CASCADE

CASCADE project:
Community Safety Action for Supporting Climate Adaptation and Development

Overview of climate risk drivers, hazards and consequences

CASCADE
COMMUNITY SAFETY ACTION FOR SUPPORTING CLIMATE ADAPTATION

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Project note

CASCADE – Community Safety Action for Supporting Climate Adaptation and Development project is a unique, innovative project bringing together civil protection specialists and climate change adaptation experts to fight the impacts of climate change jointly. As an EU Strategy for the Baltic Sea Region's Flagship project under Policy Area Secure, CASCADE operates as a pilot example for cross-sectoral cooperation in the region.

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INTRODUCTION

This inventory of climate risk drivers and hazards is a useful reference for understanding the links between potential drivers, hazards, and their potential impacts of climate change - direct, indirect and even cascading - on society. The inventory accompanies the integrated risk assessment methodology as an appendix. To exemplify the hazards, examples from the Baltic Sea Region (BSR) are used when available. Furthermore, references to whether and how these hazards were included in National Risk Assessments or similar documents in specific countries in the BSR region is included. Examples are brought from national risk assessment related documents from Denmark (DEMA 2017), Finland (Finnish Ministry of the Interior 2019), Norway (DSB 2014), and Poland (RCB 2015) and Sweden (MSB 2013).

This document is prepared as a part of the Development of Guidelines on Integrated Climate Change and Disaster Risk Response Management Work Package (WP2) of the CASCADE[1] project. The main objective of work package 2 is to develop guidelines for local-level public administration to achieve a common understanding, integrated and complex approach to risk management measures with the inclusion of climate change adaptation aspects. A Baltic Sea Region (BSR) focused overview of climate change related hazards with different consequences is part of the activities of WP2 of CASCADE project.

[1] Project “CASCADE Community Safety Action for Supporting Climate Adaptation and Development” (2019-2020) funded by the European Union Civil Protection and Humantarian aid, **http://www.cascade-bsr.eu/**.

I. CLIMATE RISK DRIVERS

Climate risks are a result of climate related hazards, vulnerability and societal exposure (see Figure 1). These main drivers of climate related hazards include temperature change, precipitation intensity, windstorms, and sea-level rise, but also others such as salinity, water temperature, as well as humanmade drivers such as air pollution. These drivers are influenced by natural variability and anthropogenic climate change (lefts side of Figure 1). Vulnerability and exposure are influenced by socioeconomic processes within society, including socioeconomic development pathways, measures taken within society for both adaptation and mitigation, and governance. It should be noted that inequalities which stem from uneven development processes within society can lead to differentiated vulnerability and exposure. As a result, different groups within society can become exposed to climate change related risks at different levels (Oppenheimer et al. 2014).

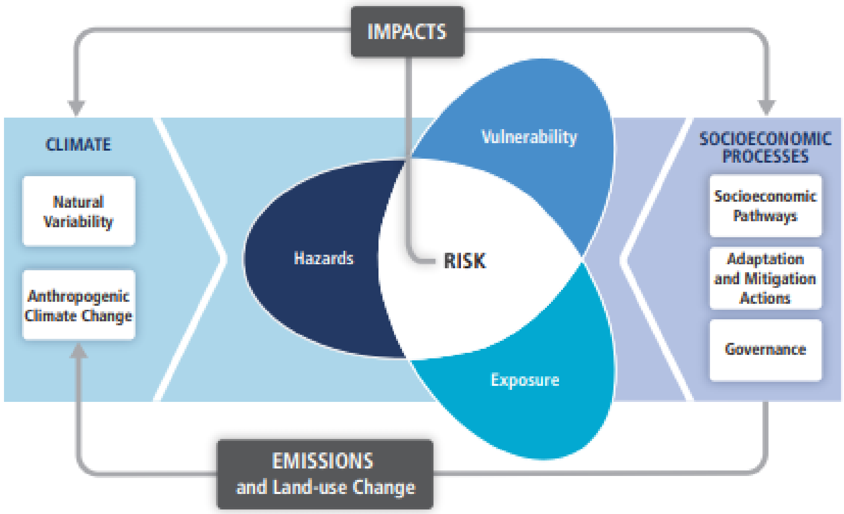

Figure 1 The interaction among the climate hazards, exposure, and vulnerability producing the risk.
Source: (Oppenheimer et al. 2014)

Further information about key climate risk drivers:

- Air temperature (from the BaltAdapt project website)
- Precipitation (from the BaltAdapt project website)
- Rise in sea levels (for low and high emissions scenarios) (from the EEA website)
- Others (from the BaltAdapt project website)

Resource for climate information:

- Copernicus CLIPC: European Climate Information Portal which provides data and models from a variety of sources as well as a toolbox related to indicators.

II. CLIMATE CHANGE RELATED HAZARDS

Climate change related hazards are events which have a variety of direct and indirect consequences for society. Hazards impact the environment, human health and wellbeing, as well as our physical assets, such as critical infrastructure. As countries nowadays depend on the global world economy, there are also several potential transboundary hazards. This chapter follows this logic (see Figure 2) with subsections on the hazards and their consequences.

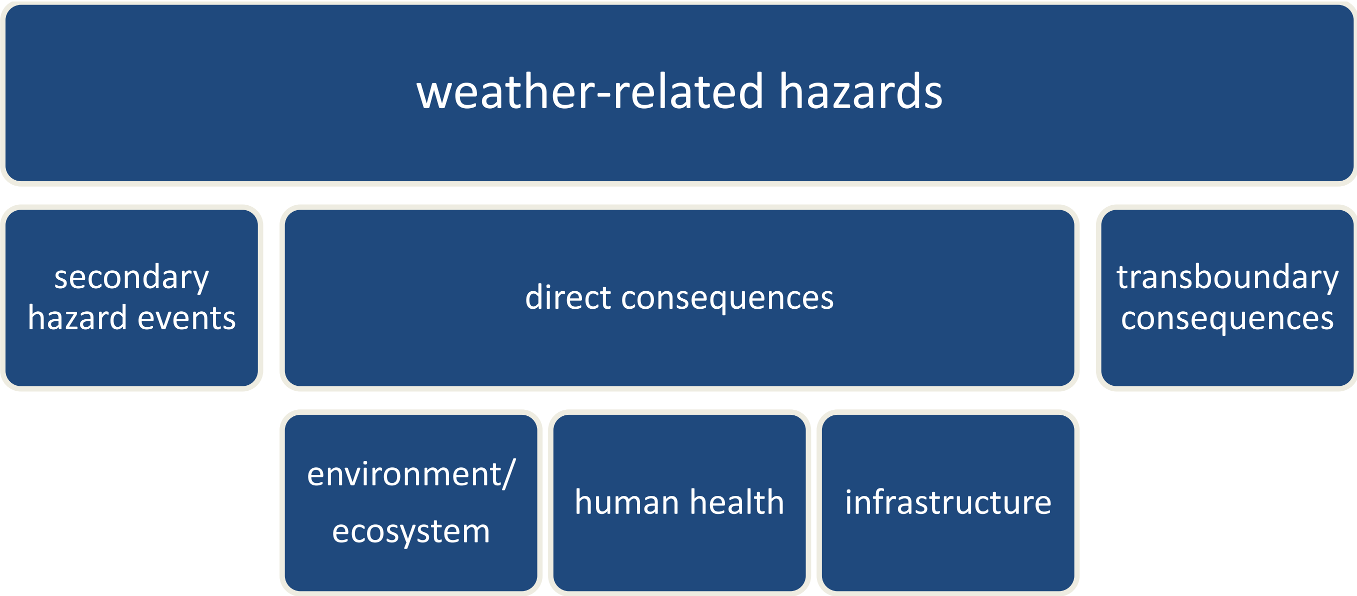

Figure 2 The components of Chapter II. *Source: authors*

Projected climate change impacts (note the particular emissions scenarios used for each):

- EEA Urban Adaptation Map Viewer shows climate projections for Europe for various hazards and consequences. It also has a City Fact Sheet tab which also covers some cities in the BSR region.
- RESIN project interactive Climate Risk Typology tool which provides European subnational level mapping of risks with indicators. Note: Click on the Indicators word under Map Symbology to see a list of indicators which can be selected to be spatially visualised. Indicator categories include Hazard, Vulnerability, Exposure and Adaptive Capacity. It is also possible to see the data for the selected areas by toggling the Show/Hide Map controls in the upper right corner. This data provides useful information for risk assessments. For more information, please see http://european-crt.org/uses.html

1 WEATHER RELATED HAZARDS

The above climate risk drivers, such as changes in temperature, precipitation intensity, winds, and sea-level rise, influence the characteristics of hazards, such as severity, frequency, etc. The impact that these hazards have on society is determined by vulnerability and exposure (Figure 1). Thus, the impacts of the hazards on society depend on how society is structured and geographically located.

As extreme weather covers many different types of weather, such as strong windstorms, extreme heat and cold, heavy precipitation, etc., there are also differences in how it plays out across the Baltic Sea Region (BSR). In the Baltic Sea Region, cities identified extreme weather such as rainstorms, heat waves, and flash/surface floods as among the most significant climate hazards (Paju 2019). The risks related to extreme weather conditions can be especially problematic for vulnerable populations (Paju 2019). Forzieri et al. claim that climate change could increase climate-extreme related fatalities 50-fold exposing 350 million Europeans to climate extremes by 2100 (2017).

In their 2016-2017 National Risk Assessments (NRAs), all eight BSR countries had considered extreme weather events in their NRAs, some even at a high or very high risk level (see Table 1). (European Commission 2017a). The NRAs included storms, extreme temperatures, as well as frequent freezing and thawing in areas which have had more consistent weather etc. Only three of those NRAs accounted for projected climate change impacts for extreme events, and three of the assessments considered specific cascading effects (European Commission 2017a).

Table 1. Extreme weather risk in national risk assessments (when available).

Country	Specific risk type	Relative risk (likelihood/impact)	Climate change	Cascading effect
DE	Storm/extreme temperature			
DK	Storm/hurricane heavy rain/ cloudburst	Storm/hurricane: critical risk Rain/ cloudburst: very serious risk	X, accounts for future projections	Energy infrastructure (power failures); emergency response capacity;
EE	Severe storm/ extreme temperature	Storm: High Extreme T°: Low		
FI	Winter-/ Thunderstorm	Winterstorm: 4/5 / 3.5/5 Thunderstorm: 2/5 / 4/5	X	Infrastructure + health; impacts on road network (less ground frost)

Country	Specific risk type	Relative risk (likelihood/impact)	Climate change	Cascading effect
LT	Storm/hurricane/tornadoes/ snowfall/ drought/hail/heat/frost/heavy fog/floods	Drought: very high risk Other: high risk; Extreme weather events Electric sector impacts: Very high probability / Highest impact on political and social impact (large) Environmental sector: High probability / Insignificant impact – all impact categories Road & Transport sector: High probability / Highest impact is political and social impact (large) Aviation Transport sector: High probability / Highest impact is political and social impact (catastrophic) Telecommunications sector: High probability / Highest impact is political and social impact (limited)	X	Hydrological and meteorological phenomena: in-depth analysis for the electric sector; environmental impacts; impacts on road and air transport sector, telecommunications; Drought: in-depth analysis for the agricultural sector (including cascading effects); increase in concentrations in open water; Impacts on neighbouring countries
LV	Storm	High risk		
NO	Storm (cyclone is given as example scenario) Heavy rainfall Heatwaves in the future	High likelihood, medium consequences Very high likelihood, small consequences	X	Storm surge, loss of power, contamination of drinking water
PL	Rainfall, snowfall, storms / extreme temperature (heat, frost) / windstorms (including hurricanes and whirlwinds)		X, in relation to the CC between the past and the current situation, but not future CC, refer to national adaptation strategy.	Consequences ranging from local flooding, streets turning to urban rivers, damage to agriculture, buildings and property mud- and landslides
SE	Storm/heat-wave	Heat-wave: serious human/ economic/ environmental impact		

Source: EC 2017, Green text colour indicates the use of the updated risk profile based on newer national risk assessments which were available, table modified by authors (see DEMA 2017; Finnish Ministry of the Interior 2019; DSB 2014; RCB 2015; Lithuanian Fire Protection and Rescue Department 2018; DSB 2019a).

In the following sub-chapters, the hazards from different types of extreme weather are briefly described, along with examples of how risk assessments at various levels have accounted for them.

1.1 Heavy precipitation events

In the future, heavy precipitation events are likely to become more frequent, especially in Scandinavia and northern Europe during the winter (EEA 2019b). The Polish national risk assessment summary (2015) identifies two types of hazardous rainfall: intense, long-lasting rainfall, and heavy, torrential rainfall over a shorter period.

