – Will Jätkäsaari disappear under water? https://www.youtube.com/watch?v=Sgqf5RSJ83A
73 Vähäkäkelä et al., 2007 https://www.hel.fi/static/hkr/julkaisut/tulvakohteet/tulvakohteet_esiselvitys.pdf (in Finnish)
74 Jaakonaho et al. 2015 http://www.ymparisto.fi/fi-FI/Vesi/Tulviin_varautuminen/Tulvariskien_hallinta/Tulvariskien_hallinnan_suunnittelu/Tulvariskien_hallintasuunnitelmat/Helsingin_ja_Espoon_rannikkoalueen_tulva%2829184%29 (in Finnish)
75 Helsinki Region Infoshare: 3D city model of the City of Helsinki http://www.hri.fi/fi/dataset/helsingin-pintamalli
76 Helsinki mapservice (terrain model) https://kartta.hel.fi/?setlanguage=en#
77 Ympäristöraportoinnin asiantuntijatyöryhmä, 2010 https://www.hel.fi/static/helsinki/paatosasiakirjat/Kvsto2010/Esityslista14/liitteet/Helsingin_kaupungin_ymparistoraportti_2009.pdf?Action=sd&id=%7BF1C3E306-0784-45AC-A2D0-87C16C131C43%7D (in Finnish)
78 Tulvakeskus: Flood map service http://paikkatieto.ymparisto.fi/tulvakartat/Html5Viewer_2_7/?locale=fi-FI (in Finnish)
79 Votsis, & Perrels, 2016 http://doi.org/10.1007/s11146-015-9530-3
80 Votsis, 2017b http://doi.org/10.1016/j.compenvurbsys.2017.04.005

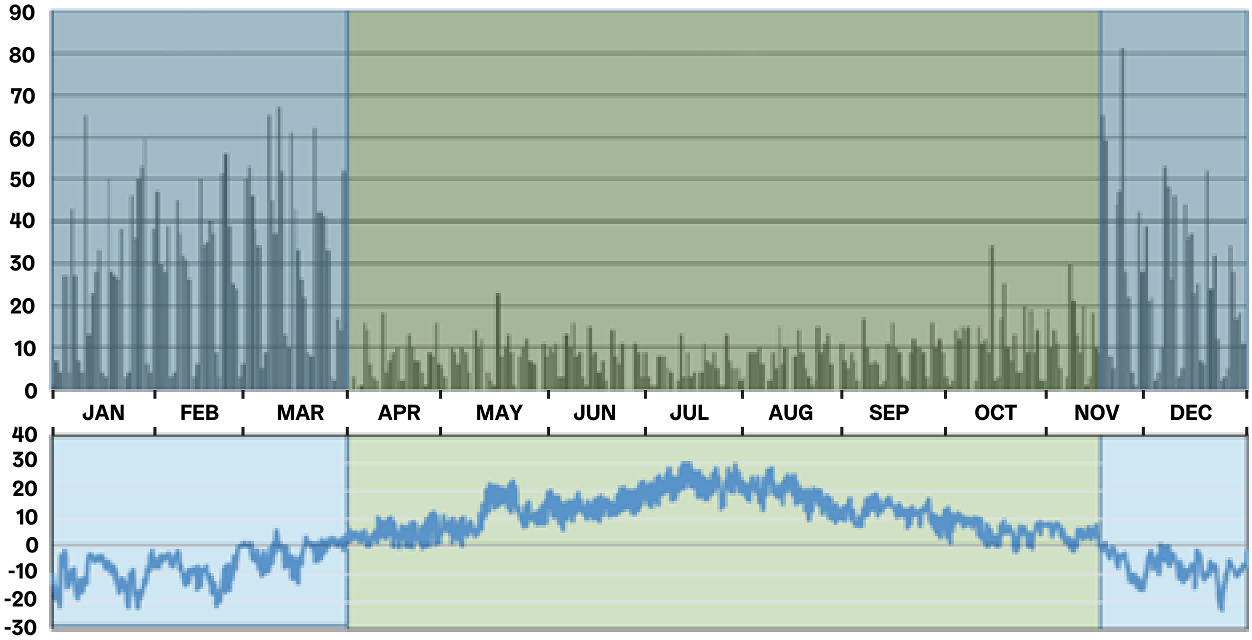
6 Winter climate to see the greatest changes

6.1 Slipping accidents will increase in zero-degree weather

Slippery winter conditions cause a significant health risk (Figure 16) and have economic impacts. At the City of Helsinki's expert workshop, impacts of slippery conditions were identified.

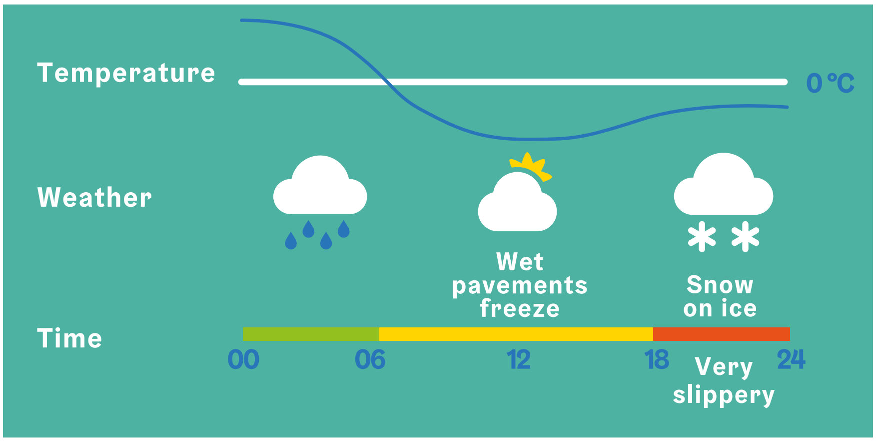
Winter causes extremely slippery days, resulting in the number of slipping accidents compared to an ordinary winter day multiplying, and in worst cases, the number of people seeking treatment can overwhelm healthcare services. The slipperiness of pavements develops as the result of the temperature fluctuating above and below zero and rainfall, and it is also affected by the level of maintenance measures. The slipperiest pedestrian conditions occur in situations in which light snow or rain falls onto an icy surface (Figure 18). Additionally, in days with heavy snowfall, the most traffic-heavy areas can develop tamping slipperiness if the snow is not cleared from the pavements quickly enough.

Figure 16. The number of slipping accidents will increase considerably when the temperature drops to zero and below. Work commute-related daily slipping accidents in Uusimaa in 2010 (upper image, source: Finnish Workers' Compensation Centre) and air temperature measured in Kumpula, Helsinki (lower image)[81].

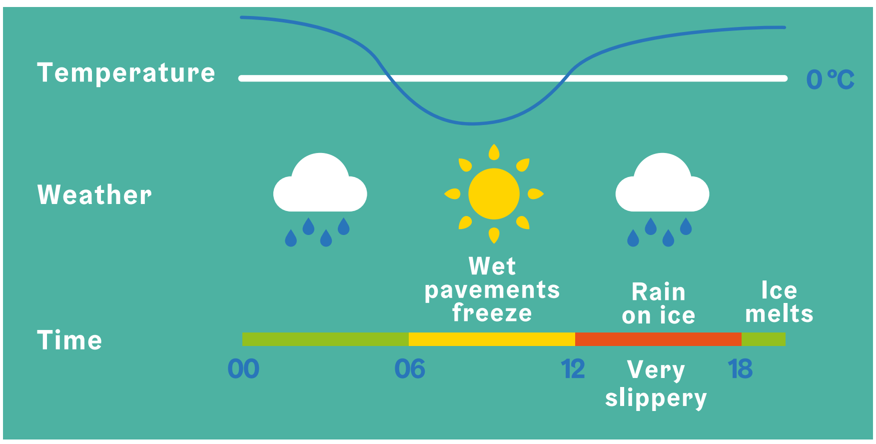


Figures 17-18. The slipperiest conditions for pedestrians develop when rain or snow falls onto icy pavements. Image: Finnish Meteorological Institute

Snow falls onto an icy surface



Rain falls onto an icy surface



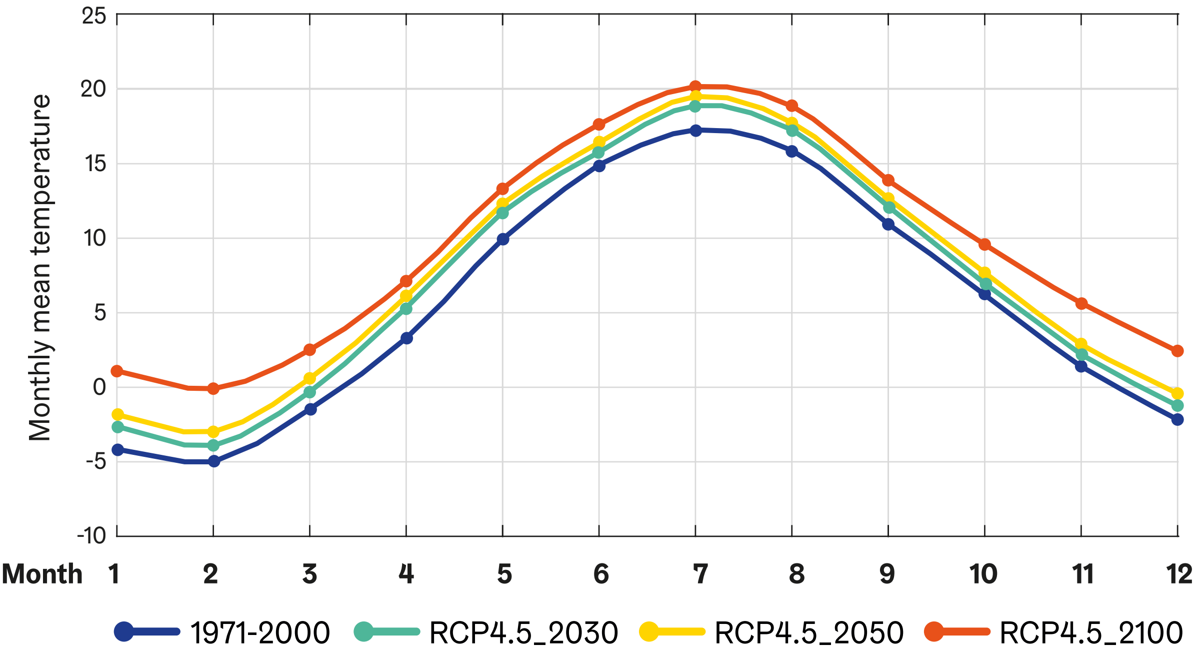


Figure 19. Changes in the monthly mean temperatures in accordance with the RCP4.5 climate scenario of moderate greenhouse gas emissions for 2030, 2050 and 2100 compared to 1971–2000[82].

6.1.1 Slippery conditions may become more common in the coming decades

In the coming decades, slippery conditions could become more common in mid-winter as days in which the temperature fluctuates above and below zero become more common. Figure 19 presents observed monthly average temperatures in the Helsinki metropolitan area, as well as temperatures following the RCP4.5 climate scenario of moderate greenhouse gas emissions for 2030, 2050 and 2100. For example, January and February will be approximately two degrees warmer in 2050 than in 1971–2000, and the mean temperature for March will rise above zero. It is worth noting that by the end of the century, the monthly average temperatures will already be above zero degrees on average.

6.1.2 Assessing the economic impacts of slipping accidents is difficult

Assessing the overall costs of slipping accidents is difficult, as the accidents are not systematically recorded. Patients and their recovery should be monitored for a long time after the accident in order to establish the overall harm. Assessing the decrease in work productivity is difficult, and various estimates are used in assessing the costs of lost well-being. Based on assessments used in the health sector, the annual indirect costs amount to 420 million euros at national level. Based on the traffic sector's figures, the same number of slipping accidents results in annual indirect costs of 2.4 billion euros. However, the direct costs are known reasonably well. The average figure is approximately 6,000 euros in cases of typical injuries, such as a broken wrist or ankle, and approximately 30,000 euros in cases of hip fractures.[83]

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81 Hippi et al., 2017 http://hdl.handle.net/10138/224484
82 Mäkelä et al, 2016 http://hdl.handle.net/10138/170155 (in Finnish)
83 Suomalaisen Lääkäriseuran Duodecimin ja Suomen Ortopediyhdistyksen asettama työryhmä, 2017 http://www.kaypahoito.fi/web/kh/suositukset/suositus?id=hoi50040 (in Finnish)

Figure 20 presents compensation paid by the Public Works Department (current Urban Environment Division) of the City of Helsinki for slipping accidents that have occurred in the City's maintenance responsibility areas. **In particular, winters with heavy snowfall have increased the amount of compensation paid for damages in recent years.** As the City's responsibility for clearing the snow from pavements expands and will cover the city centre in the future, the City will have to prepare for increasingly large compensation sums.[84]

6.1.3 Slipping injuries are the most serious for older people

People of all ages have slipping accidents, but the most serious injuries are suffered by elderly people. Health care is sought most commonly by people aged 50–64. In elderly people, hip fractures can lead to a collapse in health and premature death.

Slipping accidents in the winter season often cause long sick leaves from work and thus significant economic costs as well. According to data compiled from Posti's database of accident statistics, in the Helsinki metropolitan area, the most common length

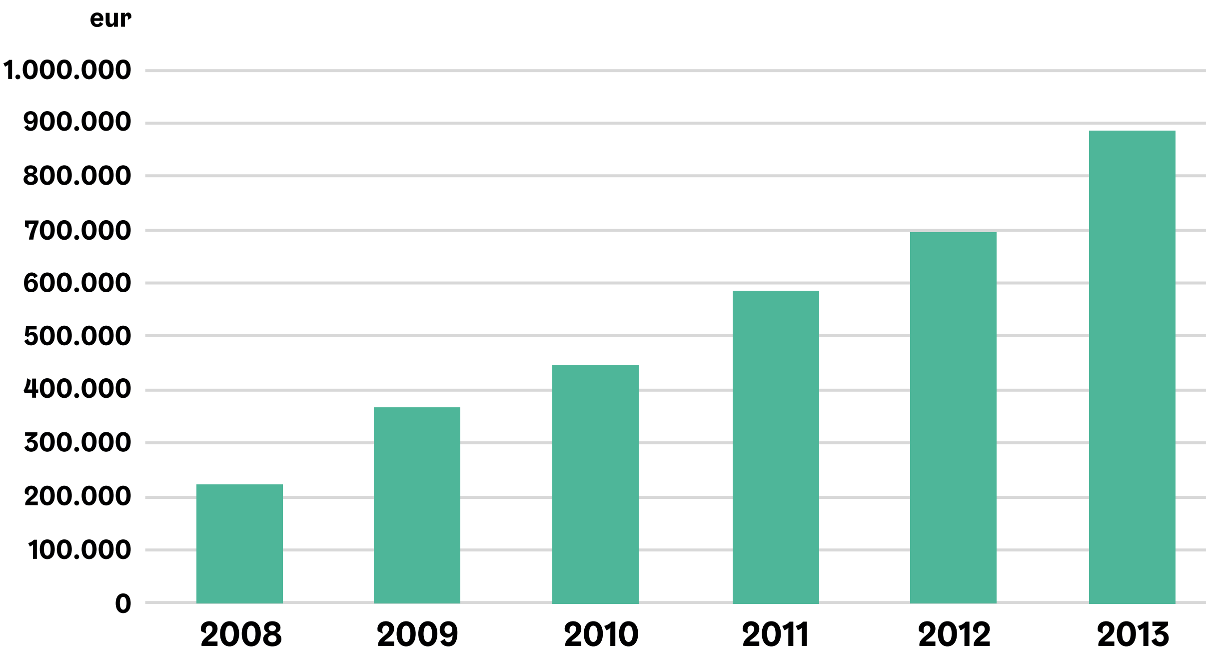

Figure 20. Compensation paid by the Public Works Department of the City of Helsinki for slipping accidents in 2008–2013.

of sick leave among post carriers due to a slipping accident fell between three days and one month[85].

Street maintenance is a significant factor in the slipping risk. In Helsinki, the City has assumed overall responsibility for a large proportion of the city's street area. Thus, the City takes care of the winter management of both roadways and pavements. Properties are left with the task of maintaining their own yard areas. In the city centre, the City takes care of the maintenance of roadways and separate or combined pavements and cycling lanes, etc. Properties take care of, inter alia, snow clearing and gritting of pedestrian lanes and winter maintenance of a bus or tram stop if the stop is on the pavement by the property. The Helsinki City Transport Utility HKL takes care of stops in the middle of a street.[86] The Helsinki Central Park is maintained by the City's Culture and Leisure Division (former Sports Department). Street maintenance resources are the most significant factor with which the slipping risk can be reduced by the City.

The residents' own preparedness is also important in reducing slipping risks. This can be achieved by better communication and information provision. Accordingly, Helsinki has been involved in the *Pysy pystyssä* (Stay up) campaign aimed at citizens. Due to increasing immigration, information should also be provided in English and possibly other languages as well. However, no research has been conducted on whether immigrants have a higher risk of slipping. In addition to information provision, the City can also carry out concrete measures to support people's own preparedness. Some cities have provided their residents with non-slipping devices and offered shoe studding services.[87]

The City of Helsinki's goal is to promote winter cycling and develop the winter maintenance methods for cycling routes. Helsinki's goal is to increase winter cycling. Walking and cycling conditions will be improved by expanding the network covered by intensified winter maintenance with at least one new route in 2018.[88] No research has been conducted on the slipping risk associated with winter cycling. However, researching the matter is important, as cyclists face a different kind of risk to that of drivers and pedestrians. A better understanding of the risk would facilitate elaborating on the warnings issued to winter cyclists, for example.

In Helsinki, the risk of ground frost damage is relatively low for both roads and railways.

6.2 Road traffic actors must prepare for snow storms and slipperiness in the future as well

The worst road traffic conditions do not typically occur on the same days as the slipperiest conditions for pedestrians. When the temperature drops below zero, moisture can freeze on the road surface, making the road slippery. On the main roads, the road surface can generally be prevented from freezing with correctly timed salting by utilising weather forecast and observation

[84] Helsingin kaupungin tapaturmien ehkäisytyöryhmä 2011–2014, 2014 https://dev.hel.fi/paatokset/media/att/df/dfad0ece1d2776f48fbc5c267ecc90aaf1e8faaf.pdf (in Finnish)
[85] Posti records statistics of all accidents among post carriers in its database. The sick leave lengths are divided into five classes as follows: no absence, absent for the rest of the day, absent for 1–2 days, absent for 3 days–one month, absent for more than a month. (Hippi et al., 2017)
[86] Hippi et al., 2017 http://hdl.handle.net/10138/224484
[87] Raahen Seutu, 19.12.2017 https://www.raahenseutu.fi/article-6.1.1187784.9dff056937 (in Finnish)
[88] Helsingin kaupunki, kaupunginkaslia, 2017 https://www.hel.fi/static/kanslia/Julkaisut/2017/HKI_TA_2018_web.pdf (in Finnish)

information. However, if it snows for a long time, traction on the road surface is significantly reduced. Particularly at low temperatures, traffic can cause tamping of snow into an icy film over the road surface, increasing the accident risk. **The friction between the road surface and the tyre has a significant effect on braking distances.** If the speed of a vehicle is 100 km/h and the friction coefficient drops from 0.8 (dry road) to 0.2 (road covered with a thin film of ice), the braking distance increase up to four times, from 50 metres to 200 metres[89]. In poor driving conditions, the friction coefficient is lower than 0.3 and lower than 0.15 in extremely poor conditions. The braking distances in the different friction classes can be roughly described as follows: when the friction coefficient is lower than 0.3, the braking distance increases two and a half times, and when the friction coefficient is lower than 0.15, the distance increases approximately five times compared to the distance needed on dry asphalt[90].

The conditions are especially challenging when it snows heavily and the temperature is lower than -5 degrees. In such cases, the frosty snow can billow, reducing visibility significantly. At the same time, the friction coefficient of the road surface decreases on the snowy or tightly tamped surface and braking distances increase. The worst pile-ups in the Helsinki metropolitan area in recent years took place in such conditions on 17 March 2005 and 3 February 2012. The pile-ups involved hundreds of vehicles. Heavy traffic can also polish tamped snow into an icy film. When the visibility is poor, the role of friction becomes more important as any obstacles ahead cannot be seen from far away and the reaction time can thus be short.

Climate change makes the winter season shorter, but traffic and maintenance actors must still be prepared for intense snow storms. Between 1981 and 2010, Southern Finland had an average of 12–20 annual cases in which more than six centimetres of snow fell within a day. In 2021–2050, the probability of such snowfalls will decrease by 10–25 percentage points compared to the climate model reference period of 1971–2000 according to both the RCP4.5 and RCP8.5 climate scenarios[91]. On average, the climate has become warmer over the last few decades, and the trend is expected to continue in the coming decades as well. However, the impacts will not be distributed evenly and the annual variation will remain.

Extreme temperatures will rise clearly and the heaviest snowfalls may even increase. Both low temperatures and snowfalls will become less frequent in Northern Europe, where the number of extremely cold days may decrease by 30–40 in the 2050s compared to the current situation. On the other hand, heavy snowfalls (more than 10 cm/day) will not become less frequent. In fact, they may become slightly more frequent than now. When it snows, the snowfall may be heavy.

Freezing rains, in which the water is supercooled, are very rare in the Finnish climate. **The probability of freezing rains is likely to increase somewhat due to climate change[92], and the effect in Helsinki will primarily be an increase in slipperiness.** The predictability of freezing rain is lower than that of normal rain or snow, but they can be predicted on a short time scale, thus making it possible to prepare for them.

6.2.1 In winter 2012, a snow storm halted traffic

Snow storms have significant impacts in Helsinki. In February 2012, road traffic in the Helsinki metropolitan area was halted due to a pile-up caused by heavy snowfall and strong winds (Figure 22).

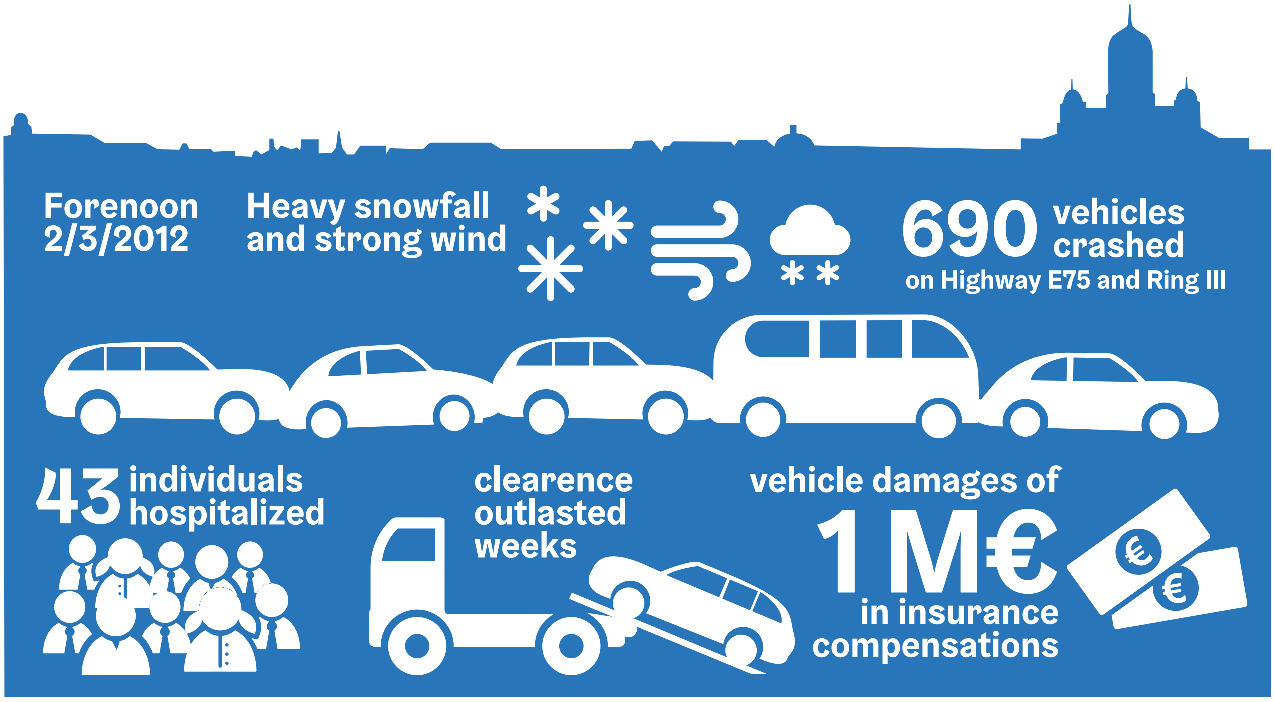

Figure 22. Impacts of the February 2012 snow storm in the Helsinki metropolitan area.

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89 Haavasoja & Pilli-Sihvola, 2010 http://www.sirwec.org/Papers/quebec/11.pdf
90 Haavasoja & Pilli-Sihvola, 2010 http://www.sirwec.org/Papers/quebec/11.pdf
91 räinen & Vajda, 2016 https://www.researchgate.net/publication/308034040_Present_and_future_probability_of_meteorological_and_hydrological_hazards_in_Europe
92 Kämäräinen et a., 2017 http://doi.org/10.5194/nhess-17-243-2017

VR (the rail traffic company) also had to halt its train traffic during the day. At 6 am, VR announced that its trains would be running late over the course of the day. Several trains were cancelled, and train traffic was plagued by disruptions. Additionally, the underground metro trains ran late due to door and brake problems, tram routes were changed and trams were stuck in the snow, and buses had problems as well.[93]

6.2.2 Snow storm risk greatest for road traffic

In Helsinki, particularly large traffic volumes affect the amount of traffic jams and crashes considerably. Another significant factor is people's behaviour during snow storms. Commuting to work by car increases the traffic volumes on roads, and driving without taking the weather situation into consideration increases the risk of crashes considerably. Reducing speed limits, for example, should decrease pile-ups or accidents occurring in them. Clearing snow in the city requires space reservations for snow, which should also be taken into consideration in planning. For example, green areas can be used for storing of snow in winter. Long-term effects may occur if, for example, rescue services and healthcare have insufficient resources in possible pile-up situations and people's access to care is delayed. **The potentially increasing share of tram traffic of public transport in Helsinki may increase the risks related to snow storms.**

Using studded tyres on cars is very common in Finland. However, they cause wear to the road surface and thus increase the street maintenance costs and reduce air quality. Friction tyres are an alternative, as they do not increase the skidding risk of cars compared to studded tyres in normal winter conditions. **In the most difficult weather conditions, the choice of tyre matters**: the traction properties of friction tyres are not as good as those of studded tyres. The situation is made difficult also by the fact that drivers cannot see ice that is covered by snow, making it more difficult to predict situations. Switching to studless winter tyres is not without its problems, as estimates indicate that it can increase the risk of accidents.[94]

Traffic technology is developing rapidly, and it is possible that the majority of cars will be self-driving in 2050. Thus, the impacts of the changing winter conditions on, for instace, aspects such as accident risks are difficult

93 Helsingin Sanomat, 3.2.2012 http://www.hs.fi/kotimaa/art-2000002519173.html
94 Mikkonen, 2012 https://asiakas.kotisivukone.com/files/nastatutkimus.kotisivukone.com/tiedostot/tutkimusraportit/kolaririskin_vahentaminen_nastattomassa.valmixa.pdf (in Finnish)

Snow storm risk greatest for road traffic

to estimate. **However, the functionality of self-driving cars in exceptional weather situations is important in winter conditions such as those in Helsinki.**

The Nasta project involved assessing measures to reduce the impacts of weather on traffic. In particular, the methods are related to situations in which car drivers have switched to friction tyres. However, the recommendations can be generalised to pertain to car traffic in general:

1. Anti-skid treatment and snow clearing were seen as the primary way to reduce the risk to traffic. In particular, clearing pavements and cycling lanes of snow should be taken care of, so that pedestrians and cyclists do not need to use car lanes.

2. Weather warnings, real-time warnings and safety cars can be used to increase drivers' preparedness for the situation. Safety cars could be introduced in the most difficult situations in the most difficult sections of the traffic network. Safety cars are equipped with highly visible warning blinkers and signs prohibiting overtaking.

3. Communication about the increasing accident risk, especially when switching to studless tyres, is an important method. Providing information about public traffic services and the ways to use them is one example of ways to avoid the risk of crashes.

4. Favouring remote working on weather warning days should be kept in mind.

Examples of methods facilitated by smart traffic in the future include adjusting winter speed limits in urban areas and providing real-time information about the conditions, changing speed limits and exceptional situations on the traffic routes.[95]

Helsinki's vision of being the most functional city in the world requires that exceptional weather conditions are also taken into consideration when planning the functionality of the city. The smoothness of residents' everyday life in situations such as snow storms is significantly reduced, and the City can affect this by allocating resources for snow clearing and maintaining the roads and pedestrian lanes. However, an interesting topic to think about is the threshold values of exceptional situations in which the City does not have to act as in normal conditions. These situations require residents' and for example workplaces' independent adaptation.

6.3 Fog is likely to increase in autumn and hinder the traffic sector

Changes in fogginess due to climate change have not really been researched. **However, it is possible that fog will increase in autumn as the onset of winter is delayed.** This may affect car and ship traffic, and possibly sea pilot operations as well.

6.4 Climate change makes winters darker and winter depression more severe

Climate change reduces the amount of sunlight in the winter months, which may cause exacerbated winter depression. In the current climate, approximately 1% of the population of Finland suffers repeatedly from winter depression. Additionally, up to 40% of the population suffer from milder winter depression symptoms – sleep disorders and appetite fluctuation – without being in an actual state of depression[96]. The symptoms of winter depression expose people to the risk of physical illnesses as well, such as metabolic syndrome.