Heavy precipitation events, especially heavy rain, can result in a variety of other hazard events – flooding, flash floods, mud or landslides, which can cause damage to structures and buildings, and also impact the economy due to disruption to the business (Necci et al. 2018). Especially in urban areas, extreme precipitation can result in widespread and costly consequences related to health, property, infrastructure, etc. For example, a cloudburst in Greater Copenhagen in July 2011 was considered the most costly single event in Europe of that year (DEMA 2017). For more information about the projected changes in the magnitude of heavy rain, please see EEA's visualisation of select climate change impacts in Europe**.**

A large amount of snowfall is also considered problematic because it must be removed from places where it is problematic for society (blocking movement and transportation), as well as due to the weight it places on structures, including components of power systems, and buildings. Substantial amounts of snow can also cause avalanches and extended periods of high snowfall can lead to more severe flooding in the spring.

The Danish National Risk Profile 2018 assessment of the challenge and the consequences of extreme rainfall is presented in Figure **3**. Extreme rainfall occurs frequently, but due to the early warning and measures implemented, consequences can be reduced. The Hazard potential from extreme rainfall is the highest among property, then decreasing in hazard potential for much lower for the economy and vital societal functions, the environment and health and life (DEMA 2017).

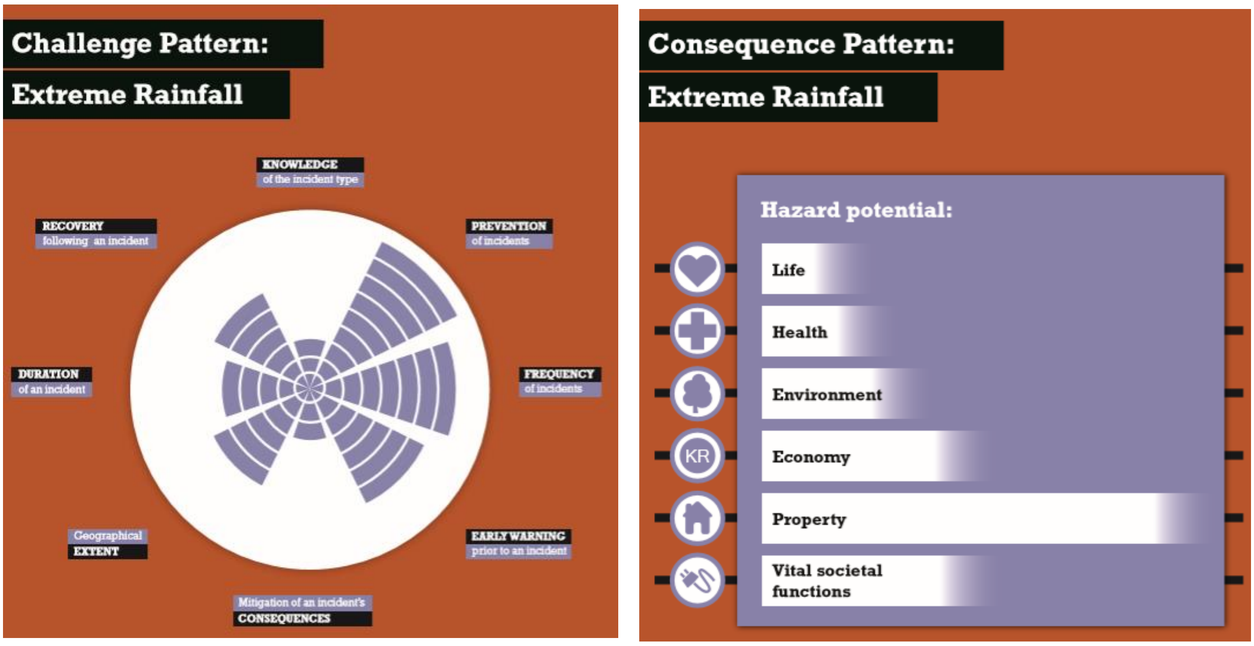

Figure 3 Assessment of extreme rainfall in the Danish National Risk Profile 2018. *Source: DEMA (2017)*

1.2 Windstorms

Windstorms such as hurricanes and cyclones are storms with very high winds which form over the water, but when moving the land can cause severe damage. The high winds in these events can involve flying or falling objects or collapsing structures. They are also known for damage to forests. It is not clear how exactly climate change will impact windstorms across Europe. However, "most studies agree that the risk of severe winter storms, and possibly of severe autumn storms, will increase" for areas including northern Europe over the 21st century (EEA 2016).

Windstorms can have impacts in a variety of environments. For example, Gudrun Cyclone in January 2005 which impacted Denmark, Estonia, Finland, Lithuania, Poland and Sweden had winds gusts up to 46 m/s along the Danish coast and sustained winds of up to 33 m/s in Sweden. Gudrun's impacts included forest losses, power cuts, accelerated coastal processes including coastal erosion, and coastal flooding. The insured losses were estimated to be between 1 and 1,5 billion EUR and the affected people in the BSR region included millions in Sweden, up to 200 000 in Denmark, 254 000 in Estonia (Haanpää et al. 2007). In forestry, the thawed ground provides less support to tree roots than frozen ground during storms. It can result in largescale forest damage, which means that the expected increase in Europe's winter temperatures makes its forests susceptible to such damages (Tapio 2017).

Denmark, Lithuania, Poland and Norway have included hurricanes and/or whirlwinds in their NRAs (see Table 1). In its National Risk Profile, Denmark includes hurricanes and strong storms (DEMA 2017). It is estimated that hurricanes and strong storms occur frequently and although not preventable, due to the early warning, consequences can be reduced. The hazard potential from hurricanes and storms (Figure 4) is the highest among property, environment, vital societal functions, economy and then less so for health and life (DEMA 2017). Figure 5 represents a risk assessment of impacts from hydrological and meteorological phenomena in Lithuanian NRA.

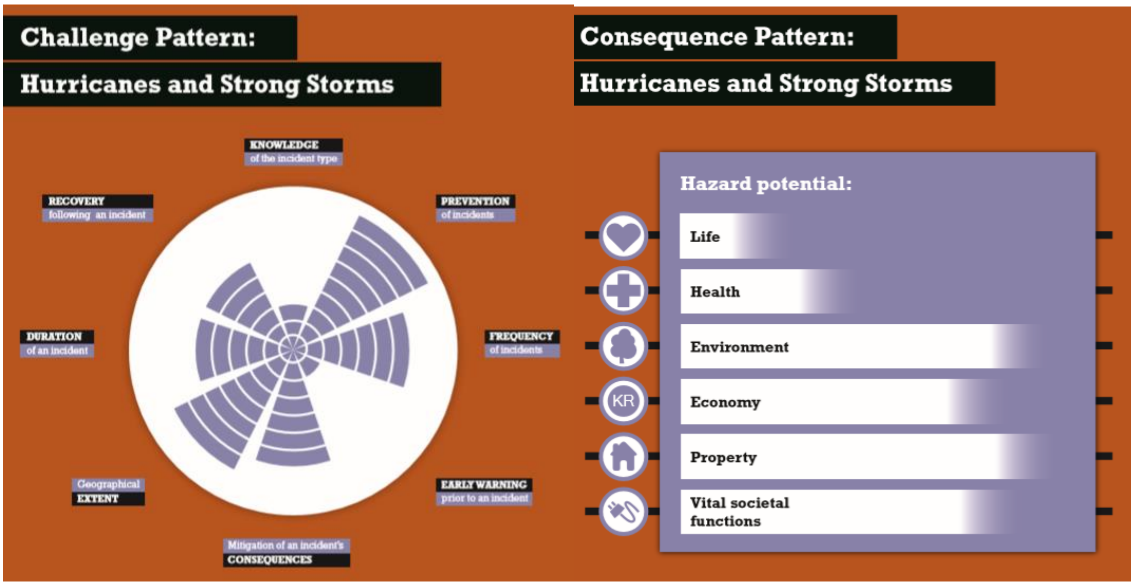

Figure 4. Assessment of hurricanes and strong storms in the Danish National Risk Profile. *Source: DEMA (2017)*

5				4	
4					
3				3	1
2				5	
1				2	
	1	2	3	4	5

Figure 5 Political and social impacts from hydrological and meteorological phenomena in Lithuania. *Impact on the vertical access and probability on the horizontal access. Within the matrix, 1 represents power outage, 2 represents environmental sector, 3 represents disruption of road-based transport, 4 represents air-based transport, and 5 represents telecommunication disruptions. Source: Lithuanian Fire protection and rescue department (2018)*

1.3 Extreme temperatures

For the Baltic Sea region, extreme temperatures, especially heat waves, are seen as a risk. Four of the BSR countries included extreme temperature in their NRA's (see Table 1). Heatwaves are prolonged periods of high heat. According to WHO, they are situations in "which the maximum and minimum apparent temperatures are over the ninetieth percentile of the monthly distribution for at least two days." (WHO 2020). Lithuania and Poland consider a heatwave to be when the maximum temperature is at least 30 C for at least three days (Radišauskas et al. 2014). Poland has further classifications such as "hot days", "periods of heat", and "waves of hot air" depending on the maximum temperature and time period (DRB 2015). Figure 6 shows projections of heat-waves in the BSR area for 2020-2052.

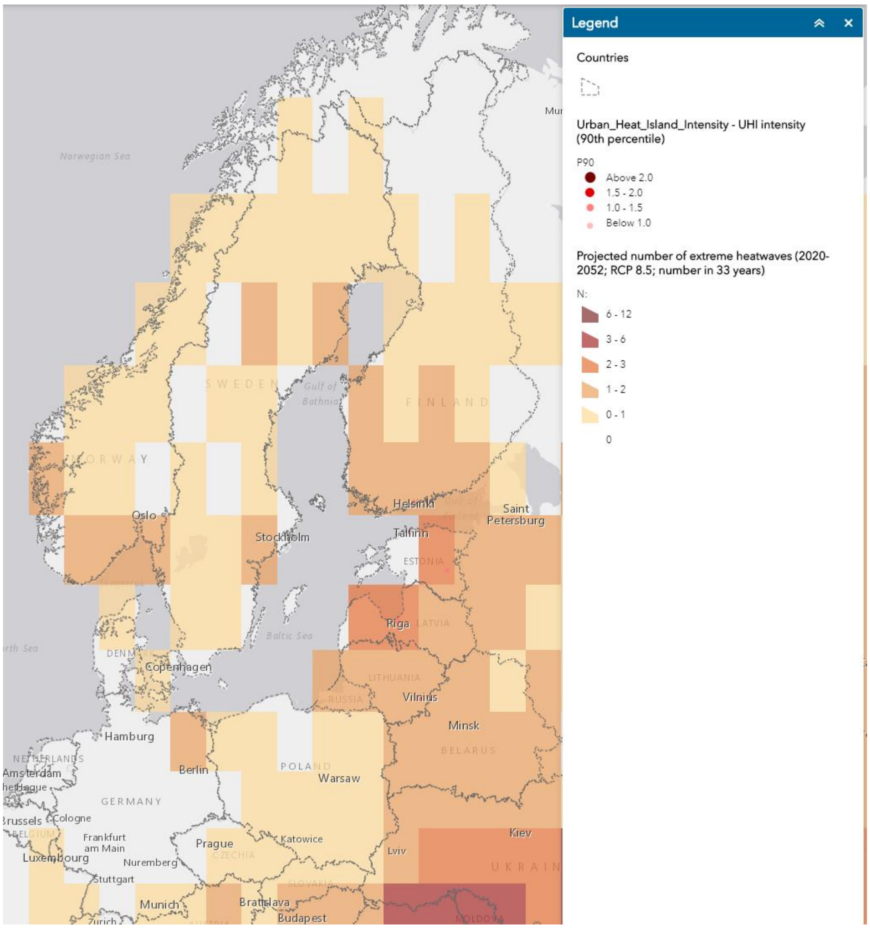

Figure 6 Screenshot of the Baltic Sea Region in regards to heatwaves projections 2020-2052. *Shown is the projected number of extreme heatwaves (2020-2052; RCP 8.5; number in 33 years), Source: EEA (n.d.)*

In general, extreme heat can impact transportation systems, telecommunication systems, electricity supply systems, increase the risk of droughts, forest fires and affect human health. More details can be found in the Appendix. The effects of heatwaves on human health are presented in Section 2.3.3 and on critical infrastructure can be found in Section 2.4.

Urban heat Islands are the result of higher temperatures in urban areas compared to surrounding areas which can increase the intensity of heatwaves in specific locations (Carter et al. 2015). More information available: Urban Adaptation Map Viewer and EEA website**.**

Poland includes heavy frosts, or days when the minimum air temperature is below -20C in its NRA due to increased fatalities and the damage to property. They also consider various other impacts on society. See Table 1 for further details.