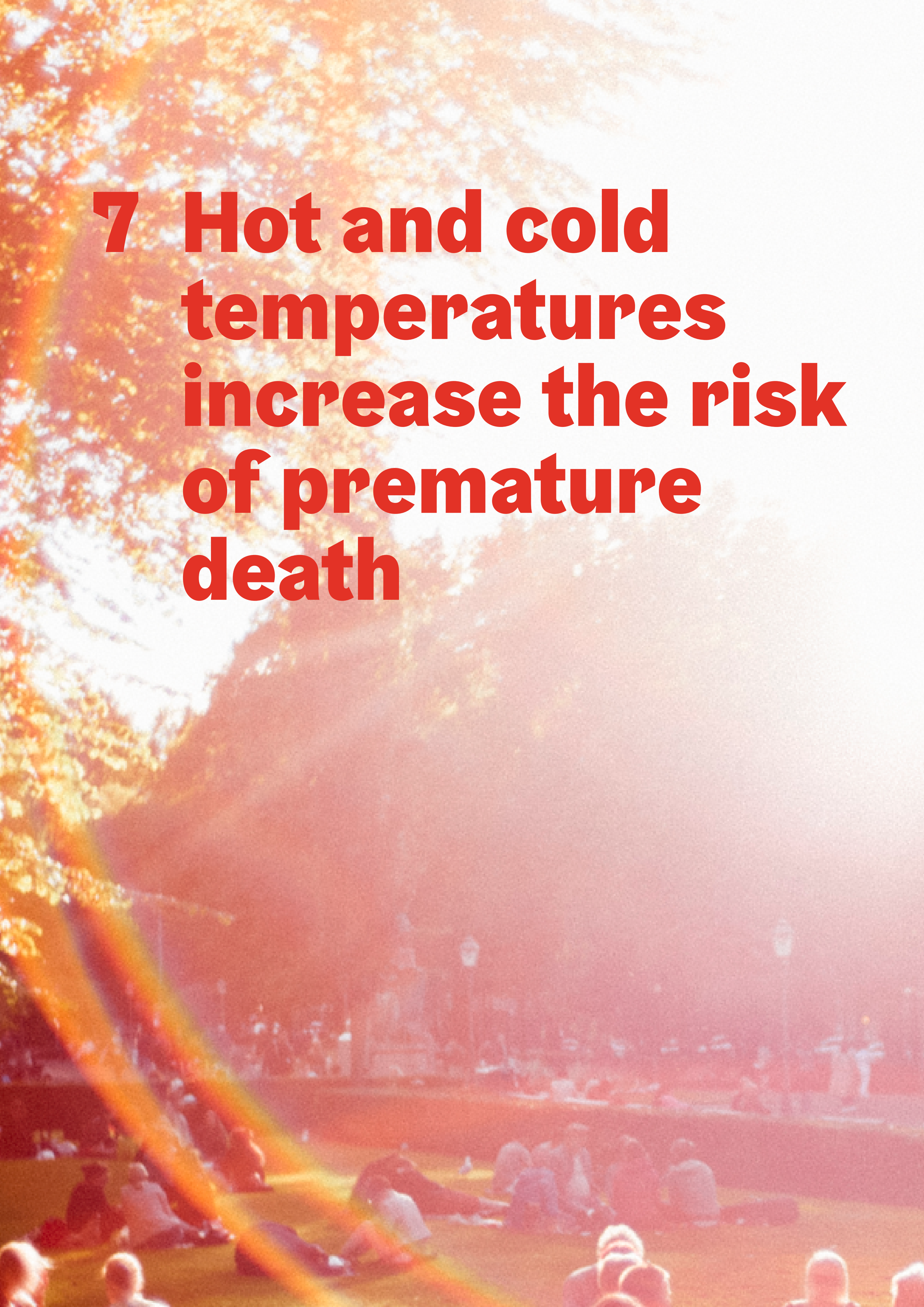
Suicide rates are at their peak in spring, which is thought to be caused by the rapidly increasing amount of sunlight. However, the levels of light in the preceding winter months play a role as well. The less sunlight accumulates over the winter, the more suicides will occur[97]. This is at its most evident from November to March. Men's suicide risk due to lack of light increases more than women's. The dependence of suicides on climate factors in Finland was researched using 32-year time series data. The weather dependency of suicide attempts has been researched in the Helsinki metropolitan area[98], and the attempts were found to be strongly connected to the atmospheric pressure and its changes. There is currently no research information about how climate change will affect the number of suicides. **However, the first conclusion that can be drawn from the correlation between suicides observed in the current climate and climate factors is that the decrease in the amount of sunlight in the winter season due to climate change will increase the risk of suicides**. It should be noted, however, that many other factors, such as the quality of mental health work, have a more significant effect on the number of suicides than climate change.

6.5 Rainfall in winter will increase nutrient loading into water bodies

Rainfall in winter is expected to increase due to climate change. The effects of winter rains are diverse. When precipitation occurs in the form of water instead of snow, it may cause storm water problems, the impacts of which are discussed in greater detail in Chapter 5.1. **Nutrient loading into water bodies will increase due to increasing rainfall in winter.** In winter, the low evaporation level will increase the impacts compared to summer conditions. Furthermore, rain occurring in winter increases the risk of slipping accidents, which is discussed in Chapter 6.1. Slipping accidents and other traffic problems will increase if rain is followed by freezing temperatures.

95 Mikkonen, 2012 https://asiakas.kotisivukone.com/files/nastatutkimus.kotisivukone.com/tiedostot/tutkimusraportit/kolaririskin_vahentaminen_nastattomassa.valmixa.pdf (in Finnish)
96 Huttunen, 2016 http://www.terveyskirjasto.fi/terveyskirjasto/tk.koti?p_artikkeli=dlk00377
97 Ruuhela, et al. 2009 http://doi.org/10.1007/s00484-008-0200-5
98 Hiltunen, et al. 2012 http://doi.org/10.1007/s00484-011-0518-2

7 Hot and cold temperatures increase the risk of premature death



Heat increases mortality rates from the first hot day, and the impact continues for a few days. The health impacts of temperature conditions at population level are best indicated by the temperature dependency of mortality rates. Mortality is at its lowest when the climatic conditions (temperature, humidity, wind, solar radiation) are typical, increasing towards both temperature extremes – very low and very high temperatures (i.e. in a U shape). At individual level, the health effects vary depending on factors such as age and chronic illnesses.

In Finland, mortality is at its lowest when the average daily temperature is 13–17 °C. In Southern Europe, for example, the corresponding minimum mortality temperature is 20–25 °C[99][100]. The minimum mortality temperature is lower in colder climate zones than in warmer zones. This temperature is also a good indicator for the climate people have adapted to in the long term. A more accurate form of the temperature dependency of mortality, i.e. how much the mortality risk increases towards temperature extremes, depends on numerous socio-economic and other vulnerability factors.

Mortality is higher in winter than in summer. There is clear seasonal variation in mortality rates. However, the higher mortality rate in winter is not related exclusively to temperature. Instead, it is explained by factors such as influenza seasons and possibly people's behaviour. Exposure to heat waves

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[99] Näyhä, 2005 http://doi.org/10.3402/ijch.v64i5.18026
[100] Näyhä, 2007 http://doi.org/10.3402/ijch.v66i5.18313

and cold is also related to people's work and activity. People working out of doors are directly exposed to outside temperatures, while indoor workers' exposure also depends on the properties of the building. In the winter season, people also spend more time in heated indoor facilities, reducing exposure to cold stress. This chapter focuses primarily on the impacts and risks caused by heat.

7.1 Climate change raises the highest summer temperatures

In Finland, heat waves refer to days on which the maximum temperature exceeds +25 degrees. The Finnish Meteorological Institute issues heat wave warnings in accordance with the following threshold values:

- *Hot*: maximum daily temperature exceeds +27 degrees and the minimum temperature +14 degrees
- *Very hot*: maximum daily temperature exceeds +30 degrees and the minimum temperature +18 degrees
- *Extremely hot*: maximum daily temperature exceeds +35 degrees and the minimum temperature +20 degrees

In the current century, significant heat waves have occurred at least in 2003, 2010 and 2014.

Due to climate change, the highest daily temperatures will rise in summer more or less the same rate as the mean temperatures: for example, if the mean temperature has risen by 2.3 °C by 2050 compared to 1971–2000, the highest measured summer temperatures will also be approximately 2.3 °C higher than those in 1971–2000[101].

The health risk caused by heat is affected by daytime and night time temperatures, the duration of the heat wave, humidity, wind and the amount of solar radiation.

7.2 Urban heat island effect increases the health risk caused by heat

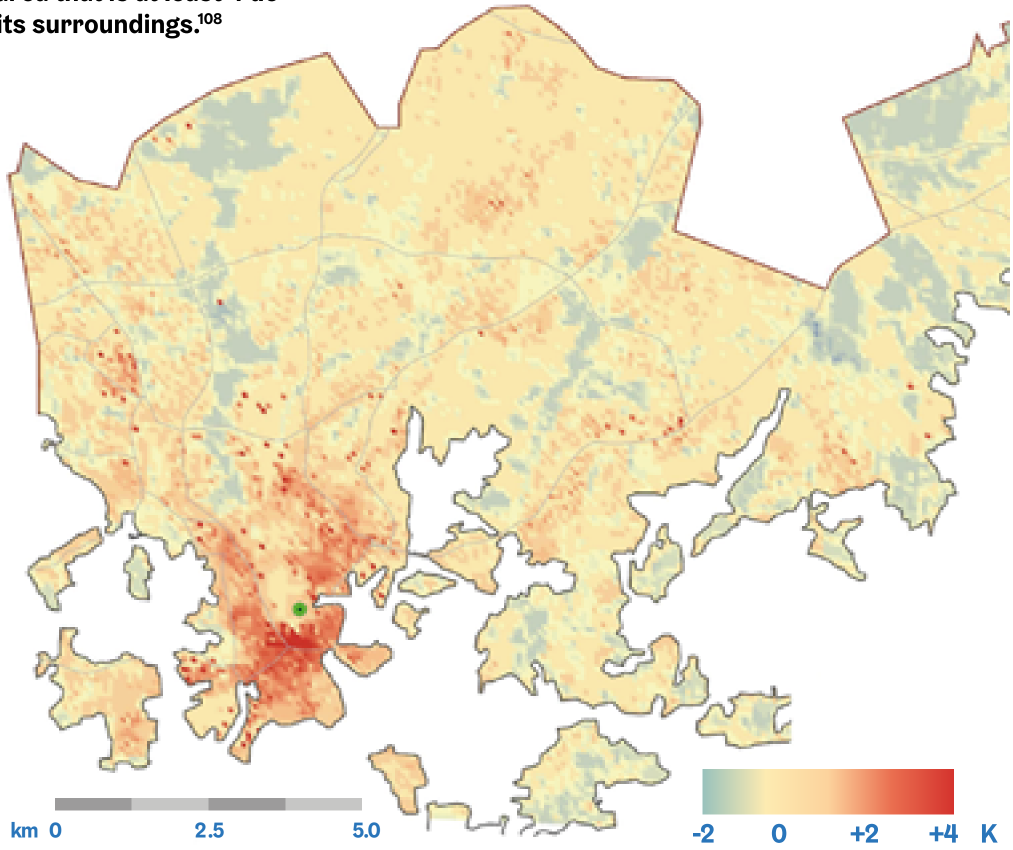
Due to the urban heat island effect, urban areas are warmer than their surrounding rural areas. Thus, **the urban heat island effect increases exposure to heat waves and reduces exposure to cold temperatures**. **The urban heat island (UHI) effect is created from the waste heat produced by buildings, transport and industry, as well as from the solar radiation stored in the city's structures being released as heat**. The thermal properties of the city's building materials determine how much energy is stored and, correspondingly, how much the buildings release energy into the atmosphere.[102] The sewage system decreases the amount of water vapour during rainfall. Water vapour stores thermal energy, so reduced evaporation also raises the temperatures in the city.[103]

The intensity of UHI is affected by the size and structure of the city, the population density and the building materials used. The intensity usually correlates with the size of the city and the height of its buildings in relation to the width of its streets. The building materials affect both the storage of solar radiation and the city's energy efficiency, i.e. amount of waste heat[104]. The intensity of UHI is also affected by, for example, factors such as the relief of the surface of the area and its location in relation to water bodies[105 106 107]. **The potential impact of climate change on the UHI effect is very complex, as the effect depends primarily on the urban structure and its related factors.** More research information is needed on the topic.

Trees and construction of green areas reduce the intensity of the UHI effect. In Helsinki, the sea also has a major effect. Especially in early summer, the probability of a heat wave is lower near the coast than inland. However, in early winter before the sea freezes over, coastal areas are typically warmer and more humid than inland areas. The weather situation, especially the direction and speed of air currents, affects how far inland the impact of the sea reaches.

The map in Figure 25 depicts the urban heat island in Helsinki from July 2009 to June 2010. The map is based on temperature measurements taken over the course of a year, which were used to calculate a regional estimate of the UHI in Helsinki. The greatest differences during this measurement period compared to the Kaisaniemi weather station were +4 degrees. During the measurement period, no actual heat waves occurred in the summer months, so there is no clear picture of how representative the map would be of temperature differences during a heat wave.

Figure 25. Urban heat island in Helsinki on average between 7/2009 and 6/2010. The reddest colour indicates an area that is at least 4 degrees warmer than its surroundings.[108]



[101] Mäkelä et al. 2016 http://hdl.handle.net/10138/170155 (in Finnish)
[102] Climate Proof City: What is an urban heat island? https://ilmastotyokalut.fi/kaupungin-lampotilaerot/mika-on-lamposaareke/urban-climate-research-in-the-city-of-turku/
[103] Oke, 1987, [104] Oke, 1987
[105] Drebs, 2011 http://urn.fi/URN:NBN:fi-fe201201121058
[106] Suomi & Käyhkö, 2012 http://dx.doi.org/10.1002/joc.2277
[107] Turun yliopisto, 18.11.2014 http://ilmasto-opas.fi/fi/ilmastonmuutos/sopeutuminen/-/artikkeli/ce71e82c-24a4-4566-985a-8955d12b717c/lamposaarekeilmion-ymmartaminen-tukee-kaupunkisuunnittelua.html (in Finnish)
[108] Drebs, 2011 http://urn.fi/URN:NBN:fi-fe201201121058 (in Finnish)

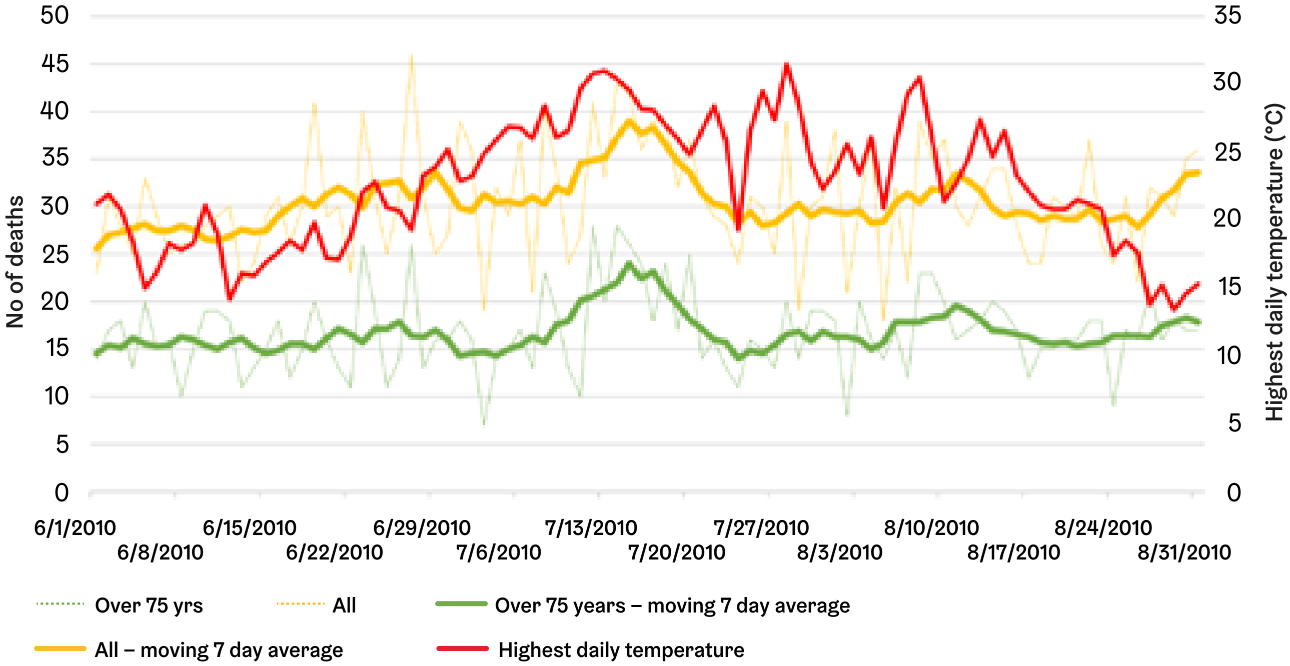


Figure 26. Number of deaths (yellow = all deaths; green = those aged over 75) in the HUS area in the summer of 2010. The daily numbers are depicted with dashed lines and the moving 7-day average with solid lines. Highest daily temperature as the regional average for the HUS area (red line). Data: Statistics Finland and the Finnish Meteorological Institute. Image: Reija Ruuhela.

7.3. The heat wave of summer 2010 increased mortality rates

The heat wave experienced in July 2010 is estimated to have caused 60 premature deaths in the Helsinki University Hospital HUS area, 30–40 of which occurred in Helsinki. Figure 26 depicts the variation in the number of deaths daily and as a moving 7-day average in the HUS area. There is great daily variation in the number of deaths, so the moving average clarifies the increase during the heat wave.

Heat is already a challenge for the employees of the City of Helsinki. For example, day care centres should have shaded areas or spots built in their yards for the staff and the children. Additionally, public transport drivers should have an opportunity to take breaks and ensure sufficient hydration.

7.4 The health risk caused by heat is the greatest for elderly people in non-air-conditioned facilities

Elderly and chronically ill people are the most sensitive to heat. The 2003 heat wave caused more than 200 premature deaths in Finland, while the 2010 heat wave caused approximately 300 deaths[109]. Mortality increased by 21% on average, and especially among people aged over 75. Examined by cause of death, mortality increased in the following disease categories: cardiovascular diseases, respiratory system diseases, mental health disorders and nervous system diseases. In addition to the increasing mortality risk, extreme temperatures can exacerbate the symptoms of chronically ill people and increase the need for treatment. Based on the FINRISK 2007 survey, 12% of people suffer from heat-related heart and respiratory tract symptoms in relatively normal summer temperatures as well, but among more sensitive groups, the figure can rise to 60%[110].

The largest increase in mortality was witnessed at healthcare treatment facilities, indicating that preparedness for heat waves in the healthcare system should be developed.

The connection between high temperatures and mortality can only be verified by a statistical analysis, except for actual heat strokes, individual deaths are difficult to connect to heat. However, the increase in mortality rates caused by heat can clearly be observed from the data. By taking the seasonal variation into consideration in the determinination of the baseline mortality, i.e. daily mortality is compared to its expected value, the effects of temperature extremes on mortality can be established. Using this analysis method, we can conclude that **heat stress increases mortality in Finland more than cold stress**.

The effects of extreme temperatures on mortality rates can occur with a delay. The effects of cold do not occur as quickly and intensely as those of heat, but cold can slightly increase mortality for multiple weeks. **In terms of the overall effect, cold-related mortality is more significant than heat-related.**

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[109] Kollanus & Lanki, 2014 http://www.duodecimlehti.fi/lehti/2014/10/duo11638
[110] Näyhä ym. 2017 http://doi.org/10.1007/s00484-016-1243-7

The risk caused by heat stress is the greatest among people aged over 75, but the mortality risk due to heat stress increases among working-age people as well (Figure 27).

In terms of heat, non-air-conditioned indoor facilities are a major risk. Indoor temperatures can become very high during heat waves, especially in small apartments with windows facing south or west.

This makes heat a more significant risk than extreme coldbecause, in most cases, vulnerable groups can protect themselves from the cold in Helsinki by entering heated indoor facilities. Cooling systems in apartment buildings are not yet very common. However, district cooling systems are currently being built for many properties.

When planning cooling methods, it should be ensured that carbon dioxide emissions do not increase considerably. Solar protec-

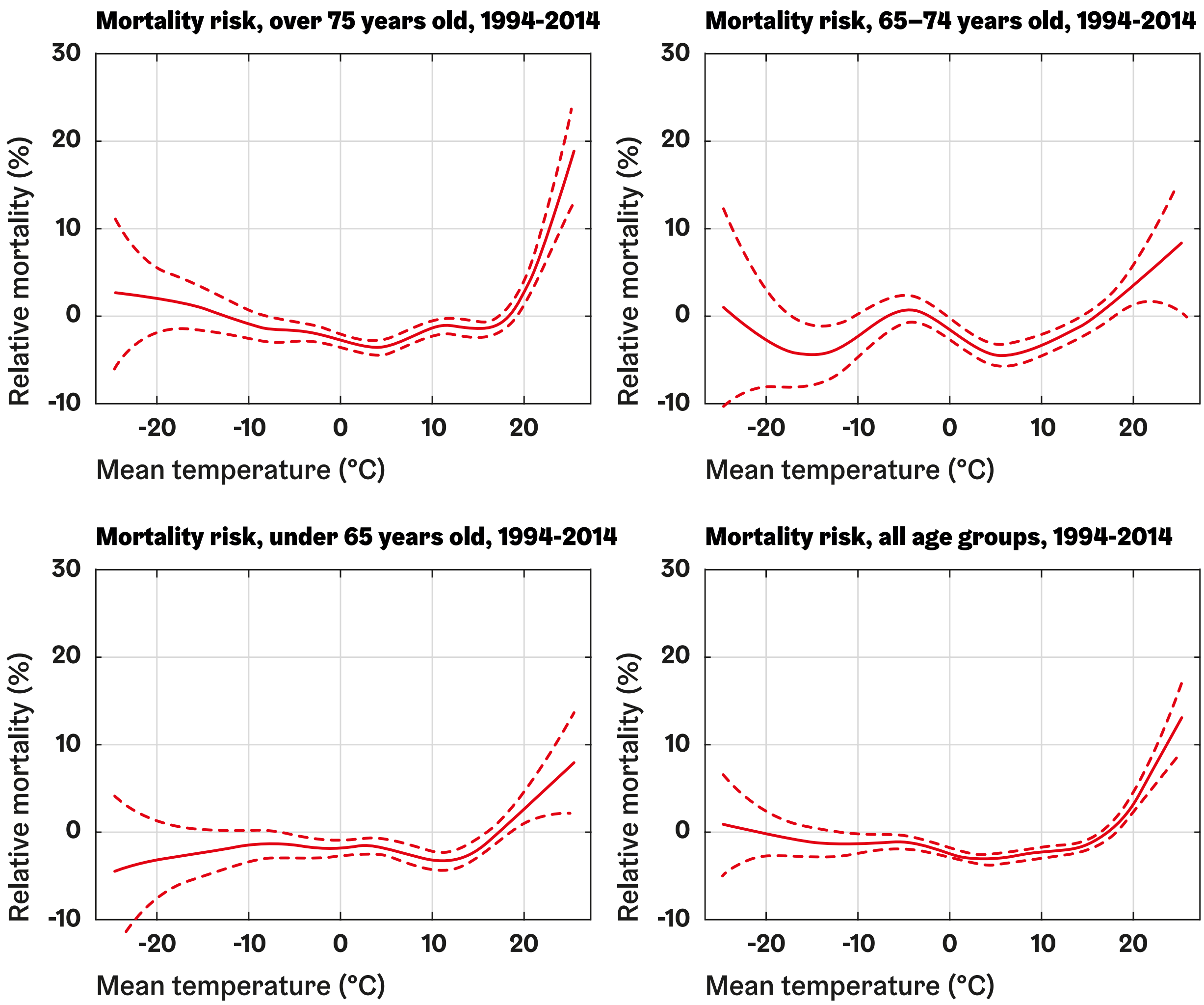


Figure 27. Relative mortality as a function of the mean temperature in the HUS area, all age groups and in separate groups of ages under 65, 65–74 and over 75. T the method compares actual mortality with the expected mortality value at the time in question, implying that negative values are also possible, i.e. mortality can be lower than its expected value. The expected value includes the seasonal variation in mortality.[111]

tion can be used to reduce the need for air conditioning and cooling. **Accordingly, solar protection for structures should be taken into consideration in new construction**, e.g. canopies, the g-value (total solar energy transmittance) of windows and window placement[112]. Old buildings can also be protected from excessive heat by, for example, means such as window blinds and awnings.

Special attention should be paid to the health risk caused by heat in home care for elderly people, which is a rising trend in the elderly care. More thought should also be given to how elderly people's homes could be made safer during high temperatures. Helsinki has areas that have a statistically significantly higher number of people aged over 75 living at home than other parts of the city. The ageing of the population increases the significance of this risk.

[111] Ruuhela et al. 2017 http://doi.org/10.3390/ijerph14080944
[112] Energiatehokas koti, 9.1.2018 http://www.energiatehokaskoti.fi/suunnittelu/rakennuksen_suunnittelu/ikkunat_ja_niiden_suuntaus (in Finnish)

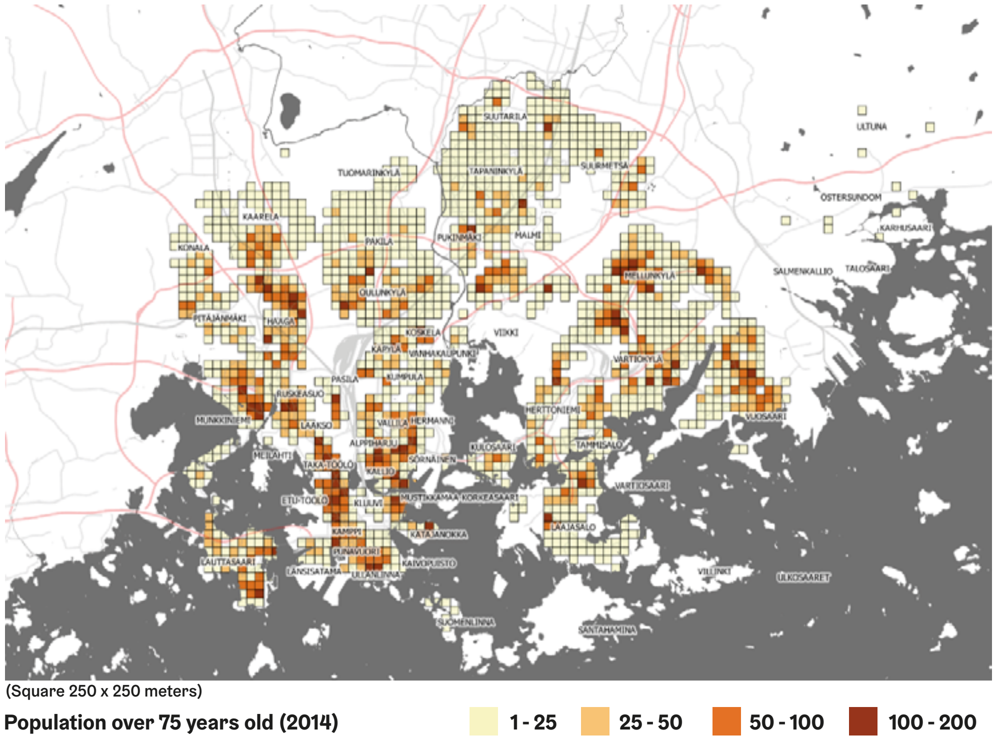


Figure 28. Regional placement of Helsinki residents aged over 75. The greater the number of people aged over 75, the darker the colour. Data: HSY. Map: Athanasios Votsis.

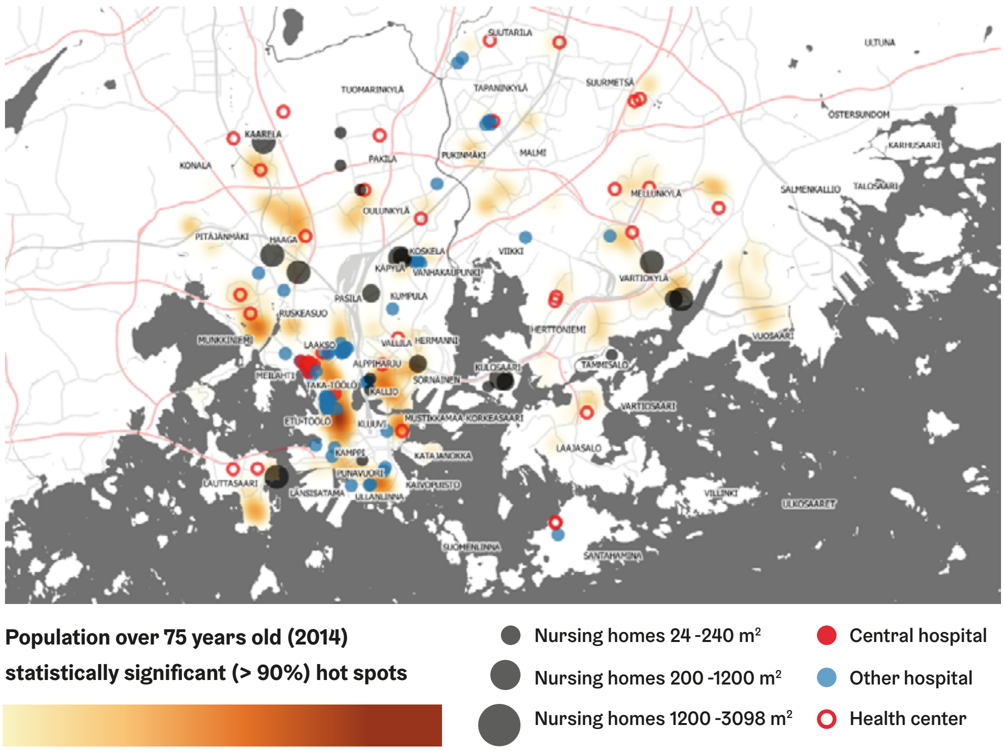


Figure 29. Areas of Helsinki with the most people aged over 75 (reddish colour) and related critical infrastructures. The grey circles represent retirement homes of varying sizes, the red circles represent central hospitals, the blue circles represent other hospitals and the red and white circles represent healthcare centres. Materials: HSY. Map: Athanasios Votsis.