1.4 Frequent freezing and thawing cycles

In the Northern parts of the Baltic Sea Region, the average warmer temperature during the winter means that there can be long periods where temperatures hover around zero or change between freezing and above-freezing causing so-called black ice (Lahtvee et al. 2015). This freezing-melting cyclical phenomenon is listed as a climate hazard with high risk level with expected increased intensity and frequency in the City of Turku's climate risk assessment (see Figure 7). Black ice is a dangerous weather phenomenon for both pedestrians and drivers. It can cause times more accidents with vehicles than wet roads and snowy roads because it is difficult for a road user to notice matt thin ice layer. Black ice can have consequences for human health (e.g. through car accidents or slipping and falling) and infrastructure (e.g. the need for road maintenance) (see sections 2.3 and 2.4).

Climate hazard type	Risk level	Expected change in intensity	Expected change in frequency	Timeframe	Reliability of estimation
Extreme heat	!	↑	↑	▶▶▶	*
Extreme cold	!	?	?	▶▶▶	*
Extreme precipitation	!!!	↑	↑	▶	***
Floods	!!!	↑	↑	▶	***
Sea level rise	!	↑	↑	▶▶▶	*
Droughts	!!	↑	↑	▶	*
Storms	!!!	↑	↑	▶	*
Diseases	!!	↑	↑	▶	***
Changes in ecosystem	!!!	↑	↑	▶	***
Introduced species	!!!	↑	↑	▶	***
River erosion	!!!	↑	↑	▶	***
Freezing-melting cycle	!!!	↑	↑	▶	***

Figure 7 Climate risks presenting a threat to Turku, FI. *The risks are identified in the risk and vulnerability assessment. Key: Risks: !-!!! represents low to high risk level; Expected change in intensity: arrow pointing up represents growth while arrow pointing down represents decline; Timeframe: one triangle represents short-term, two triangles represent mid-term, while three triangles represent long-term; and Reliability of estimation: *-*** represent low to high reliability. Source: Turku City Council (2018).*

2 CONSEQUENCES AND CASCADING EFFECTS

Climate related hazards have consequences or effects – both direct and secondary. Direct effects are the primary effects, such as loss of life or property, asset damage, infrastructure damage, or traffic blockages caused by a hazard event such as a storm. Secondary hazard events are events which follow, such as a landslide, mudslide or flood.

Primary and secondary events are both likely to have consequences in society. For example, the direct effects of a flood can further create a chain of cascading effects throughout society, such as the power disruption creating short-term but critical disruptions for telecommunications networks, heating, or rescue services which society relies on. An example of a long-term event is physical storm damage to a landscape of an area which the local area depends on for tourism revenue.

Cascading effects can be described based on the resulting cascading flows of impacts. Abajo et al. (2015) define cascading effects as “a sequence of events in which each one produces the circumstances necessary for the initiation of the next [event].“ Impact chains cross-sectoral and national boundaries due to our interdependent society (Pescaroli and Alexander 2015). Many of our infrastructures are networked and rely on each other. We are also highly dependent on global supply chains for supplies. When a hazard event impacts suppliers abroad or critical infrastructure even at home, the effects cascade out. The interaction between conventional, well-known hazards and less well-known ones based on recent developments in society, through advances in technologies and increased interconnectedness, brings more unpredictable and cascading consequences (OECD 2011). In 2013, only few EU Member states had included the consequences to society, employment or transboundary issues in their climate adaptation plans or strategies. In 2017, many EU member states were in the process of adding transboundary risks in their adaptation strategies or plans. However, only four had done so (Smithers et al. 2018).

Many countries across the BSR considered cascading effects in their NRAs (2016-2017), in connection with extreme weather events, floods, human diseases, and animal diseases (European Commission 2017a). However, instead of using the “cascading effect” term, they may use the word “consequences”. As is seen in Table 2, the consequences are quite extensive in their reach in society. In this report, we will talk about consequences when speaking about direct effects, including secondary hazard events, and the term cascading effects when referring to those resulting from the direct impact or secondary events.

Table 2 Examples of the extent of consequences analysis in national risk assessments.

Country	Topics covered by consequences analyses in NRAs
Denmark	Life; Health; Environment; Economy; Property; and Vital societal functions.
Finland	Leadership; International and EU activities; Defence capability; Internal security; Economy, infrastructure and security of supply; Functional capacity of the population and services; Psychological resilience
Lithuania[2]	Impact on life and health of the population; Impact on the property and the environment; political and/or social impact (Continuity of government and other government agencies; Business continuity; Ability to effectively control the uncontrolled movement of people; Supply of food and drinking water to the population; Provision of health care services to victims; Communication and postal activities; Transport system activities and the Need for civil protection system forces). Also, further assessments of secondary hazards and their consequences in various sectors.
Norway	Life and health (death, serious injuries and illness); Nature and culture (long-term damage to the natural environment, irreparable damage to the cultural environment); Economy (direct financial losses, indirect financial losses); Societal stability (social and psychological reactions, impact on daily life); Democratic values and capacity to govern (loss of democratic values and national capacity to govern, Loss of territorial control)
Poland	Population; Economy; Property, including infrastructure; Environment; Impact on the functioning of CI (Yes/No) and the impact on critical infrastructure (description)

Source: DEMA (2017)*, DSB* (2019a)*, Finnish Ministry of Interior* (2019)*, Lithuanian Fire Protection and Rescue Department* (2018) *and RCB* (2015)*.*

In the following section, we will go over the consequences and cascading effects related to climate change. This will include looking at secondary hazard events, consequences for human health, the environment or ecosystem, as well as infrastructure and transnational effects.

2.1 Secondary hazard events

Secondary hazard events take place as a result of another event. In this section, we will look at flood events, forest and wildfires, as well as maritime ice sheets as examples of secondary hazard events relevant to the BSR in the context of climate change.

2.1.1 Flood events (incl. storm surge)

Flooding is considered the main risk in terms of European emergency management. Flood events occur due to a variety of reasons:

[2] Based on translation from Lithuanian to English using Google Translate programme.

- Fluvial floods or flooding of river and surface water floods, take place when the watercourse at a certain location is not able to absorb the heavy precipitation or snowmelt from sources within the river basin upstream (EEA 2019b; RESIN 2017).
- Pluvial floods, or flash floods from heavy rains, take place when local drainage capacities are exceeded. (EEA 2019b; RESIN 2017). This can result from low surface permeability which keeps precipitation from being able to be absorbed into the ground causing excessive surface run-off (EEA 2019b).
- Coastal flooding, or storm surges, is when the coast is flooded by seawater, e.g. due to storm winds and waves (RESIN 2017). Storm surge results from tropical or extra-tropical storms and is driven by wind, pressure and waves. Storm surge can cause flooding over large areas, especially in low coastal floodplains and river deltas (Poljanšek et al. 2019).
- Sea level rise can create permanent inundation (flooding).

Some areas deal with multiple types of flooding. Generally speaking, floodplains and coastal areas are most vulnerable to flooding, and thus development or the accumulation of valuable assets in these areas increases risk exposure (European Commission 2017a). Figure 8 below shows historical data on pluvial floods and projected coastal flooding in the Baltic Sea region.

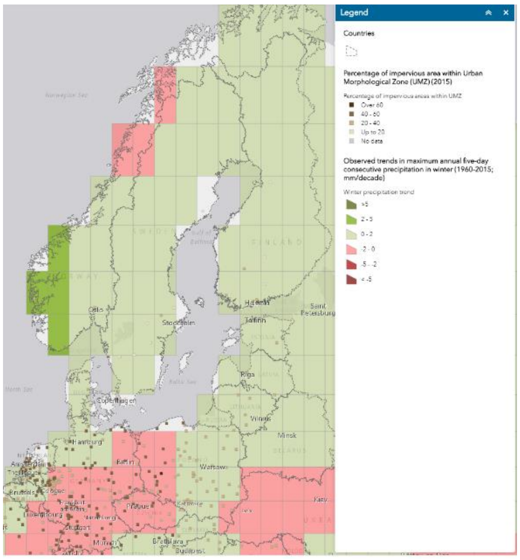
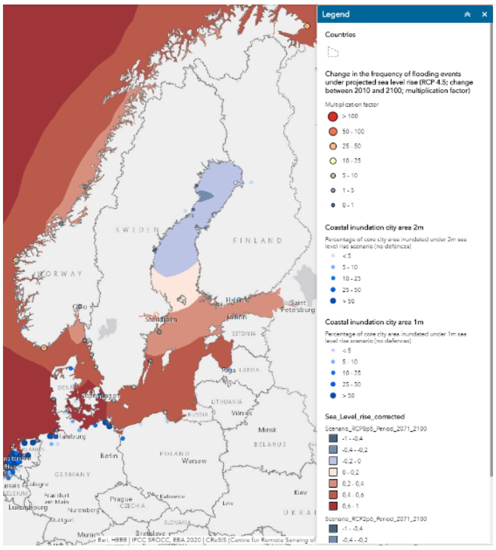

Figure 8 Screenshots of the Baltic Sea Area in regards to [pluvial flooding]() (historical) and [coastal flooding]() (projected).** Source: EEA **(n.d.)

Factors such as surface permeability or runoff from higher elevations or upstream areas can affect flooding and are thus an issue for urban areas (Carter et al. 2015; EEA 2019b). For example, buildings and residential areas closer to the sea or rivers are at higher risk of being damaged by the storms, sea-level rise, and floods (Deppisch et al. 2015). Also, densely built areas with high levels of impermeable surfaces are at risk for flooding. For this reason, building construction, urban planning and land use management practices and the related policies can be used to mitigate the impacts of flood events (Deppisch et al. 2015; European Commission 2017a).

In the Baltic Sea Region, cities have identified extreme weather such as river floods, coastal floods, and flash/surface floods as among the most significant climate hazards (Paju 2019). In Europe, river flooding is already the second-highest natural hazard source of economic losses (second to storms) (EEA 2019b). Sea level rise is expected to impact infrastructure more in the southern Baltic Sea and coastal cities such as Gdansk, in particular (Deppisch et al. 2015). North-west Germany, Denmark, and southern Sweden are countries and regions with the largest shares of low-lying areas (EEA 2019b). For more information on the projected change in the frequency of coastal flooding events between 2010 and 2100 as well as the populations affected by coastal flooding up to 6m, please see EEA's visualisation of select climate change impacts in Europe.

The Polish NRA considers the flood as a temporary flow of water over normally dry land. The water may originate from natural watercourses, water reservoirs, channels or from the seaside. The Polish NRA includes both climate related (pluvial and fluvial and coastal) floods, as well as floods caused by damage of hydro-technical facility. They do not consider the overflow of water caused by water rise in sewage systems to be flooding. Flood risk is assessed as moderate in the Polish NRA, though the level of risk differs spatially (see Figure 9).

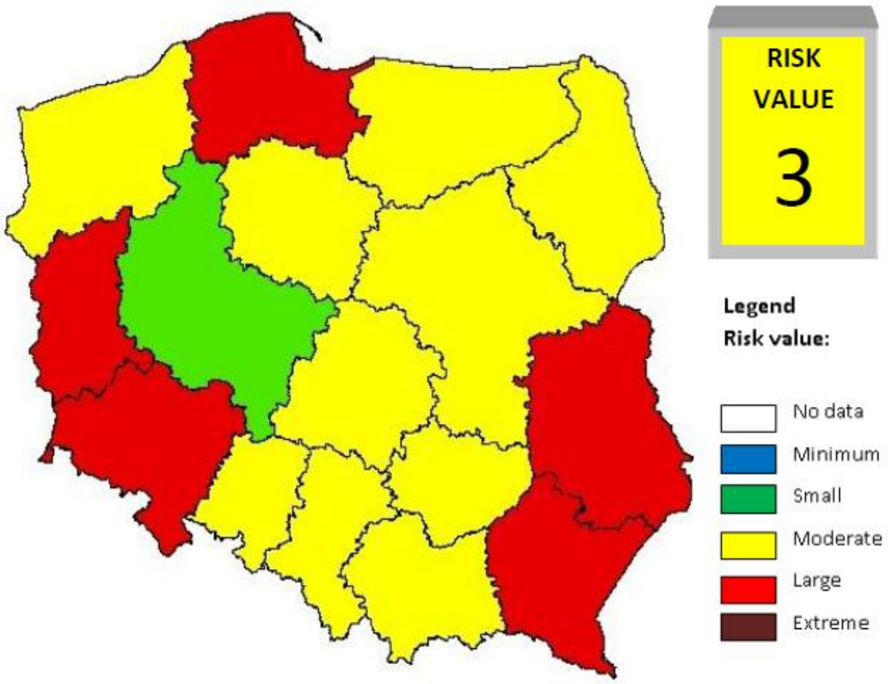

Figure 9 Assessment of risk of flooding in Poland's NRA. *Source: RCB* ***(2015)***

A 2017 review of EU National Risk assessments (NRAs) found that all Baltic Sea Region countries included flooding of some sort in their NRAs (2016-2017), some even at a significant, high or critical risk level (see Table 3). Only one of those NRAs accounted for projected climate change impacts for flooding risk, and four of the assessments considered specific cascading effects (European Commission 2017a). However, some NRAs have been updated since the report and have accounted for climate change and/or cascading effects. In Finland's most recent NRA and the Danish National Risk Profile account for climate change rather thoroughly, suggesting a positive change in the trend towards integrating climate and disaster risks (DEMA 2017; Finnish Ministry of the Interior 2019).

Table 3: Flooding risk in national risk assessments (when available).

Country	Specific risk type	Relative risk (likelihood/impact)	Climate change	Cascading effect
DE	Winter/summer flood		X	
DK	Storm surge/ Coastal flooding	Critical risk	X - accounts for future projections	Impacts on water supply for domestic and industrial use; business continuity; critical transport infrastructure; hazardous facilities
EE	Flood in populated areas	High risk		
FI	Rapid urban flooding	3/5 L./ 2.5/5 I.	X	Power supply; water quality disruptions
LT	Fluvial / coastal flood	Acceptable to High risk		Power supply/transport
LV	Fluvial/coastal flood	Significant risk		Hydrotechnical infrastructure
NO	Snowmelt and heavy precipitation Flood	Moderate likelihood, large consequences Medium likelihood, medium consequences	X	Numerous landslides, flood defences breached; large consequences include deaths, injuries or illnesses, with higher uncertainty for economic impacts over 5-10 billion NOK
PL	Pluvial/ snowmelt/ storm surge/ hydrotechnical failure	Moderate risk	X	See Table 1 for the consequences of flooding from rainfall
SE	Fluvial/pluvial			Infrastructure

Source: EC 2017, Green text colour indicates the use of the updated risk profile based on newer national risk assessments which were available, table modified by authors (see DEMA 2017; Finnish Ministry of the Interior 2019; RCB 2015; DSB 2014; DSB 2019a).

2.1.2 Drought

Droughts can result from a combination of factors such as increased temperatures and reduced precipitation. When atypical dry spells continue long enough, they can cause a hydrological imbalance (RESIN 2017). There are four phases of drought: meteorological (due to dry weather patterns), agro-meteorological (agricultural), hydrological, and socio-economic (the final most severe phase). (Radišauskas et al. 2014). However, these climate change conditions, together with other processes like urbanisation and economic development, can lead to increased demand for water, e.g. for agricultural and household needs. The increased water abstraction required to meet the higher level of demand can impact both river flows and drought frequency (Carter et al. 2015). In this way, cities can be seen as a competitor with other users of water, and for this reason, during droughts, some entities such as cities may suffer from water scarcity (EEA n.d.).

Even in the BSR, drought is a hazard that affects the countries differently. Examples of changes in soil moisture-based drought occurrence and severity and drought hazard in Europe are shown in Figure 10 and Figure 11. For more information on the projected changes in the frequency of meteorological droughts for two emissions scenarios (medium and high emissions scenarios), please see EEA's visualisation of selected climate change impacts in Europe. From these maps, it is logical that drought is considered a major risk in the Lithuanian National Risk Analysis (Lithuanian Fire Protection and Rescue Department 2018).

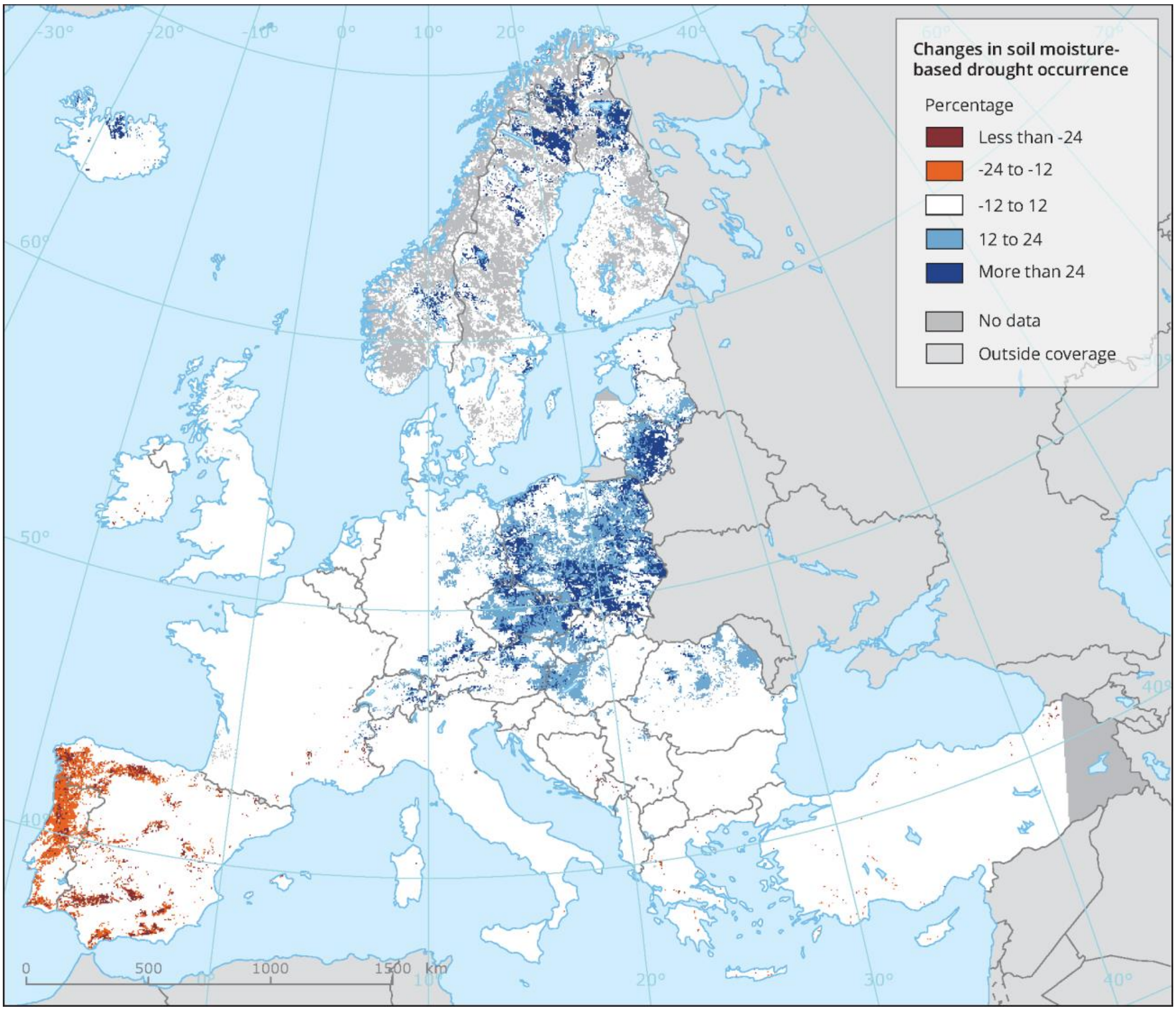

Figure 10 Changes in soil moisture-based drought occurrence and severity across Europe. *Source: EEA (2019a)*

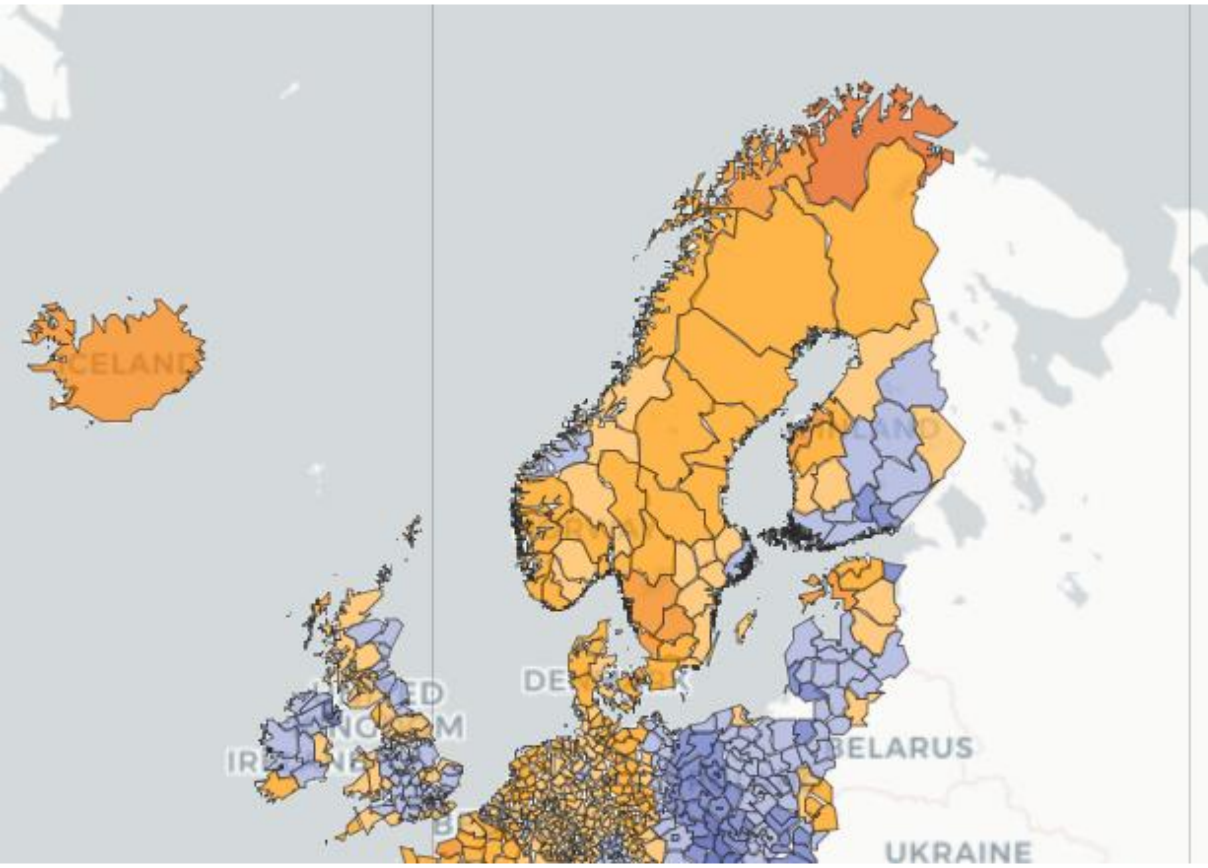

Figure 11 European Climate Risk Typology – drought hazard. *Source:* ***(Carter et al. 2018)***

2.1.3 Forest fire and wildfire

Climatological hazards such as forest fires are considered by national emergency authorities across the EU to represent a substantial disaster risk. They are a relevant issue also for the Baltic Sea Region. The characteristics of forest fires are determined by the interaction of localised issues such as meteorological and climatic conditions, forest type, topography, sources of fire and local preparedness to contain it, as well as forest management practices (European Commission 2017a). Prolonged dry periods also increase the risk of forest fires (Finnish Ministry of the Interior 2019). The combination of climate change (precipitation and temperature changes), pests and diseases (which are also influenced by climate change), and various management processes can make forest landscapes drier, less resilient, and more susceptible to burn in the case of a fire.

For more information about the projected change in fire danger in Europe, please see [EEA's visualisation of select climate change impacts in Europe] using low and high emissions scenarios.

A 2017 review of EU National Risk assessments (NRAs) found that five Baltic Sea Region countries included forest fire or wildfire in their NRAs (2016-2017), some even at a significant or high-risk level (see Table 4). For example, according to its most recent NRA, the number of forest fire warning days in Finland is expected to increase by 5–10 days from the current level by the end of the century. As the climate gets warmer, there will also be days with strong winds, high temperature and low humidity - which increase the likelihood of the first to spread and result in extensive forest fires (Finnish Ministry of the Interior 2019).

Table 4: Forest-fire / wildfire risk in national risk assessments (when available).

Country	Specific risk type	Relative risk (likelihood/impact)	Climate change	Cascading effect
DE	X		X	
DK				
EE	Extensive forest/bush-fire	High risk		
FI	Simultaneous major forest fires	Average L ⅖ Impact	X (5-10 more forest fire warning days annually by 2100)	
LT	Fire and forest fire (including peat fires)	Very high probability / insignificant impact on life and health and property and environment		Assessment of consequences in the environmental sector; pests in fore after forest fires
LV	X	Significant risk		
NO	X	High likelihood, small overall consequences	X, it is uncertain how climate change affects the risk assessment, but that the risk increases in frequency and scope if there is less snow in lowland areas, more wind, and higher temperatures and drought.	Smaller consequences include financial losses, evacuation and social unrest. Medium consequences are limited to nature and the environment; no larger consequences.
PL	X	Moderate		Ecological damage
SE	X	Localised		

Source: EC 2017, Green text colour indicates the use of the updated risk profile based on newer national risk assessments which were available, table modified by authors (see Finnish Ministry of the Interior 2019).