People aged over 75 living in Helsinki and critical healthcare institutions are presented in Figures 28 and 29.

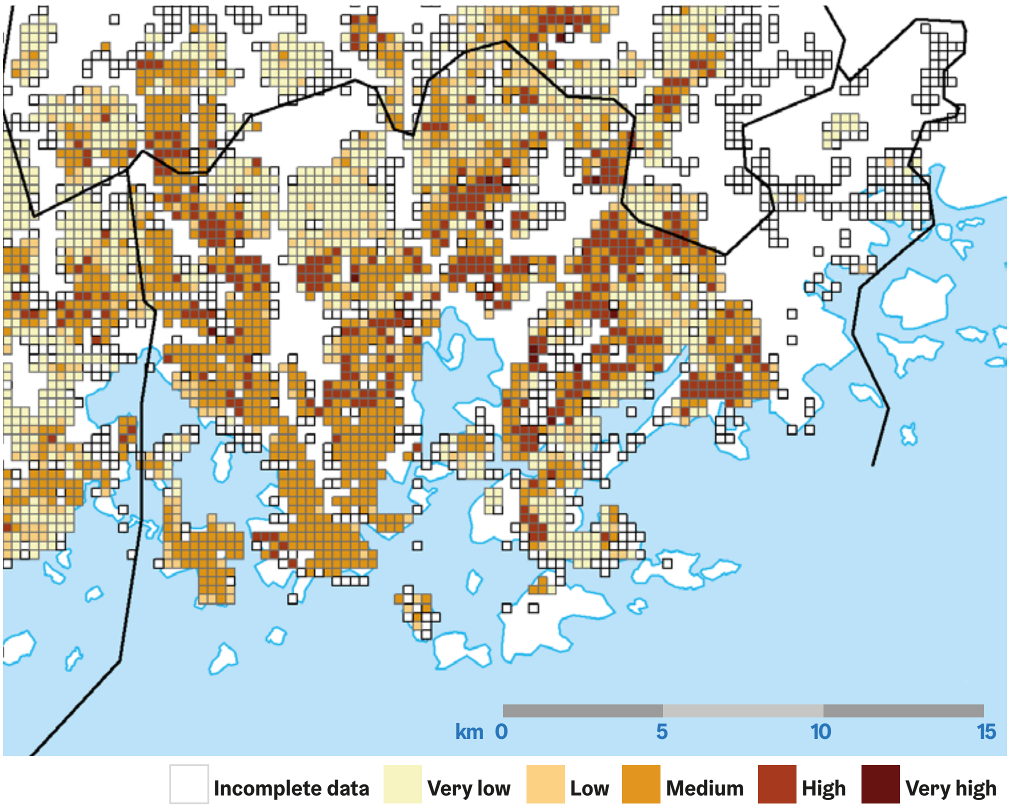
The analysis of social vulnerability to climate change in the Helsinki Metropolitan Area (Kazmierczak 2015) presents a combination indicator that describes the vulnerability of different areas to heat waves. The indicator uses the following factors: People's age, the number of people who have completed basic education, the level of unemployment, the level of income and the form of housing. The environmental factors used are the proportion of vegetation and water areas of the total area (Figure 30[113]).

7.5 The risk caused by heat waves will increase and the risk caused by cold will decrease

Climate change is estimated to increase the number of hot days in Helsinki. As the population ages and care of the elderly becomes increasingly focused on home care, it is expected that the health risks caused by heat waves will increase as well. This can be reacted to by preparing for the situation in healthcare and care of the elderly.

The health risk caused by cold temperatures is likely to decrease due to climate change, but it will not be eliminated. Thus, risk groups must continue to prepare for extremely cold temperatures.

Figure 30. Social vulnerability to heat waves in the Helsinki metropolitan area[114]. The dark colours indicate high vulnerability, while the light colours indicate low vulnerability. White indicates that not enough data was available for the assessment.



[113] Kazmierczak 2016 https://www.hsy.fi/sites/Esitteet/EsitteetKatalogi/Raportit/Social-vulnerability-to-climate-change-Helsinki-metropolitan-area_2.pdf

[114] Kazmierczak 2016 https://www.hsy.fi/sites/Esitteet/EsitteetKatalogi/Raportit/Social-vulnerability-to-climate-change-Helsinki-metropolitan-area_2.pdf

A cold-related, potentially increasing risk is homeless people's exposure to cold temperatures. Helsinki has made great efforts to eliminate homelessness. It must be ensured that homeless people have enough shelters in winter. No deaths among homeless people due to freezing temperatures have been reported in recent years, but the increasing number of paperless people, for example, may cause the number of homeless people to increase.

At the workshop organised during the risk assessment, the level of acceptable impacts during high temperatures was considered. For example, the Social Welfare Act has a section on securing necessary care and financial support[115] (Section 12), and the Health Care Act states that local authorities shall provide their residents with access to medical care services, including but not limited to the prevention and curing of illnesses and alleviation of suffering (Section 24)[116]. **The social and healthcare authorities of Helsinki are already prepared for exceptional situations in their operations, and the starting point is that basic tasks must be carried out uninterrupted in all conditions.**

7.6 Adaptation measures should focus on reducing the effects of heat waves

The following adaptation measures for reducing the effects of heat were identified during the risk assessment process:

- Urban green and blue areas should be used in urban planning to mitigate the urban heat island and reduce the effect of heat waves.
- Workers' well-being must be considered during heat waves by taking care of breaks and hydration.
- Retirement homes should have an action plan for heat waves.
- Heat and cold weather warnings should be utilised in healthcare services' preparedness for increasing patient numbers (healthcare centres and hospitals).

7.7 Needs for heat wave-related follow-up studies

The risks caused by high temperatures and heat waves have not been researched much in Helsinki, and many needs for follow-up studies were brought up during the risk assessment process:

- The functionality of buildings during heat waves should be studied. When building new residential buildings, heat should be taken into consideration in the planning and construction phase and energy-efficient ways to reduce overheating indoors should be surveyed.
- The cooling systems of old residential buildings and their energy efficiency should be assessed, as well as the cost effects of their renewal.
- The impact of heat on working efficiency should be studied.
- Surveying the level of preparedness for heat waves at retirement homes is important, especially in home care for elderly people.
- The level of exposure to heat should be assessed, as well as what additional factors could be taken into consideration when assessing social vulnerability.
- In addition to temperature, the heat and cold stress experienced by people is affected by air humidity, wind and

solar radiation. These factors have been combined in different thermal indexes. The use and applicability of these indexes in describing Helsinki's temperature conditions should be assessed.

The following needs for follow-up studies are related to the urban heat island effect and climate change:

- How will the UHI change as Helsinki is developed and what measures could be used to reduce the risk caused?

- What are the possibilities for using street trees, green roofs and other forms of urban green to cool urban heat islands and reduce the impacts of climate change?

- How accurately does the existing UHI map depict the temperature differences in Helsinki's urban area during heat waves? When the UHI effect was studied[117], no actual heat waves occurred in the summer months.

- What is the heat loss of buildings in winter and how does it affect the UHI effect?

- How will the changing UHI and warming climate affect health risks?

Generally speaking, there is not much information related to summer and its impacts. Thus, the need for further research regarding a potential increase in alcohol consumption and, for example, an increase in the number of tasks related to disorderly behaviour in public places was identified.

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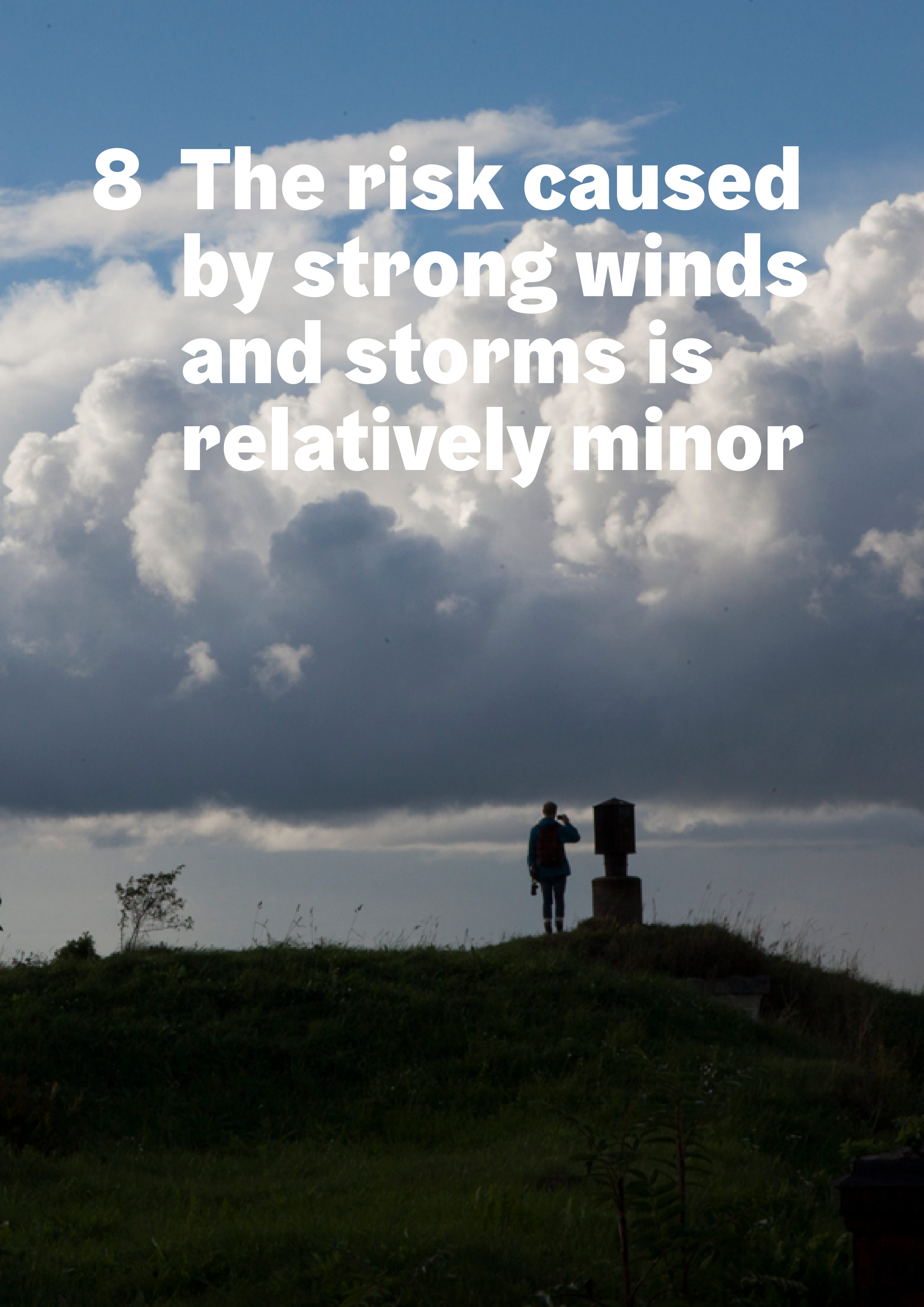
[115] Sosiaalihuoltolaki 1301/2014 https://www.finlex.fi/fi/laki/ajantasa/2014/20141301 (in Finnish)
[116] Terveydenhuoltolaki 1326/2010 https://www.finlex.fi/fi/laki/ajantasa/2010/20101326 (in Finnish)
[117] Drebs, 2011 http://urn.fi/URN:NBN:fi-fe201201121058 (in Finnish)

8 The risk caused by strong winds and storms is relatively minor



8.1 Winds and thunderstorms are not likely to change significantly

Long wind speed observation time series indicate that both mean and stronger winds have slightly decreased in Finland over the last decades. This also applies to Helsinki and its shore areas especially in terms of mean wind speeds, but **as regards the strongest winds, the direction of the change is uncertain**.[118] No similar analysis has been carried out regarding storm winds and especially wind gusts.

Based on climate scenarios, the mean wind speeds will change very little in Helsinki. Figure 31 presents the changes in accordance with the RCP8.5 scenario, which represents very high greenhouse gas emissions. The image shows that up to the middle of the 21st century, the percentage change in mean wind speeds is no greater than a few percent. However, it should be noted that the different model results (grey area) differ from one another considerably. Some of the climate models estimate an increase of almost 10% in the wind speeds, while others estimate an equal decrease.

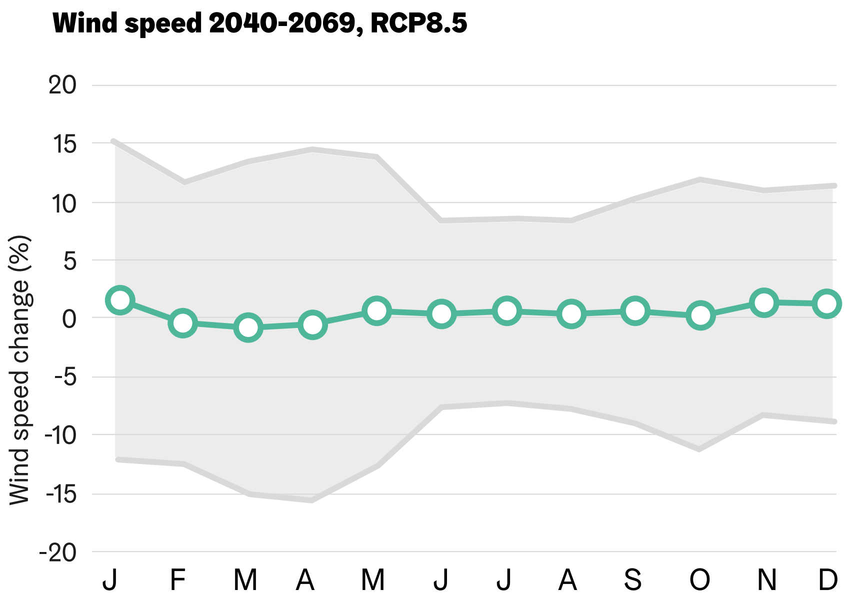
Changes in strong winds have not yet been estimated based on the latest climate models, but according to the Finnish Meteorological Institute's expert estimate, they are likely to change at the same rate as the mean winds, i.e. by a few percent.

On the other hand, changes may occur in wind directions. Older climate models can be used to conclude that western winds appear to become more common, while eastern winds will become less common[120].