The Norwegian NRA (2014) includes forest fire and assesses the risk through “three simultaneous forest fires” scenario. It acknowledges the uncertainties around how climate change will impact the risk of forest fires in Norway. They assess the likelihood of a forest fire scenario to be high, but the overall consequences to the society as small (see further in Figure 12). The risk analysis of this scenario was updated in 2018, and the assessment results were slightly changed. The updated risk assessment also included the likelihood of a similar scenario to happen on a national level. The likelihood at the national level was rated as moderate for the three simultaneous fires scenario (DSB 2019b). The rating for the overall consequences did not change.

Likelihood assessment							
		VERY LOW	LOW	MODERATE	HIGH	VERY HIGH	EXPLANATION
Likelihood that the event will occur in the course of a year: 1%					◎		Once every 100 years based on historical data and experiential data, as well as meteorological data.
Consequence assessment							
SOCIETAL ASSET	CONSEQUENCE TYPE	VERY SMALL	SMALL	MEDIUM	LARGE	VERY LARGE	
Life and health	Death	◎					Less than 5 deaths as a direct or indirect consequence.
	Injuries and illness		◎				20-100 injuries or ill people as a direct or indirect consequence.
Nature and the environment	Long-term damage			◎			100 km² in total, significant environmental changes, several decades before restoration of the normal state.
Economy	Financial and material losses		◎				Approximately NOK 500 million.
Societal stability	Social unrest		◎				A large number of people in the urban area may be directly affected, and expectations of management may create anger and aggression.
	Effects on daily life		◎				The evacuation of 10,000 inhabitants for 1–2 days may be necessary, reduced navigability, disconnection of power supply.
Capacity to govern and control	Weakened national capacity to govern						Not relevant.
	Weakened territorial control						Not relevant.
OVERALL ASSESSMENT OF CONSEQUENCES			◎				Small consequences overall.

Low uncertainty ◎ Moderate uncertainty ◎ High uncertainty ◎

Figure 12 Risk assessment of forest fire scenario in Norwegian NRA 2014. *Source: DSB* ***(2014)***

2.1.4 Maritime ice sheets

Due to climate change, it is projected that overall ice cover in the Baltic Sea will decrease. However, extreme temperature conditions will occur, and if the capacity to deal with those conditions has been decreased, problems will ensue. For example, there is a risk that the ice-breaking fleet will be reduced in size due to milder winters and thus result in a shortage in the case of extreme cold conditions where ice-breaking is needed. (Finnish Ministry of the Interior 2019). The further effects of reduced marine ice cover are explained in section 2.2.4.

2.2 Consequences for the environment and ecosystem

2.2.1 Coastal erosion

Storms, sea level rise and floods can result in coastal erosion, which is the loss of land along the coastline. Erosion takes place through waves, currents, tides, ice, or storms. Coastal meadows and low-lying coastal areas are especially susceptible. Soft cliffs in Sweden, Denmark, Germany and Poland have already been severely affected by strong wind and high-water levels, and the cliff erosion is expected to increase in the future. High erosion of the soft cliff may lead to cliff retreat and landslides. Coastal erosion is a particularly severe problem in Germany (75% of sandy coasts are at risk to be eroded) as well as in the Baltic States and Poland. It can have severe consequences on tourism and local recreation possibilities (Łabuz 2015).

2.2.2 Plant diseases and pests

Similar to the reasons for the risks for the spread of human and animal diseases, climate change brings new risks for plants. With climate change, new plant species will be viable and start to be cultivated in new areas. These plants will act as a host for new plant hazards helping them to gain foot in a new area. It is estimated that winters will be milder in many regions of the BSR. Warmer weather allows plant hazards to survive over the winter (Finnish Ministry of the Interior 2019). Plant pests and diseases can impact crop production (European Commission 2017a) and forest health.

The Lithuanian National Risk Analysis links forest pests as a sectoral impact of hurricanes and storms which cause tree damage (Lithuanian Fire Protection and Rescue Department 2018). In the latest Finnish National Risk Assessment, invasive pests and diseases represent the most significant individual risks to forests due to a combination of climate change and the international plant trade (Finnish Ministry of the Interior 2019). Due to the significance of the forest sector to the Finnish national and subnational economy, damage to forests would have wide-reaching economic and social impacts. Similarly, climate change will bring new plant diseases, pests, and weeds to agriculture. Impacts include killed plants, contaminated land, limits to plant or plant-product exports. In Finland, the threat from plant hazards and plant diseases was estimated to increase, and indirectly impacting economy, infrastructure, and security of supply, as well as the psychological resilience in a negative way (Finnish Ministry of the Interior, 2019). The trend of likelihood and impact for plant hazards-plant diseases as assessed in the Finnish NRA can be seen in Figure 13.

Threat scenario/disruption	Trend of likelihood	Impacts of the threat scenario/disruption on vital functions						
		Leadership	International and EU activities	Defence capability	Internal security	Economy, infrastructure and security of supply	Functional capacity of the population and services	Psychological resilience
Plant hazards – plant disease epidemic	↑	*	*	*	*	**	*	**

Figure 13: The assessment of the trend of likelihood and impact for plant hazards.

*Yellow colour signals indirect impact (in contrast with direct impact), * signals minor impact, ** signals other negative impact, *** represents preventing or severely compromising impact. Source: Finnish Ministry of the Interior **(2019)**, key on p22.*

2.2.3 Animal diseases (epizootic)

Epizootic diseases are diseases found in animal populations. Climate change may increase the spread of infectious vector-borne transmissible diseases affecting animals. Epizootic diseases include the impact on the production and supply chains related to the particular food products, as well as the spread of the disease to human populations (zoonosis, see 2.3.1). The highest current risk for the EU includes classic swine fever, African swine fever, foot and mouth disease and avian influenza (European Commission 2017a). With such infections, the risk of highly spread contagion is avoided through culling animal stocks and disinfecting areas, which can have a large impact on the agricultural sector and other related sectors (DEMA 2017). Costs for the private sector include those for eliminating the outbreak, production losses, and potentially reputational loss. Nationally, it could result in other countries banning their exports. For some countries, like Denmark, such losses would result in lost export revenue for a significant sector (DEMA 2017).

A 2017 review of EU National Risk assessments (NRAs) found that five Baltic Sea Region countries included epizootic risk of some sort in their NRAs (2016-2017), most at a high or serious risk level (see Table 5). Projected climate change impacts for epizootic risks were accounted for in one NRA, and specific cascading effects were only considered in three assessments, mainly relating to cross-border impacts (European Commission 2017a). The most recent Danish National Risk Profile continues to recognise the link between climate change and epizootic diseases. It describes the cascading effects related to the agricultural sector and the national economy (DEMA 2017). The hazard potential from the animal disease in Denmark is highest among economy, and property, with much less of an impact on the other themes (see Figure 14).

Table 5. Epizootic risk in national risk assessments (when available).

Country	Specific risk type	Relative risk (likelihood/impact)	Climate change accounted for	Cascading effect
DK	Animal disease (and zoonosis)	Serious risk (economic impact and property impact)	X, accounts for future projections	Disruption of agriculture (also from cross-border)
EE	Epizootic	High risk: Medium L./Serious I.		
LT	Epizootic — Avian flu and African swine fever (ASF)	Avian flu: High risk ASF: Very high risk		Cross-border avian migratory flows High volatility of ASF
LV				
PL	Epizootic	Moderate risk		
SE	Epizootic			Pandemic outbreak (cross border risk)

Source: EC 2017, Green text colour indicates the use of the updated risk profile based on newer national risk assessments which were available (see DEMA 2017).

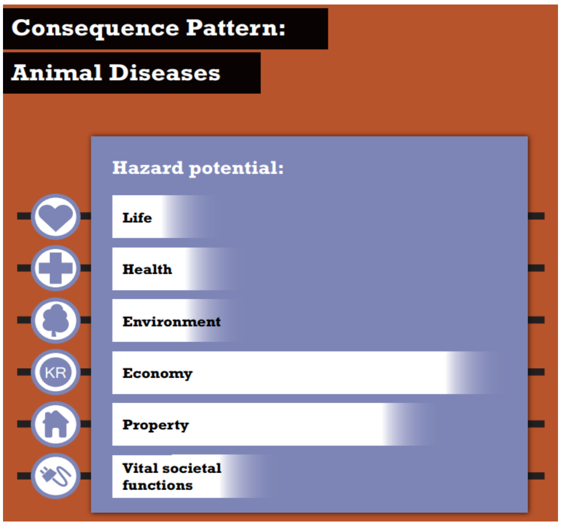

Figure 14. Assessment of the consequences of animal diseases. *Source: DEMA* ***(2017)***

2.2.4 Biodiversity loss

Climate change drives biodiversity loss and ecosystem change on land and in water and is expected to strengthen as a driver in the future. Biodiversity loss threatens our society in that it decreases the resilience of our socio-ecological systems to function. It undermines human-made processes which depend on our ecosystem. In Europe, 14% of habitats and 13% of species of interest are under pressure due to climate change (European Commission 2017a). More information about this is available on the BaltAdapt website.

The Baltic Sea ecosystems are already under high pressure from human drivers, making it particularly vulnerable to further impacts of climate change. One unique feature of central and northern Baltic Sea are the archipelago coasts, which are very important for biodiversity but at the same time vulnerable to climate change. The combined effects of climate change and post-glacial uplift, a characteristic of the Baltic Sea region, however, are still unknown.

Coastal birds and seabirds may be affected by climate change due to alteration of water salinity, temperature and acidity and can have a cascading effect on food webs. Coastal birds and seabirds may also be influenced by changing weather conditions, especially rain and wind (Niemelä et al. 2015). This can result in bird mortality and further indirectly lead to changes in the quality and quantity of food and habitats. The latter is mainly affected by sea-level rise, storm events and erosion.

Climate change related changes may cause invasion of non-indigenous aquatic bird species and mammalian predators, which can significantly alter coastal and archipelago ecosystems and bird communities. The rising temperature causes the species both in the water and on land to migrate towards northern areas, but it also prolongs the productive period (Niemelä et al. 2015). In Figure 15 it can be seen how the City of Turku has assessed Introduced Species to be a high risk level with expected growth in intensity and frequency already in the short term (Turku City Council 2018).

Climate hazard type	Risk level	Expected change in intensity	Expected change in frequency	Timeframe	Reliability of estimation
Extreme heat	!	↑	↑	▶▶▶	*
Extreme cold	!	?	?	▶▶▶	*
Extreme precipitation	!!!	↑	↑	▶	***
Floods	!!!	↑	↑	▶	***
Sea level rise	!	↑	↑	▶▶▶	*
Droughts	!!	↑	↑	▶	*
Storms	!!!	↑	↑	▶	*
Diseases	!!	↑	↑	▶	***
Changes in ecosystem	!!!	↑	↑	▶	***
Introduced species	!!!	↑	↑	▶	***
River erosion	!!!	↑	↑	▶	***
Freezing-melting cycle	!!!	↑	↑	▶	***

Figure 15 Climate risks presenting a threat to Turku, FI. *The risks are identified in the risk and vulnerability assessment. Key: Risks: !-!!! represents low to high risk level; Expected change in intensity: arrow pointing up represents growth while arrow pointing down represents decline; Timeframe: one triangle represents short-term, two triangles represent mid-term, while three triangles represent long-term; and Reliability of estimation: *-*** represent low to high reliability. Source: Turku City Council* ***(2018)****.*

The reduction of the sea ice (both the extent and duration) causes changes in marine ecosystems, especially among the ice-dependent species, for example, due to habitat loss and alter nutrient dynamics within and under the sea ice. (Niemelä et al. 2015; Viitasalo et al. 2015) Modelling results have shown that climate change might worsen eutrophication via flows of nutrients from land with rivers that increases the phytoplankton activity. However, the flow of freshwater may bring more carbon from the land, which leads to lower phytoplankton activity. Thus, the productivity of the marine ecosystem may vary in different parts of the Baltic Sea (Viitasalo et al. 2015).

2.3 Consequences for human health

Climate change affects health through the climate drivers, as well as the resulting natural hazards described above interacting European social, economic, and technical infrastructures, as well as production systems. Climate change can further strengthen existing inequalities and vulnerabilities. Particular groups at risk across Europe include the elderly, children, workers who work in exposed environments, and migrants (WHO 2020). Some of the main consequences for society include diseases, heat waves, and slippery roads.