On average, Helsinki has annually 13 days of thunder. The thunder season takes places primarily between May and September, during which the average number of lightnings is approximately 26/100 km^2. On average, thunderstorms are most common in August. Thunderstorms can also occur in Helsinki in cold months (October–April), but they typically cause only a few lightnings. It is typical of Finland' thunder climate that the

[118] Laapas & Venäläinen, 2017 http://doi.org/10.1002/joc.5124
[119] Ruosteenoja et al., 2016 http://www.geophysica.fi/pdf/geophysica_2016_51_1-2_017_ruosteenoja.pdf
[120] Ruosteenoja et al., 2013 http://hdl.handle.net/10138/42362

Figure 31. **Percentage changes in monthly mean wind speeds according to the RCP8.5 scenario representing high greenhouse gas emissions. The circles indicate the mean of the model results and the grey area indicates a 90% uncertainty range.**[119]



mean annual number of lightnings (or even more) can occur in one thunderstorm. One example of this is storm Kiira on 12 August 2017.

According to the latest research information[121], the number of storms will increase in Europe by the end of the century. For example, the RCP8.5 scenario indicates a 30–60% increase. The increase can be seen especially in the late 22nd century. However, it is very uncertain which European countries will experience more and which countries will experience potentially fewer storms. The increase in the number of storms is likely to be the greatest in Southern and Central Europe, while in Northern Europe, the change could be minor. It is important to understand that as climate becomes warmer, an individual storm in Helsinki, for example, could be more intense than before, or that the proportion of the most intense storms among all storms could be greater in the future compared to the current situation, even if no change occurs in the overall number of storms.

8.2 The 2017 storm Kiira damaged trees and overwhelmed the emergency telephone number

The impacts of strong winds and storms on people and economic activities have been relatively minor in Helsinki due to proper risk management. In the summer of 2017, storm Kiira swept over Helsinki, causing the Helsinki City Rescue Department approximately 500 requests for rescue operations, and all of Helsinki's 13 volunteer fire departments were alerted.[122] The most critical problem was that the Kerava Emergency Response Centre was overwhelmed, and in Helsinki, the average queuing time for the emergency telephone number was almost 20 minutes at its longest[123]. Helsinki had a procedure in place in which the Rescue Department's Situation Centre prioritised the Emergency Response Centre's duties and distributed them to the rescue units. For example, the outdoor festival Flow had to cancel performances due to the storm Kiira, but personal injuries were avoided. The storm had sizeable impacts on Helsinki's forest areas and parks. It felled or damaged approximately 10,000 trees around Helsinki. Furthermore, it left upright trees that are susceptible to new damage[124]. The aftercare kept Helsinki City Construction Services Stara busy long into the autumn.

8.3 The majority of Helsinki's power lines are underground cables

Unlike in other parts of Finland, storms rarely cause power outages in Helsinki. This is due to the 96% underground cabling degree of Helen Electricity Networks' electricity network. In Helsinki's newest district, Östersundom, the situation is different, because the district is covered by Kerava Energy's distribution network.

Helsinki holds many significant public events, many of which take place outdoors in summer. The event organisers are responsible for the safety of their events, and legislation[125] provides that a rescue plan must be created for public events estimated to be attended by more than 200 people. The Helsinki City Rescue Department instructs the organisers of public events to prepare for different weather conditions. At outdoor events, the weather conditions must always be considered in the rescue plan. Key matters to consider include but are not limited to evacuation planning, instructing the attendees to prepare independently and the proofing of the structures. Monitoring weather forecasts is ultimately the responsibility of the event organiser, and the organiser must assess the situation and carry out the necessary procedures. Recently, more attention has been paid to the supervision of public events in terms of weather conditions.

Boating is also sensitive to strong winds, and boaters may be caught unprepared. **Consequently, it is very important for boaters to follow weather forecasts to reduce the risks.**

8.4 The risk caused by winds and storms is not likely to change significantly

The frequency of strong winds and storms, such as storm Kiira, is estimated to increase somewhat in the future, but the changes in winds will probably remain minor. The risk caused by strong winds and storms will not necessarily change significantly due to changes in windiness[126 127], but the decrease in ground frost in the winter season will make trees more exposed to strong winds[128].

Event organisers must anticipate the potential risk caused by storms and strong winds, and citizens must be reminded of risks, such as those caused by falling trees.

121 Groenemeijer, et al. 2016 https://www.researchgate.net/publication/308034040_Present_and_future_probability_of_meteorological_and_hydrological_hazards_in_Europe
122 Puranen, 14.8.2017 http://pelastustieto.fi/pelastustoiminta/operatiivinen-toiminta/kiira-myrsky-riehui-vakinaiset-ja-vpkt-toissa-kellon-ympari/ (in Finnish)
123 Hätäkeskuslaitos, 14.8.2017 http://www.112.fi/ajankohtaista/uutiset/2/0/kiira-myrsky_ruuhkautti_keravan_hatakeskuksen_73940 (in Finnish)
124 City of Helsinki, 31.8.2017 https://www.hel.fi/uutiset/fi/kaupunkiymparisto/kiira-310817 (in Finnish)
125 Valtioneuvoston asetus pelastustoimesta 2011/407 (3 § 1) https://www.finlex.fi/fi/laki/ajantasa/2011/20110407 (in Finnish)
126 Groenemeijer, et al. 2016 https://www.researchgate.net/publication/308034040_Present_and_future_probability_of_meteorological_and_hydrological_hazards_in_Europe
127 Outten & Esau, 2013 http://doi.org/10.5194/acp-13-5163-2013
128 Lehtonen et al. 2018 https://doi.org/10.5194/hess-2017-727

9 Diseases and ecological changes also create risks

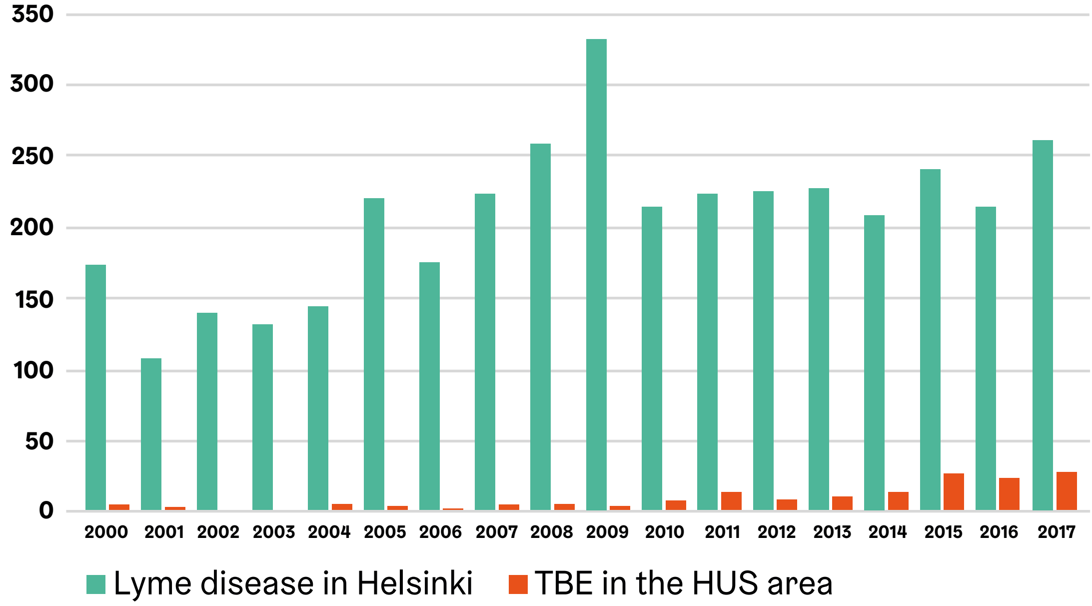
9.1 Vector and water-borne disease risks depend on weather and people's behaviour

In Helsinki, the most significant vector-borne diseases are the tick-borne Lyme disease and tick-borne encephalitis (TBE). They are called vector-borne diseases because they are spread by transmitter organisms, i.e. vectors. According to latest research information, ticks have spread to nearly every part of Finland. 15–20% of the ticks carry Lyme disease and approximately 1.5% carry TBE[129]. The transmission of these diseases to people is largely related to people's behaviour, especially free-time hobbies. On the islands off the coast of Helsinki, ticks carry TBE, against which a vaccine is available. There is no vaccine against Lyme disease, but the disease can be treated with antibiotics.

In Helsinki, the risk of tick-borne diseases is at its highest in the archipelago. However, ticks are found almost everywhere, but **there are no exact figures for Helsinki in terms of how large a proportion of ticks carry pathogens**. Several cases of Lyme disease are reported each year in Helsinki, and cases of TBE have been increasing in the HUS area since 2010 (Figure 32). However, it must be taken into account that some of Lyme disease cases may have been contracted elsewhere, but the doctor's diagnosis was given in Helsinki.

[129] Reumaliitto: Enjoy the summer – protect yourself against ticks https://www.reumaliitto.fi/fi/punkki (in Finnish)

Figure 32. Prevalence of Lyme disease in Helsinki (green bars) and prevalence of TBE in the HUS area (orange bars) in 2000–2017. Source: THL infectious disease register[130]



Weather and climate conditions affect the presence and activity of ticks, and warming climate will probably increase the prevalence of ticks and tick-borne diseases as the growing season becomes longer. Ticks thrive in temperatures of +5–25 °C and high humidity, and they cannot withstand long droughts. Thus, the tick season begins with the growing season and ends with freezing temperatures. However, the active temperature is different in the different phases of ticks' three-phase lifecycle. In the spring, the rise in temperature makes it possible for the larvae and the nymphs to feed at the same time, which increases the prevalence of disease microbes.

Helsinki Region Environmental Services Authority HSY, which is the water utility of the region, draws its raw water from Lake Päijänne. Due to the level of the quality monitoring of the household water, there is only a minor risk of water-borne diseases. Climate-related water-borne diseases are usually related to torrential rains, as impurities in the soil contaminate household waters. Such situations are the most likely in areas with small water plants whose raw water quality monitoring is irregular, or in areas in which water is drawn from wells.

In Helsinki, it is possible for water-borne diseases to spread from the beaches, and the weather connection is related to both people's behaviour and the development of microbial strains. During the summer of 2014 heat wave, approximately 1,500 people fell ill, which was connected to contaminated bathing waters.[131] When the weather is warm, people use beaches, and several confirmed epidemics are based on faecal contamination. The presence of blue-green algae also increases in warm and calm conditions. In warm waters, microbes spread more rapidly than in cold waters. Torrential rains, on the other hand, can wash disease microbes from the soil into the shore waters.

9.2 The risk of plant diseases increases as climate changes

Due to climate change, plant diseases and insect pests will also be more likely to spread to urban trees. One of the latest disease cases found in Helsinki was a case of *Hymenoscyphus fraxineus* diagnosed in horse-chestnuts in autumn 2017, but elm disease is yet to be observed. In 2016, the broadleaf tree-destroying Asian long-horned beetle was found in the City of Vantaa, bordering Helsinki in the north. In 2017, Helsinki studied the potential occurrence of the species. The risk will increase due to climate change. To adapt, increasing monitoring and species diversity can be used.

9.3 The Baltic Sea is susceptible to changes

Climate change affects the biodiversity of the Baltic Sea. The rise in the sea water temperature will change the species composition and, for example, species that have adapted to cool water will probably regress while more southern species thrive[132].

Due to warming climate, invasive species will prevail in the Baltic Sea more easily than before. Heavy ship traffic has already introduced around one hundred invasive species, some of which have been able to become established[133]. The Prussian carp is a fish species that has benefitted from warming and eutrophication. The species has arrived in the coastal waters of Helsinki in recent years from Estonia. The species is able to withstand very low-oxygen conditions[134]. New species compete for resources with the existing species and can change the food chains[135 136].

The geographical prevalence of organisms is also affected by the salinity of the Baltic Sea, which may decrease due to climate change[137 138]. The salinity will decrease due to increased rains, which cause fresh water to run into the Baltic Sea. The decrease in salinity may threaten so-called key species, whose existence several other species are dependent on. Of the species of fish currently fished in the Gulf of Finland, low salinity can have an adverse effect on the reproduction of at least the European sprat and the European flounder. Then again, the European sprat may benefit from a moderate rise in temperature[139].

An increase in carbon dioxide concentration in the atmosphere increases the dissolution of carbon into sea water, causing the water to acidify. Acidic water dissolves calcium compounds and hinders the growth of organisms with a calcareous skeleton, which affects food chains. It is estimated that acidification will reduce some mussel species living in the Baltic Sea, for example[140].

At the end of the century, the majority of the Gulf of Finland will remain without ice cover over average winters, as the ice winters on the Baltic Sea will become shorter by an average of 1–3 months compared to the current situation[141]. The lack of ice will reduce the mixing of the sea water and increase its layering. The water currently mixes in winter as the surface water approaches freezing point, whereby it becomes heavier than the warmer water below it. This results in the surface water descending through the deep water, causing efficient mixing. If the surface water no longer becomes cooler than the deep water due to warming climate, the mixing may stop entirely. This would hinder the oxidation of the deep water and slow down the transfer of nutrients to the surface, which in turn would have an adverse impact on the water organisms living in the Baltic Sea.[142]

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130 Terveyden ja hyvinvoinnin laitos. Statistical database of the infectious disease register https://www.thl.fi/ttr/gen/rpt/tilastot.html (in Finnish)
131 Kauppinen et al. 2017 http://dx.doi.org/10.2807/1560-7917.ES.2017.22.8.30470
132 Mäkinen et al., 2008 http://hdl.handle.net/10138/37930
133 Mäkinen et al., 2008 http://hdl.handle.net/10138/37930
134 Urho, 2011 www.rktl.fi/www/uploads/pdf/uudet%20julkaisut/tyoraportit/kalasto_ilmastonmuutos.pdf (in Finnish)
135 BACC Author Team, 2008 http://www.hzg.de/imperia/md/content/baltex/springer_bacc_complete.pdf
136 Urho, 2008 http://urn.fi/URN:NBN:fi-fe2015102915235
137 Graham, 2004 http://doi.org/10.1579/0044-7447-33.4.235
138 HELCOM, 2013 http://helcom.fi/Lists/Publications/BSEP137.pdf
139 Urho, 2011 www.rktl.fi/www/uploads/pdf/uudet%20julkaisut/tyoraportit/kalasto_ilmastonmuutos.pdf (in Finnish)
140 Green, et al. 2004 http://doi.org/10.4319/lo.2004.49.3.0727
141 HELCOM, 2007 http://helcom.fi/Lists/Publications/BSEP111.pdf
142 Viitasalo, et al. 1995 http://doi.org/10.1093/plankt/17.10.1857

Eutrophication is the most significant factor threatening underwater habitats, and warming climate may increase it[143]. Eutrophication is caused by nutrients from the soil and farmlands dissolving into water and being transferred to the Baltic Sea via rivers. The nutrient runoff will increase due to increased rains caused by climate change, bare soil and the increase in sea water temperature, which expedites the degradation of organic matter on the sea floor[144]. In the Baltic Sea, eutrophication causes problems such as the water becoming more turbid and the sea floor becoming devoid of oxygen. It also increases the occurrence of filamentous algae, which displace other species.[145]

In the Gulf of Finland, the rise in temperature, the sea water becoming increasingly layered and phosphorus being released from the sea floor can increase the occurrence of toxic blue-green algae blooms – unless the nutrient loading from land can be reduced[146].