2.3.1 Diseases (including zoonosis) and pandemics

A change in climate conditions can affect the occurrence of diseases and viral pandemics, which either are new to an area or that humans do not yet have immunity to. Infectious diseases can spread directly from human to human (anthroponoses), e.g. influenza or animal to human (zoonosis), e.g. avian flu. They can also spread via a vector such as a mosquito or tick (WHO 2003).

Climate conditions (temperature and precipitation) alters habitats for bacteria, insects as well as the seasonal patterns of larger animals which insects travel with. Together with additional pressures such as habitat loss and modification, agricultural development, pollution and overexploitation of species globally, climate change also heightens the risk of pandemics related to zoonotic diseases (UNEP 2020). Though not all pandemics will be climate-driven, climate change can increase the probability of pandemics taking place. Some vector-borne diseases can spread to new areas through insects such as mosquitoes and ticks (DEMA 2017). Tick-borne diseases are projected to spread towards the north (Scandinavia and the Baltic countries), it is anticipated that 3,8% overall habitat expansion in Europe by 2040-2060 (European Commission 2017a). The EEA has created a map visualizing vector-borne diseases using the climactic suitability of specific cities in Europe for tiger mosquito (Aedes albopictus) 2008-2009 as an example (EEA n.d.).

Increasing water temperature has induced an increase in the number of vibriosis infections in the Baltic Sea countries. Also, heatwaves and higher sea temperatures create increased risk of bacterial vibriosis infections, which was already experienced in the Nordics during a 2014 heatwave (Baker-Austin et al. 2016; European Commission 2017a). BSR cities considered the increased tick population and the increased risk for Borrelia (lime disease) as well as water-borne diseases as potential long-term social risks from climate change in their CDP Cities Questionnaires 2018 (Paju 2019).

A 2017 review of EU NRAs found that (see Table 6) three BSR countries included the transmission of diseases from animals to humans (zoonosis), within their NRAs. One of those accounted for climate change. Furthermore, seven countries included pandemic risk of some sort in their NRAs (2016-2017), some even at a high or critical risk level or with potentially catastrophic impacts, but not in relation to climate change (European Commission 2017a). However, some of the NRAs have been updated since the report. For example, the National Risk Profile for Denmark recognizes the link between climate change and highly virulent diseases.

Table 6. Human disease, zoonosis and pandemic risk in national risk assessments (when available).

Country	Specific risk type	Relative risk (likelihood/impact)	Climate change	Cascading effect
DE				
DK	X Zoonosis (and animal disease)	Critical risk Serious risk	X	Key societal functions including health care sector, business continuity, socio-economic losses, psychological impacts on society
EE	X	Very high risk		
FI	Nationwide pandemic flu Zoonosis	High L/ unpredictable I		Pandemic outbreak (can affect FI and vicinity)
LT	X	Very High Risk		
LV	X	Medium L/ Catastrophic I		
NO	X Zoonosis and pandemic Foodborne diseases	High likelihood, large consequences High likelihood, low consequences	 X	High rate of absence due to illness in all sectors, reduced public service and transport service provision, and poorer treatment offerings for other illnesses, fear in society, and financial losses in the economy.
PL	X	Moderate risk	Links epidemics to water contamination, as well as catastrophic events such as floods or droughts; document links to climate change, but not specifically for this risk	
SE	X	Catastrophic impacts		Pandemic outbreak

Country	Specific risk type	Relative risk (likelihood/impact)	Climate change	Cascading effect
	Zoonosis (and epizootic)			(cross border risk)

Source: EC 2017, Green text colour indicates the use of the updated risk profile based on newer national risk assessments which were available, table modified by authors (see DEMA 2017; DSB 2014; DSB 2019a; RCB 2015).

The Norwegian NRA report includes infectious diseases as one of the risk categories in its risk assessment. The risk is assessed through the scenario “pandemic in Norway”. This scenario’s likelihood is assessed as high and overall consequences to the society as large, especially on life and health, but also the economy and social stability (see further details in Figure 16) (DSB 2014). The risk analysis of the scenario was updated in 2018, and the assessment results were slightly changed. Indirect financial consequences were assessed as very large. Social unrest was rated as very large. The new rating for the overall consequences was very large (DSB 2019a).

Likelihood assessment

	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH	EXPLANATION
Likelihood that the event will occur in the course of a year: 1-2%				◎		Once every 50 to 100 years based on the historical frequency.

Consequence assessment

SOCIETAL ASSET	CONSEQUENCE TYPE	VERY SMALL	SMALL	MEDIUM	LARGE	VERY LARGE	
Life and health	Death					◎	Around 6,000 deaths as a direct consequence of the pandemic and 2,000 due to inadequate treatment for other illnesses.
	Injuries and illness					◎	A total of 35,000–40,000 must be admitted to hospital, and approximately 10,000 will require intensive care.
Nature and the environment	Long-term damage						Not relevant.
Economy	Financial and material losses				◎		NOK 5-50 billion.
Societal stability	Social unrest				◎		Uncertain and frightening consequences, lack of a vaccine, very many are affected.
	Effects on daily life			◎			Reduced public service and transport offerings.
Capacity to govern and control	Weakened national capacity to govern		◎				High absence due to illness, and many are affected by the high number of fatalities.
	Weakened territorial control						Not relevant.
OVERALL ASSESSMENT OF CONSEQUENCES					◎		Large consequences overall.

Low uncertainty ◎ Moderate uncertainty ◎ High uncertainty ◎

***Figure 16: Assessment of pandemic in Norway scenario in Norwegian NRA 2014.** Source: DSB **(2014)**.*

2.3.2 Diseases related to air or water pollution

There are several potential climate related effects which impact human health via either water or air pollution. Forest fires or measures used to mitigate slippery roads and walkways can spread particulate matter into the air, which when inhaled can reduce life expectancy, mainly through reduced cardiopulmonary health (Simpson et al. 2015).

Water can also become polluted through heavy rains or flooding incidents which bring drinking or surface water into contact with contaminants. Sewer systems can become overloaded with heavy rains or storm surge, forcing the sewage water to surface where it is not supposed to (Deppisch et al. 2015). This can spread waterborne diseases. Flooding can also result in surface floodwaters infiltrating areas with hazardous materials, such as chemicals, which can then be spread through the water.

2.3.3 Effects on health from heat waves

Extreme temperatures compromise the general well-being of people and stress their bodies. For example, high temperatures create situations in which the body's methods of internal temperature regulation are compromised (RESIN 2017). Also, after warm days, warm nights can cause thermal discomfort, which has negative health effects (Radišauskas et al. 2014). But heatwaves can have direct impacts on both health, as well as infrastructure. Heat related risk depends on a variety of issues, including individual conditions, the level of exposure, and the ability to adapt to hot weather conditions. There are also differences in heat tolerance of those living in northern and southern Europe, who encounter similar temperatures more commonly (Lanki and Kollanus 2014; WHO 2008). The elderly, children, those with medical conditions, the homeless or those who labour outside are most vulnerable to the effects of extreme temperatures (Radišauskas et al. 2014). For example, in Finland, the daily mortality rate of over 75-year-olds increased by about 21% during heat waves between 2003 and 2010 (Laine et al. 2018; Lanki and Kollanus 2014).

There are other factors related to the general state of public health which determine the overall consequences of heatwaves. Thermal stress during heat waves in combination with air quality, especially in urban areas can pose a severe threat for people with circulatory diseases, blood pressure complications (Deppisch et al., 2015) or diabetes. Also, the use of medications related to certain illnesses such as mental illness and dementia, as well as activities which cause dehydration, such as alcohol or use of certain drugs, can increase the consequences (MSB 2013).

2.3.4 Slippery and icy roads

Temperatures which hover around zero can result in dangerously slippery roads and sidewalks. This situation is projected to increase in frequency in the BSR during the winters. The city of Helsinki has assessed the risk of people slipping and hurting themselves and the resulting decreased wellbeing, healthcare costs, lowered productivity, increased need for sanding or otherwise mitigating slippery surfaces. Sanding or spreading gravel also results in poor air quality and has its economic costs. Helsinki has estimated the actual costs of such weather based on compensation claims to the city. For pedestrians, the worst is when light snow or rain falls upon ice (Pilli-Sihvola et al. 2018).

2.4 Consequences for infrastructure

Climate change directly impacts a wide range of infrastructure which support societal functioning. Local authorities in the Baltic Sea Region (BSR) consider the top assets/services potentially affected by climate hazards to be transport, public health, as well as water supply and sanitation (Paju 2019). The vulnerability of critical infrastructure is critical to examine because many essential services depend on it.

2.4.1 Critical infrastructure

The EU Directive on European Critical Infrastructures (2008) defines critical infrastructure as "an asset, system or part thereof located in Member States which is essential for the maintenance of vital societal functions, health, safety, security, economic or social well-being of people, and the disruption or destruction of which would have a significant impact in a Member State as a result of the failure to maintain those functions" (European Union 2008). They make up the "backbone of modern society" (Tsionis et al. 2016) and commonly interact with other infrastructure systems and create an interconnected set of systems which are complex, interdependent, cross-border, and undergoing continuous adaptation to societal needs (Abajo et al. 2015) (see Figure 17). They also connect to global networks and systems (OECD 2019).

Energy and transport sectors are commonly accepted as CI as many other infrastructures, such as IT and communications systems, depend on them (Rome and Voss 2015; Poljanšek et al. 2019). However, what is officially considered as CI differs from country to country (Nassopoulus et al. 2015). The Sendai Framework also includes green infrastructure as CI, but this is not yet commonly applied.

While technology has helped to improve the resilience of CI, it can also increase the impact and potential likelihood of disruption to CI (European Commission 2017a). For example, with "smart infrastructure," the decentralisation and autonomous mechanisms can increase resilience by providing a higher level of redundancies which are useful in shock situations where some path-ways may be blocked. However, decentralised systems have higher numbers of links which may be weaker, which may make them more vulnerable (OECD 2019).

The OECD recommends an all-hazards approach to CI risks due to the variety of risks they face (OECD 2019). Even though urban areas are very dependent on CI, the climate risk and vulnera-bility assessments for CI which urban areas are dependent on are not always linked with overall urban climate risk assessments. For example, in Latvia, local authorities are required to provide vulnerability and risk assessments to their areas of responsibilities related to heat and power. However, because hazards that impact CI have significant cascading effects on urban areas, an integrated approach, such as a multi-risk hazard taken by Norwegian municipalities would be useful (Abajo et al. 2015; DSB 2019a).

An in-depth review of whether NRAs account for CI and cascading effects concluded that Euro-pean national level NRAs typically lacked CI dependency modelling and analysis (Poljanšek et al. 2019; Theocharidou, M. and Giannopoulos, G. 2015). In Nordic countries, critical infrastruc-ture managers take a broader societal resilience approach (all-hazards approach) in contrast of a more narrow focus on the protection of the critical infrastructure (e.g. terrorism) (Pursiainen 2018) or business-continuity which is more common in other EU countries (DSB 2019b).

A 2017 review of EU NRAs found that four BSR countries included the CI disruption in their NRAs (see Table 7). One of those accounted for climate change. (European Commission

2017a). However, Finland's updated NRA includes disruption of the power supplies, and the trend of likelihood was estimated to increase. It explicitly recognises the climate risks associated with the electrical supply. Furthermore, the NRA further points to a link between severe disruptions of energy supply

Table 7: Critical infrastructure disruption in national risk assessments (when available).

Country	Specific risk type	Relative risk (likelihood/impact: L/I)	Climate change accounted for	Cascading effect
DE	Power outage			
DK	Risks related to energy infrastructure, IT and telecommunications are integrated into extreme weather Maritime accident		X, accounts for future projections X, extreme weather mentioned, but not future projections	the cascading effects on various CI are integrated into sections related to extreme weather; examples are given
EE	Severe maritime accident; aircraft accident; rail accident; road accident	Very high risk: High L / Very serious Med risk: Very low L/Catastrophic I Med risk: Very low L/Serious I High risk: Medium L / Serious I		Widespread environmental contamination
FI	Fire in CI Major road traffic accident Major rail transport accident Major aviation accident: runway collision Major maritime accident: collision Disruption of power supplies Availability of fuels Severe disruptions in	Average L / 2,5/5 I High L / 1/5 I Average L / 1/5 I Low L / 2/5 I Average L / 2/5 I	Storms and snowpack, climate policies, reduction of ground frost, exposure of trees to wind damage, warmer weather/sea temperature and need for cooling nuclear plants. Exceptionally harsh winter which prevents maritime transport to FI ports	Strain vital societal service Chemical release Disruption of international airways Possible water contamination Preventing or severely compromising impacts on the economy (industrial processes), infrastructure, and security of supply, and functional capacity of population and services Preventing or severely compromising impacts on the economy, infrastructure, population and services Preventing or severely compromising impacts

Country	Specific risk type	Relative risk (likelihood/impact: L/I)	Climate change accounted for	Cascading effect
	ICT		Extreme weather	on the economy, infrastructure, population and services; functional capacity of population and services; psychological resilience and leadership
NO	Shortage of power due to lower precipitation, combined with lower water reservoir levels and higher needs and reduced ability to import Transport sector/Road system	Moderate likelihood, moderate to very high consequences	X, climate change seen as a primary challenge for civil protection and infrastructure investments need to recognise climate projections	Large consequences of power rationing for 2,5 month period include: injuries or illnesses, financial and material cost with higher uncertainty for impact on social unrest, and critical services impacted
PO	Disruption of electrical supplies Disruption of fuel supplies Disruption of gas supplies Threats to telecommunication systems	Risk Value 3 (Moderate) Risk Value 3 (Moderate) Risk Value 3 (Moderate) Risk Value 3 (Moderate)		Damage to functioning of ICT/ transport/building Infra; unemployment; losses in national heritage; Damage to functioning of transport; unemployment; Damage to functioning of transport; Damage to functioning of supply / ICT / Transport/building infra

Source: EC 2017 review of National Risk Assessments (2016-2017), Green text colour indicates the use of the updated risk profile based on newer national risk assessments which were available, table modified by authors (see DEMA 2017, RSB 2015, Finnish Ministry of Interior 2019, DSB 2014).