Climate change can also intensify the impacts of several harmful substances, such as heavy metals, dioxins and PCB, on marine life. A rise in the water temperature combined with decreased salinity can cause physiological stress to organisms that have adapted to cooler and more saline water. As a result, they may become more exposed to the adverse impacts of toxic chemicals accumulated in the Baltic Sea. The rise in temperature will speed up organisms' metabolism, potentially making harmful substances accumulate faster. Furthermore, metals have been observed to accumulate more easily in water organisms in low salinity.[147]

This chapter is based on the web portal Climate Guide's articles *Itämeren erityispiirteet saattavat kadota ilmaston muuttuessa*[148] (The special characteristics of the Baltic Sea could disappear as the climate changes) and *Ilmastonmuutos voi muuttaa kalalajien voimasuhteita Etelä-Suomessa*[149] (Climate change could change the balance of power between species of fish in Southern Finland).

9.4 Drought causes ecological impacts – the risk of forest fires is very minor

The most significant direct impacts of drought are probably those on nature and people's health. However, the effects of drought have not been researched much in Helsinki.

Based on the latest climate models, in Southern Finland, drought will increase primarily in spring due to snow and ground frost melting sooner than currently. In the other seasons, the climate models do not indicate as significant a change in drought in Northern Europe[150], and the difference compared to Southern Europe is considerable. Figure 33 illustrates how drought will increase in Helsinki by the middle of the century. According to the RCP4.5 climate scenario of moderate greenhouse gas emissions, the annual probability of a drought period will be 20% (recurring statistically once every five years on average), while the probability in the period of 1961–2005 was 10% (recurring once a decade on average) [151].

143 Mäkinen et al., 2008 http://hdl.handle.net/10138/37930
144 Meier et al. 2012 http://doi.org/10.1007/s00382-012-1339-7
145 Mäkinen et al., 2008 http://hdl.handle.net/10138/37930
146 Meier et al. 2012 http://doi.org/10.1007/s00382-012-1339-7
147 HELCOM, 2007 http://helcom.fi/Lists/Publications/BSEP111.pdf
148 SYKE, 31.12.2014 http://ilmasto-opas.fi/fi/ilmastonmuutos/vaikutukset/-/artikkeli/9f658194-8627-4ca9-b2e8-ed339bb4c1b9/itameren-erityispiirteet-saattavat-kadota-ilmaston-muuttuessa.html (in Finnish)
149 SYKE, 21.11.2014 http://ilmasto-opas.fi/fi/ilmastonmuutos/vaikutukset/-/artikkeli/4e34ef1e-95f5-4a93-aa0b-1011f6bf42c6/ilmastonmuutos-voi-muuttaa-kalalajien-voimasuhteita-etela-suomessa.html (in Finnish)
150 Ruosteenoja et al., 2017 http://doi.org/10.1007/s00382-017-3671-4
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The drought of 2002–2003 caused a large number of trees to die in Helsinki. Trees also have many factors that make them exposed and vulnerable to drought. Trees that are in poor condition are more sensitive to drought than healthy trees, i.e. the health history of trees affects their vulnerability. Additionally, their habitat, diseases and forest management play a role. In Helsinki, one factor that increases the vulnerability of trees is the fact that residents value old forests and old park trees, which are more susceptible to various stress factors, such as drought periods, diseases and pests.

Thus, the impacts of drought on forest growth will not necessarily increase significantly due to climate change, as for trees, drought during the growing season is the most significant factor. However, increasing drought periods must be prepared for, especially in the maintenance of green areas.

In Helsinki, increasing drought is not among the most significant risks, but in park maintenance, as well as in the nature management and forest maintenance, the possibility of drought should be kept in mind. Furthermore, species diversity should be favoured and new species tried in forest plantings.

According to the Helsinki City Rescue Department's risk analysis, the risk of forest fires is minor in the Helsinki City Rescue Service's area. The potential risk exists in the Santahamina garrison area and the larger forest areas of Northern Helsinki. The risk of forest fires is taken into account in the planning of the Rescue Department's extinguishing water arrangements, the utilisation of voluntary fire departments' resources, and co-operation with the authorities and the other rescue service areas in the Uusimaa region.

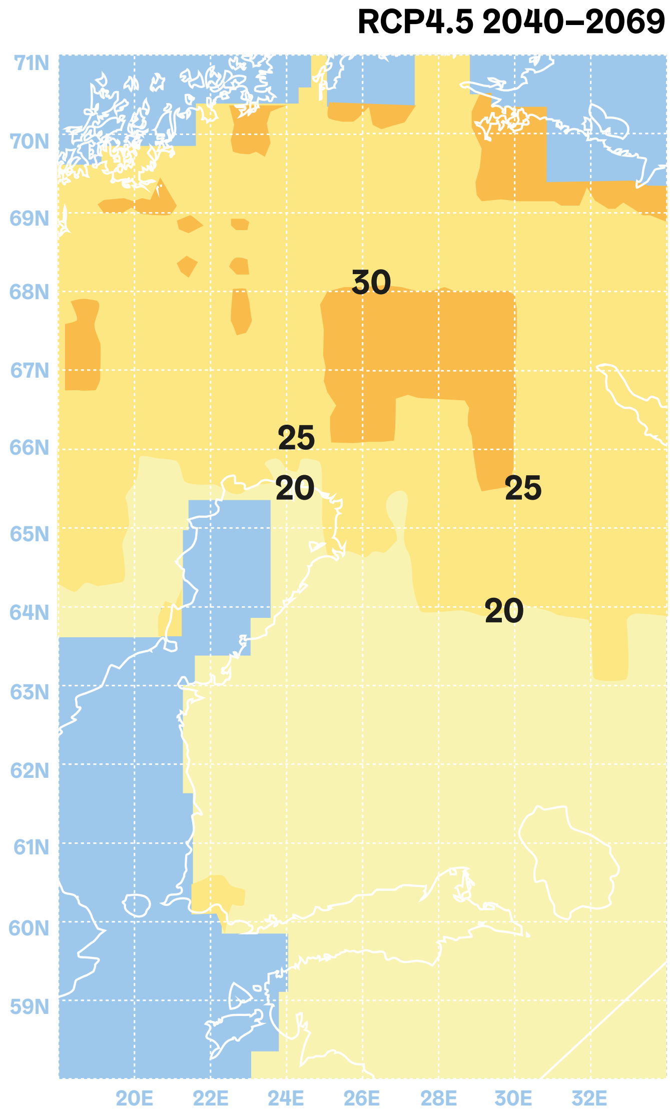

Figure 33. The annual probability of a drought period in soil (in %) in summer (between June and August) in the period 2040–2069 according to the RCP4.5 scenario representing moderate greenhouse gas emissions.[152]

9.5 Changing conditions and invasive species can threaten ecosystems

In Helsinki, the impacts of climate change on nature must be examined and taken into consideration in conjunction with urban development. As the city becomes denser, the amount of green areas is reduced and their ecological quality is often weakened, as the remaining green areas will be subjected to increasing pressure. Functioning ecosystems and diverse nature are important in the city as well. Cities' nature reserves are small and the green network is fragmented. Thus, there are plenty of disturbances. However, Helsinki still has forests, green areas and nature reserves. Many of Helsinki's islands with significant natural values will be subjected to changes due to development or when they are opened to the general public, which also increases the pressure placed on the archipelago's nature by climate change.

In addition to changes in drought (Chapter 9.4) and ground frost (Chapter 8), rain, wetness and decreased snowfall in the winter season will cause impacts on nature. **Helsinki's climate zone may change by the middle of the century, with the winter climate changing from cold to mild[153].** Thus, it has been estimated that the degree-days and temperature in the coldest month in Helsinki would be similar to the current climate of Latvia, Lithuania and parts of Denmark. The rapid change in winter conditions changes the living conditions of many plant species. Consequently, there is a significant risk of certain species being unable to adapt and spread to new areas. If the species are in habitats in which they live as significant 'key species', the impact may extend further as a disruption in the functioning of ecosystems, for example. It is not yet known how the loss of species will affect habitats and the functioning of ecosystems.

The impact of climate change on the invasive species risk in Helsinki has not been researched in detail. The Helsinki City Budget 2018 states that "climate change will also increase the risk of spreading of new plant diseases and pests. Vegetation-related risks can be prevented by diversifying the range of species of park plants and urban trees to better suit the changing climate conditions. Efforts will be made to prevent the spreading of invasive species"[154]. Invasive species and combating them are causing significant costs in the City's maintenance operations. **In combating invasive species, prevention is both more cost-efficient and environmentally friendly than repairing damage that has already occurred and combating species after they have already settled in Finland[155]**.

At the level of Southern Finland, the risk was assessed in 2012[156]. The key conclusions of the assessment are:

In the Northern European conditions, primarily the warmth of the growing season or the coldness of winter can limit the spreading of invasive species . Invasive species whose spreading and thriving are significantly limited by the wintering conditions (occurrence of cold periods in the winter season) will probably not be able to settle in Finland and expand their area of prevalence as quickly as invasive species whose area of prevalence is determined primarily by the temperature sum of the growing season. For example, among mammals, the impacts of winter conditions often manifest themselves through two main factors: the amount and duration of the snow cover and the exis-

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153 Jylhä et al., 2010 http://doi.org/10.1175/2010WCAS1010.1
154 City of Helsinki, 2017 https://www.hel.fi/static/kanslia/Julkaisut/2017/HKI_TA_2018_web.pdf (in Finnish)
155 City of Helsinki, 2015 https://www.hel.fi/static/ymk/lumo/helsingin-vieraslajilinjaus-2015-2019.pdf (in Finnish)
156 Heikkinen et al. 2012 https://helda.helsinki.fi/handle/10138/38721

tence of ice cover. Furthermore, trees and bushes may be more sensitive to winter conditions than grasses that winter on the ground level. Several insect species are also hibernate the cold winter months in sheltered locations. New species will migrate to Finland from the south as the climate zones move north. However, it is not yet known if there will be suitable habitats for them.

Different environments that have been significantly modified by human activities are places in which invasive species thrive particularly well. In Helsinki, these include but are not limited to the urban environment, harbours, industrial areas and roadside areas. Plenty of invasive species also occur in various wetland and shore environments.

The impacts of climate change will manifest themselves as strengthening invasive species populations, the development of new viable populations, the spreading of species into entirely new areas and the intensifying of their adverse impacts, as well as the spreading of new invasive species capable of reproducing in nature. **Due to climate change, the number of invasive species may increase and the current invasive species may survive and reproduce in areas that are currently climatically unsuitable for them.**

In the coming decades, climate warming will make it possible for harmful invasive species that currently occur in the Baltic countries and Denmark to spread and thrive in Finland. The harmful invasive species of these countries include species that already occur in Finland (e.g. the large-leaved lupine, the rugosa rose and the American mink), species that are currently gaining a foothold in Finland (e.g. the Canada goldenrod, which has already spread in many areas in Helsinki) and species that are yet to significantly escape into the wild or do not occur in Finland (e.g. the wild cucumber and the harlequin ladybeetle).

Climate change must be taken into consideration when selecting the plants, something that has already been done in Helsinki[157]. Increasing the species diversity in parks and street areas has been proposed and implemented as an adaptation measure. As regards forests, the nature management policies (2011)[158] state that deciduous tree plantings, among other things, are to be favoured in suitable habitats: growing beeches has been tried in different parts of the city.

[157] Tegel, 2009 https://www.hel.fi/hel2/hkr/julkaisut/2009/kasvien_kayton_linjaus_11_2009.pdf (in Finnish)
[158] Saukkonen, 2011 https://www.hel.fi/static/hkr/julkaisut/2011/luonnonhoito_web.pdf (in Finnish)

10 Focus on security of supply in transboundary impacts

Transboundary impacts refer to the interaction chains between weather and climate variability and climate change, which begin outside of Finland but eventually extend all the way to Finland. Transboundary impacts have not been researched much in Finland. The most extensive assessment was carried out in the ELASTINEN project funded by the Prime Minister's Office of Finland, and the rough estimate presented here is based mainly on the analysis of the ELASTINEN project[159]. **The risks related to transboundary impacts should be studied carefully in Helsinki.** When examining transboundary impacts, attention should be paid beyond impacts coming from outside of Finland. Impacts occurring in other parts of Finland can also have consequences in Helsinki, e.g. through agriculture.

Helsinki's security of supply (energy, food, etc.) is highly dependent on production and industry that take place elsewhere. **In primary production and industry, transboundary impacts occur especially in the availability and prices of raw materials and production factors, as well as demand in the export market.** The availability of goods and a sudden increase in prices due to, for example, an extensive drought can have significant impacts on low-income residents of Helsinki. Helsinki should also assess how dependent the city is on activities vulnerable to climate change in other parts of Finland.

The energy sector in Finland is heavily dependent on imports, and as transfer connections develop, the possibility of transboundary impacts increases. The availability and price of fossil-based imported energy have a particular impact in Helsinki. With the potential increase in the use of bio-energy, the global fluctuations in the bio-energy production due to climatologically extreme phenomena are also likely to be reflected in the price of Finnish bio-energy.

The extend of human migration related to climate change is difficult to estimate, as also political and economic reasons play a role in the background. Long-term human migration can, however, have various impacts on the population structure and culture in Finland. Furthermore, Helsinki should prepare for new extensive, partly uncontrollable immigration in services such as healthcare and the needs assessments concerning temporary accommodation and housing.

Health-related transboundary impacts can occur as diseases strengthened by climate change are transmitted to Finland. They can be transmitted by tourists, immigrants or the migration movements caused by climate change if the tourists or immigrants carry certain diseases, such as tuberculosis or the measles. The health care sector should prepare for the changing health risks. International trade can also bring pathogens to Finland. To adapt, it is important to prevent the spreading of new diseases and develop vaccines and health education.

The tourism industry is very sensitive to weather and climate conditions. **As the climate changes, the flow of tourists from Finland to other countries and vice versa can change**. Finland has been identified as a country whose attractiveness as a travel destination may increase with climate change or when the safety situation weakens elsewhere. However, it must be kept in mind that factors such as the general economic situation and development in the countries of origin have a strong effect on the development.

Long-term economic transboundary impacts are difficult to estimate. It has been estimated that climate change will decrease the global gross domestic product, which is reflected in Helsinki as well. This may have a variety of impacts on the City's operations. The international financial markets' reaction to the changing climate is also challenging to estimate.

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[159] Hildén et al., 2016
http://tietokayttoon.fi/julkaisu?pubid=15405 (in Finnish)

11 Cost efficiency is important when selecting adaptation measures

The economic efficiency of the risk management and adaptation measures should be an important criterion when selecting measures. It is also important to assess measures that have already been implemented and learn from them. Thus, economic analysis should support decision-making. The underlying purpose of economic analyses is to examine different procedures from the perspective of economic efficiency. This may help prioritise measures, also sector-specifically or at the societal level, and determine flexible measures. This chapter is based on the ELASTINEN project funded by the Government's report and research department[160], where one theme was the use of economic analysis methods in adaptation-related decision-making in Helsinki[161]. Experts from Helsinki's different departments and the Helsinki Region Environmental Services Authority (HSY) were interviewed for the assessment.

160 Proactive management of weather and climate related risks ELASTIN EN-project https://en.ilmatieteenlaitos.fi/fi/elastinen
161 Pilli-Sihvola et al. 2016 http://tietokayttoon.fi/julkaisu?pubid=15404 (in Finnish)

The most used economic analysis method in urban planning is cost-benefit analysis, which has been used in particular in assessing flood protection measures. The BaltCiCa project (2007–2013)[162] was the first project to assess the need for adapting to climate change in Helsinki. The project identified that when assessing adaptation needs and measures, economic thinking and cost-benefit analyses are needed as well. There is also a need for a cost data bank to support adaptation-related decision-making. Economic thinking in assessing adaptation measures was introduced in the Climate-proof City – Tools for Planning (ILKKA) project. The project used expert workshops to prioritise the City of Helsinki's adaptation measures by assessing the necessity of 46 actions. Additionally, seven cross-cutting themes were identified and they were used to understand the research needs related to adaptation actions and how their efficiency could be improved. The project report confirms the view that the promotion of climate change adaptation would require, among other things, the implementation of cost-benefit analyses to support decision-making[163].

In other words, the need for carrying out cost-benefit analyses in Helsinki's adaptation policy has already been identified. However, it can be concluded from the interviews that **in practice, cost-benefit analyses are not used, but a need for two other economic assessment methods was found**:

1) **Assessment of the measures' lifecycle costs:** "The use of a cost-benefit analysis in Helsinki is not necessary in all cases, as the starting point for flood risk management is the achievement of goals, i.e. the achievement and maintenance of the accepted risk level. To achieve the accepted risk level, storm water pipes and delaying and retention structures shall be planned so that floods that occur at a certain statistical frequency do not cause problems in the area. To support goal-based decision-making, the lifecycle costs of different measures should be assessed, as the investment and opportunity costs of the measures vary in the different implementation phases. For example, the initial investment and opportunity costs of the green areas of a new residential area are higher in practice than those of storm water pipes. However, in the long run, due to, for example, increasing uncertainty due to climate change, the lifecycle costs of the green areas may be lower than those of redimensioning the storm water pipes. By comparing the lifecycle costs of different measures, a certain risk level could be achieved with minimal costs.

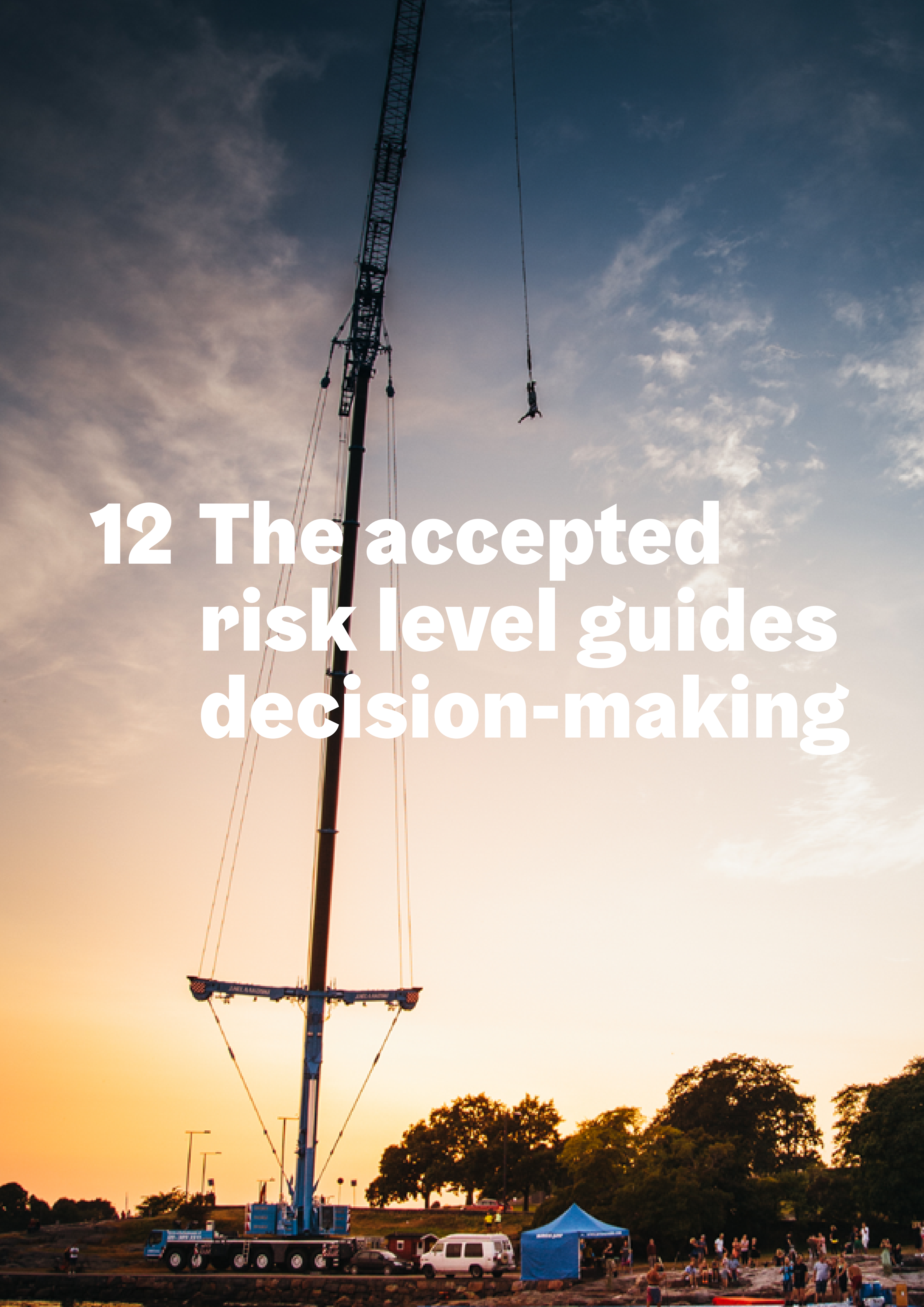
162 The BaltCICA Project http://www.baltcica.org/
163 Yrjölä & Viinanen 2012 http://www.hel.fi/static/ymk/julkaisut/julkaisu-02-12.pdf (in Finnish)

The City's decision-makers should be provided with centralised information concerning the lifecycle costs of different measures and the information tool should be readily available in different decision-making and work phases. Thus, economic prioritisation could be carried out easily in the planning phase."

2) **Cost-benefit analysis**: "The need for cost-benefit analysis has been identified in Helsinki, but there are not many cost or benefit assessments for planners and decision-makers to use. The goal orientation of urban planning hinders the utilisation of cost-benefit analyses, but using the method is especially important when explaining the benefits of green areas to different operators, for example. Cost-benefit analysis facilitates the prioritising of different measures, i.e. what measures should be carried out and in what order, taking the City's resources into consideration. The prioritisation in the ILKKA-project carried out in Helsinki was created from a stakeholder benefit perspective, and the perspective of economic efficiency was not taken into account. The measures should be examined from an economic perspective before sizeable flood damage occurs in Helsinki, as the potential impacts can be significant, especially if the flood waters enter the underground structures.

An important part of cost-benefit analysis is understanding the chains of impacts of weather and climate risks and their related uncertainties. Some historical information about the impacts is available, and it is important to start collecting it systematically. After that, the benefits (avoided damage) of the different measures can be assessed more accurately."

12 The accepted risk level guides decision-making



This weather and climate change risk assessment introduces a new concept into the discussion related to Helsinki's weather and climate risk preparedness and climate change adaptation: the accepted risk level. **Accepted risk level refers to the potential impacts of extreme weather events and climate change that are accepted as taking place, i.e. no efforts will be made to reduce them with adaptation and preparedness measures.** The notion of the accepted risk level guides the decision-making related to adaptation and preparedness, and thus the existence of the notion should be acknowledged. An interesting topic for a follow-up study would be to determine the weather and climate impact risk level accepted by residents, City elected politicians and the City's officials and organisations.

However, the accepted risk level is difficult to determine, as it involves taking social, political and economic perspectives and various interests into consideration. The accepted risk level is always based on both facts and value judgments. **The accepted risk level can be determined by experts with their own know-how, but decision-makers still have the final say on implementing the actions.**

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Global Covenant of Mayors for Climate & Energy. https://www.globalcovenantofmayors.org/ [Vierailtu 20.2.2018.]

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APPENDIX 1
Parties involved in creating the work

Climate risk working group

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Urban Environment Division (Kymp), Environmental Services (Ympa)

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City Executive Office, Safety and Preparedness Unit

Rekola, Hanna
Rescue Department

Saari, Petri
Helsinki Region Transport (HSL)

Vuosalmi, Anssi
City Executive Office, Safety and Preparedness Unit

Workshop attendees

NAME, OFFICE/DIVISION	WORKSHOP 1	WORKSHOP 2
Evokari, Viliina *Urban Environment Division, Environmental Services*	●	●
Haahla, Anu *Urban Environment Division, Environmental Services*	●	●
Haapala, Auni *Urban Environment Division, Environmental Services*		●
Huvila, Heidi *Urban Environment Division, Environmental Services*	●	●
Ignatius, Sonja-Maria *Urban Environment Division, Environmental Services*	●	●
Kankaanpää, Susanna *Helsinki Region Environmental Services (HSY)*	●	●
Kokkonen, Annukka *Social Services and Health Care Division, Facility Services*		●
Korhonen, Juha *Urban Environment Division, Environmental Services*		●
Korpi, Ilkka *City Executive Office*	●	●

NAME, OFFICE/DIVISION	WORKSHOP 1	WORKSHOP 2
Koskinen, Matti *City Executive Office, Safety and Preparedness Unit*	●	●
Lahdenperä, Paavo *Urban Environment Division, Land Use and City Structure Department (Maka)*	●	●
Lukin, Markus *Urban Environment Division, Environmental Services*		●
Nurmi, Paula *Urban Environment Division, Land Use and City Structure Department*	●	
Rantsi, Jari *Urban Environment Division, Land Use and City Structure Department*		●
Rekola, Hanna *Rescue Department*	●	
Takainen, Heikki *Urban Environment Division, Land Use and City Structure Department*	●	●
Tyynilä, Suvi *Urban Environment Division, Land Use and City Structure Department*		●
Viinanen, Jari *Urban Environment Division, Environmental Services*	●	●

APPENDIX 2
Methods

MATERIALS USED AND MATERIAL COLLECTION:

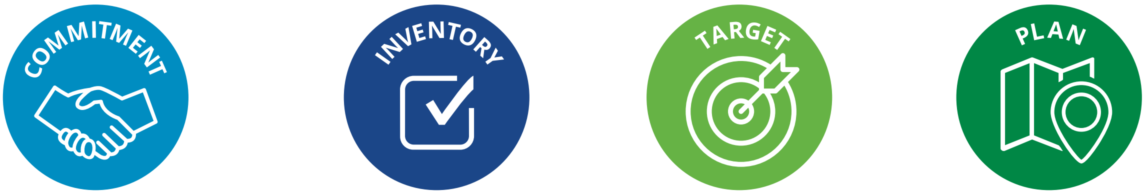
- Adaptation to climate change -related documents of the City of Helsinki
- Literature reviews on limited subjects
- Map materials
- Workshops → *The City's expert assessments of hazards and their impacts and vulnerability factors, information needs to support adaptation and outlining the City's processes.*

APPENDIX 3

Hazard listing of the Compact of Mayors

Any city or town in the world may commit to the Compact of Mayors—regardless of size or location. A city has up to three years to meet a series of requirements and fully comply, culminating in the creation of a full climate action and adaptation plan, and it will be recognized as each step is met. Many cities have already completed some of the activities and can be compliant in fewer than three years.

To commit to the Compact, a city must:



REGISTER COMMITMENT. A mayor may register on either of the Compact's standard reporting platforms—carbon*n* Climate Registry or CDP—or email a letter of intent to info@compactofmayors.org. Following its submission, a city will be contacted by the Compact support team.

TAKE INVENTORY. Within one year, a mayor must assess the current impacts of climate change in his/her city. To do so, the city must 1) Build and complete a community-wide GHG inventory with a breakdown of emissions for buildings and transport sectors, using the GPC standard; (2) Identify climate hazards; and (3) Report on both via the CDP or carbon*n* Climate Registry questionnaires.

CREATE REDUCTION TARGETS AND ESTABLISH A SYSTEM OF MEASUREMENT. Within two years, the registered city must update its GHG inventory to also include a breakdown of emissions from waste sector.; set a target to reduce its GHG emissions; conduct a climate change vulnerability assessment consistent with Compact guidance; and report in its chosen platform.

ESTABLISH AN ACTION PLAN. Within three years, a city's strategic action plan must show how it will deliver on its commitment to reduce greenhouse gas emissions and adapt to climate change.

The Compact of Mayors climate agreement[164] [165]requires identifying climate risks and reporting them annually to the Carbon Disclosure Project (CDP) or Carbonn Climate Registry (cCR) reporting systems. The City Of Helsinki reports to both systems. The hazard listing of this work is based on the cCR reporting system, in which cities must assess whether the following factors have adverse effects in the current situation or will do in the future:

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[164] Compact of Mayors. 2015. Compact of Mayors Full Guide. 22 p. https://data.bloomberglp.com/mayors/sites/14/2015/07/Compact-of-Mayors-Full-Guide_July2015.pdf

[164] In 2016, the Covenant of Mayors was merged with another international climate initiative, the Compact of Mayors, creating a new agreement/initiative called the Global Covenant of Mayors for Climate & Energy. https://www.globalcovenantofmayors.org/

From the following list of climate hazards, please indicate those which your community currently experiences, and those anticipated in the future. Please also indicate which current and/or anticipated impacts of climate change present significant physical risks to the reporting entity.

CLIMATE HAZARD	Currently experienced?	Anticipated in the future?	Presents significant physical risk to the reporting entity?
Rain storm			
Heavy snow			
Severe wind			
Tornado			
Cyclone (Hurricane/Typhoon)			
Tropical storm			
Electrical storm			
Fog			
Extreme winter conditions			
Cold wave			
Extreme cold weather			
Heat wave			
Extreme hot weather			
Drought			

CLIMATE HAZARD	Currently experienced?	Anticipated in the future?	Presents significant physical risk to the reporting entity?
Forest fire			
Land fire			
Fresh/surface flood			
River flood			
Coastal flood			
Groundwater flood			
Storm surge			
Salt water intrusion			
Ocean acidification			
Landslide			
Avalanche			
Rockfall			
Subsidence			
Water-borne disease			
Vector-borne disease			
Air-borne disease			
Insect infestation			
Other			

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