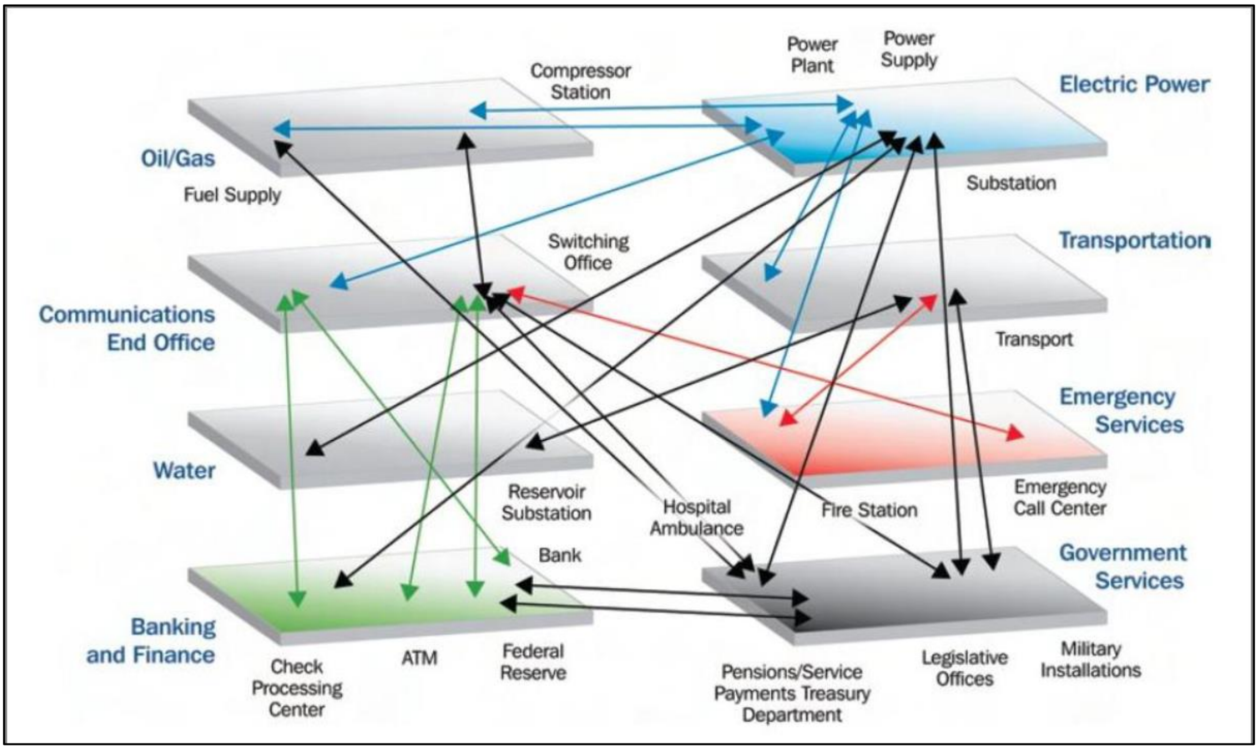

Figure 17 Critical Infrastructure Interdependencies, *Source: Ehlen and Vargas* ***(2013)***

CI disruptions can result from shocks from, e.g. natural hazards, industrial accidents and pandemics (OECD 2019), all of which can be impacted by climate change. Climate change drivers such as the increase in temperatures and sea level rise, together with the increased frequency and intensity of extreme weather events already impacts the transportation and energy infrastructure in the EU (European Commission 2017a). According to Tsionis et al., (2016), CI is increasingly unable to recover to a sufficient level when extreme natural hazard events impact them.

Climate change will increase the severity and frequency of extreme weather events, as well as create changes in temperature – all of which can impact the transport, energy, and IT systems often considered critical for societal functioning. The cascading effects, especially with quick-onset hazard events, are often multiple and include societal, economic and even environmental implications. The disruption of CI systems increases safety risks, e.g. related to accidents. Often this increases the need for health or emergency response in a situation where their capacities to respond are limited by the same or related situation. In some cases, like floods, there may even be an increase in false alarms, e.g. related to a fire which further burdens responders (DEMA 2017). Figure 18 depicts the cascading impacts of electricity failure in a hypothetical case study of a UK town. While all the effects are unlikely to take place simultaneously, they represent the complexity of identifying the effects and feedback loops. Further cascading effects to CI are presented in the Appendix.

Critical infrastructure is essential because they amplify the cascading effects due to their central role in coordinating and implementing emergency response, and recovery (Esposito and Stojadinovic 2016; Pescaroli and Alexander 2015; Rome and Voss 2015). How well CIs resume performance after a disaster has a long-term effect on the local post-disaster recovery process of the community (Esposito and Stojadinovic 2016).

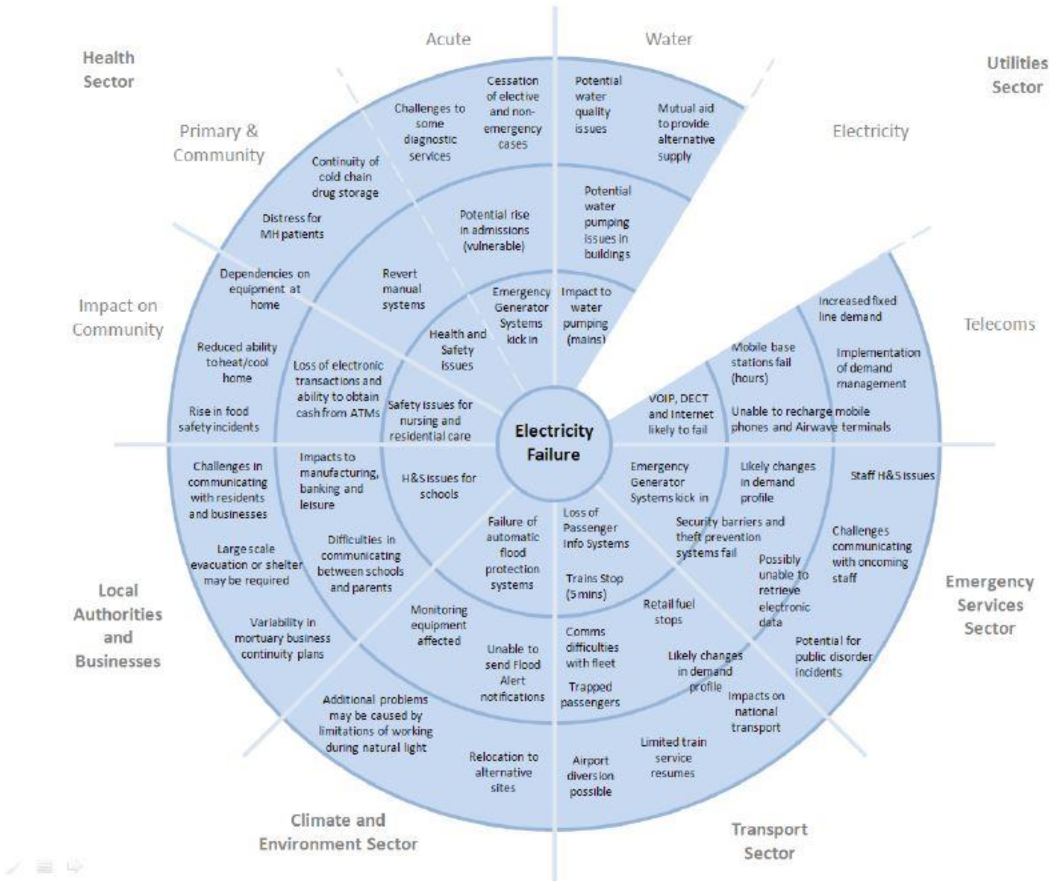

Figure 18. Onion-skin diagram of Anytown workshop discussions relating to Electricity Supply Failure, *Source: Hogan (2013)*

Only five of the Baltic Sea Region countries have included flooding or extreme weather event related cascading effects for CI in their NRAs (European Commission 2017b). However, according to Poljanšek et al. (2019), cascading effects happen more frequently than is believed.

In Finland's National Risk Assessment, disruption of water supply or water quality is considered one of the most significant threats for urban centres. Thus, although it is not officially called CI, it is a priority being included in the NRA. They consider two potential causes of water supply disruptions: power supply disruptions or overburdening of the system by floods and rainstorms. They describe how crucial power is for all parts of the water supply system - for pumping, keeping it under pressure and uncontaminated by impurities, etc. The trend of likelihood for the major disruption in power supply (from reasons not limited to climate change), the threat was estimated to remain unchanged, but directly impacting economy, infrastructure, and security of supply, as well as the functional capacity of the population and services in a way that prevents or severely compromises them, as well as indirectly negatively impacting internal security, as well as psychological resilience (Finnish Ministry of the Interior 2019), see Figure 19.

Threat scenario/disruption	Trend of likelihood	Impacts of the threat scenario/disruption on vital functions						
		Leadership	International and EU activities	Defence capability	Internal security	Economy, infrastructure and security of supply	Functional capacity of the population and services	Psychological resilience
Water supply disruptions	↑	*	*	*	*	**	**	**

Figure 19 The trend of likelihood for the major disruption in power supply

*Yellow colour signals indirect impact, while Red colour signals direct impact. * signals minor impact, ** signals other negative impact, *** represents preventing or severely compromising impact. Source: Finnish Ministry of the Interior (2019), key on p22.*

2.4.2 Natural Hazard Triggering Technological Disasters incidents (Natech)

One of the cascading effects that critical infrastructure can have on society relates to Natural Hazard Triggering Technological Disasters (Natech). Natech incidents are defined as "Technological accidents triggered by a natural hazard or disaster which result in consequences involving hazardous substances (e.g. fire, explosion, toxic release)" (Poljanšek et al. 2019).

Natech risks are relevant to all hazardous industrial sites. Industrial facilities may be sensitive to changes in the climate. Natural hazards, even of minor importance, such as lightning, low temperature or rain can damage industrial facilities, including nuclear power plants, in a way that triggers a Natech incident (European Union 2008; Girgin et al. 2019). Other relevant natural hazards include strong winds, flood events, and storms surge. In Europe, rain and flood events have the potential to trigger Natech accidents with the most significant consequences (see Table 8). The incident can be triggered through the natural hazard itself (hurricane leads to a leak) or a direct result of the natural hazard, such as the loss of power from disruption to power utilities (Necci et al. 2018).

As with CI, increasing urbanisation and interconnectedness increases the vulnerability of society. Exposure and thus potentially risk to industrial accidents are increased when hazardous goods are transported through areas with human populations, or when urban or residential areas are situated in proximity to industrial areas. Coastal areas at risk for flooding induced by heavy rain, especially in low floodplains and river deltas which also are sites for industries should consider the risks associated with the industries. Increased exposure, along with the expected increase in the frequency of natural hazards due to climate change, means that Natech risks are also likely to rise in Europe (European Union 2008).

Natech accidents happen frequently and have environmental, human and economic impacts. They are also considered an emerging risk which means that they may still be under-reported and insufficiently considered in NRAs. Vulnerability of hazardous industrial facilities to natural hazards should be assessed in terms of how the facility design accounts for climate change, as well as how the recovery or protection systems which may also be susceptible to impact. Thus, in addition, to back up critical services (power, water, communication, it should be assessed whether the sensors and safety systems and safety barriers implemented to prevent or respond to such accidents are also available or down (Necci et al. 2018; Poljanšek et al. 2019). After disasters, there is a limited capacity of responders to cope, and response can be further limited by the lack of energy supply which makes mitigation of further impacts challenging (Necci et al. 2018). Also, emergency response teams can be limited in their capacity for dealing with simultaneous hazard events, which is often the case in Natech accidents (Poljanšek et al. 2019). Natech risk governance requires diverse stakeholder collaboration across actor-communities which have tended to act within silos (technological risk, natural risk, industry, civil protection, etc.) (Girgin et al. 2019).

In Europe, small scale industrial accidents are common, but extensive industrial accidents are considered high impact/low likelihood risk. The possibility may be linked to the relatively effective prevention of such accidents through governance or a low level of such hazardous activities (European Commission 2017b). Nuclear accidents are considered a low likelihood / high impact event, but potentially with regional and even global impacts. The likelihood is low due to high levels of technical standards and high levels of governance and safety culture in place. Potential effects, however, include severe land and/or water contamination, economic losses in the agriculture and tourism, and other sectors affected by the potential disruption of power, as well as long-term health implications (European Commission 2017a).

Natech risk is inadequately accounted for in industrial risk assessments, even in countries that are otherwise prepared for natural hazard events (Girgin et al. 2019). Denmark, Lithuania, and Sweden address Natech risks stemming from severe weather phenomena, e.g. storms. These countries account for the increased risk of pollution, loss of CI, as well as potential problems from disruptions to transportation and traffic ways (European Union 2008).

Table 8: Industrial accident risk in national risk assessments (when available).

Country	**Specific risk type**	**Relative risk (likelihood/impact)**	**Climate change accounted for**	**Cascading effect**
DE	X			
DK	Accidents with dangerous substances on land and at sea; Accidents involving chemical agents	Serious to very serious	X, extreme weather events mentioned, but not climate change	Potential impacts from contamination spread; consequences assessed for various topics and examples

Country	Specific risk type	Relative risk (likelihood/impact)	Climate change accounted for	Cascading effect
EE	X	High risk		
FI	Serious chemical accident at a plant handling dangerous substances	2/5 L / 2/5 I		
LT	X	Very high risk		Potential significant impacts abroad
LV	Industrial accident in Seveso site, including potential industrial events abroad	Insignificant risk		Water/environment pollution
NO	Various major accidents: hazardous substances, nuclear accidents, offshore accidents.	Very low to moderate likelihood, small to large consequences		Various, depending on the scenario
PL	X	Moderate risk		Infrastructure
SE	Emission of hazardous substances including incidents in North & Baltic Sea areas			

Source: EC 2017 review of National Risk Assessments (2016-2017), Green text colour indicates the use of the updated risk profile based on newer national risk assessments which were available, table modified by authors (see DEMA 2017; DSB 2014; DSB 2019a).

2.5 Cascading effects from climate change abroad (transboundary impacts)

Climate risk has four main pathways for transboundary impacts: biophysical (transboundary ecosystems), trade (regional and global markets), finance (flows of capital), and people (movement of people) (Benzie and Carlsen 2016). Some of these have already been discussed in earlier sections, e.g. animal and human diseases, fires, etc.).This section will consider some further potential climate change related transnational impacts for the Baltic Sea Region through flows of goods, finances and people. The World Economic Forum report (2019) considers extreme weather events, failure of climate change mitigation and adaptation and natural disasters to be the top three risks in terms of likelihood, and all three, as well as water crises, to be in the top five risks in terms of impact.

These events can have transnational cascading effects, meaning that these effects can travel across national borders or even across the world. This takes place through the various global networks embedded in society. Figure 20 below depicts some of the pathways in which Europe is exposed to climate change impacts directly taking place in other areas. Climate impacts influence international trade systems, stability and conflict of areas, and financial and business markets and create risks for those participating in these systems. Below we consider cascading effects on food affordability, migration caused by climate related displacement, supply losses and business disruptions, and financial instability. Additional examples illustrating these categories are located in the Appendix.

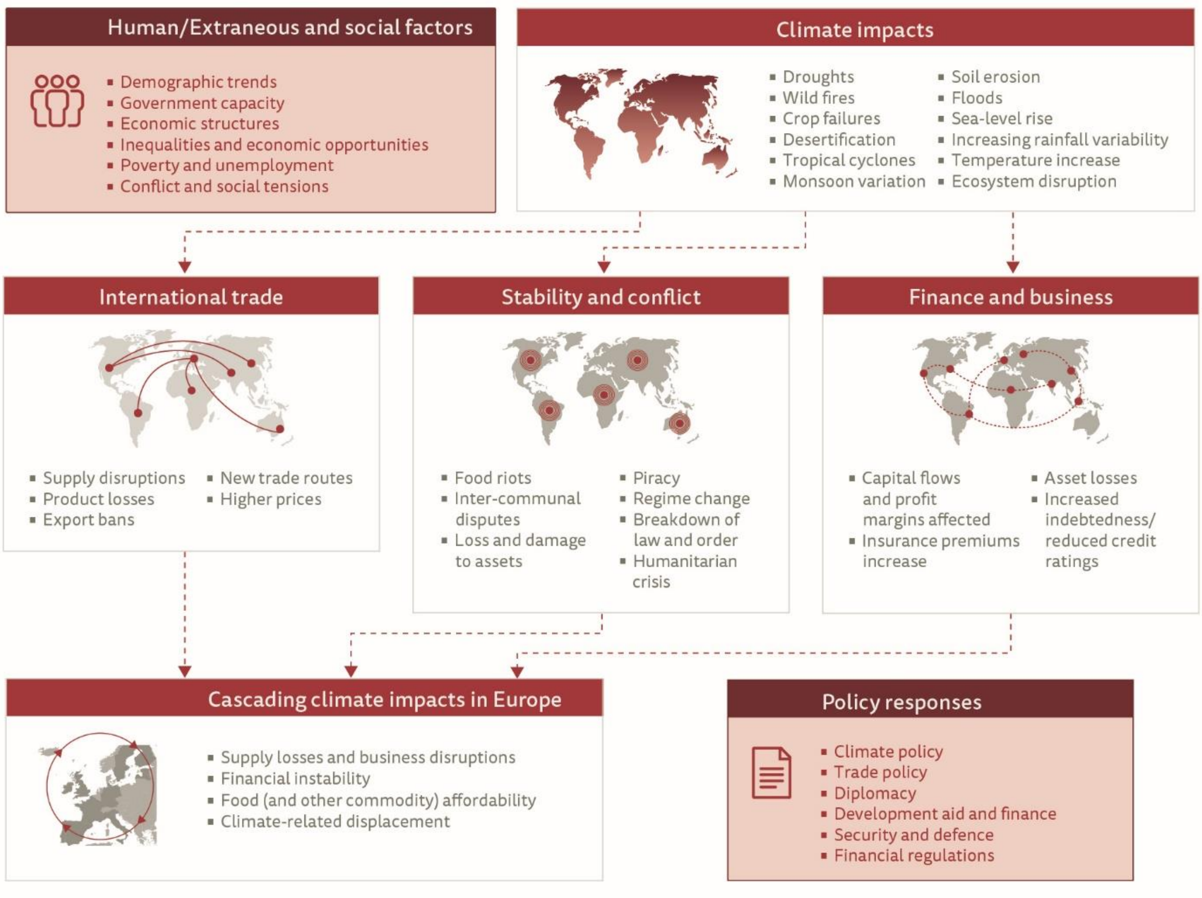

Figure 20 Some examples of Europe's exposure to cascading climate change impacts. *Source: Hilden et al.* ***(2020)***

Figure 21 provides a more disaggregated and comparative view of the exposure of European countries to transnational climate impacts. The cross-border climate impacts index accounts for exposure related indicators related to the identified pathways for transboundary risk (Benzie and Carlsen 2016). The index shows that the Nordics, Baltics, and Germany are relatively exposed due to transnational climate impacts, although their vulnerability to direct climate impacts is globally relatively low. These countries, except Latvia, have high levels of global integration and interconnectedness. Germany also had a high dependence on transboundary waterways and tended to grant asylum to refugees and migrants. Lithuania and Estonia are highly exposed to risks coming from trade and Finland and Estonia have a relatively high level of dependency on crucial commodities that were grown in highly water-stressed areas of the world (Benzie and Carlsen 2016).

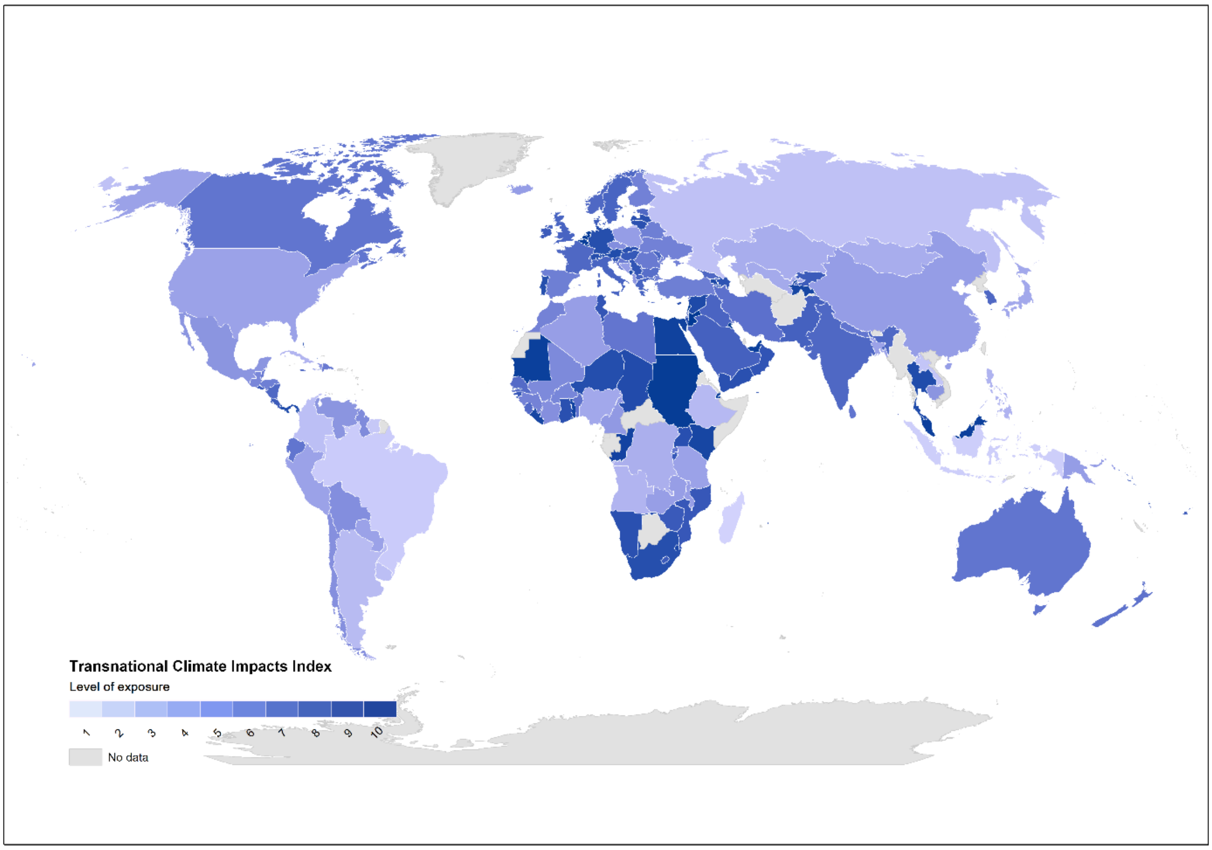

Figure 21 Exposure map for the Transnational Climate Impacts Index, *an index of exposure to the transnational indirect impacts of climate change. Source: Benzie and Carlsen (2016)*

2.5.1 Food affordability

BSR countries may be impacted by reduced food affordability due to changes in supplies of specific commodities produced abroad via trade flows (Hilden, M. et al. 2020). Climate change is projected to impact food production globally through disruptions in agricultural production and food systems. This can happen due to slow-onset changes in temperatures or extreme weather events, such as drought, extreme precipitation or storms, pest invasions or plant or animal diseases and their effects. Also, extreme weather can impact infrastructure, transport, and cause supply chain disruptions (European Union 2008). In many countries, this will show up as decreased food security, food availability, as well as food affordability (WEF 2016).

An example of a transboundary cascading effect is represented in Figure 22. This example relates to two sets of simultaneous climate impacts in two different countries - drought in Russia and extreme precipitation and flooding in Pakistan - which creates crop failure in both countries. Transnational cascading effects include deficits in global cereal production, increased prices of cereal as well as other prices to which grain is an input, riots in countries in which this adds a layer of unsatisfaction to other reasons, as well as impacts on food affordability in the UK. It should be noted that some of the BSR countries have similar levels of dependency on cereal imports as the UK (Hilden et al., 2020).

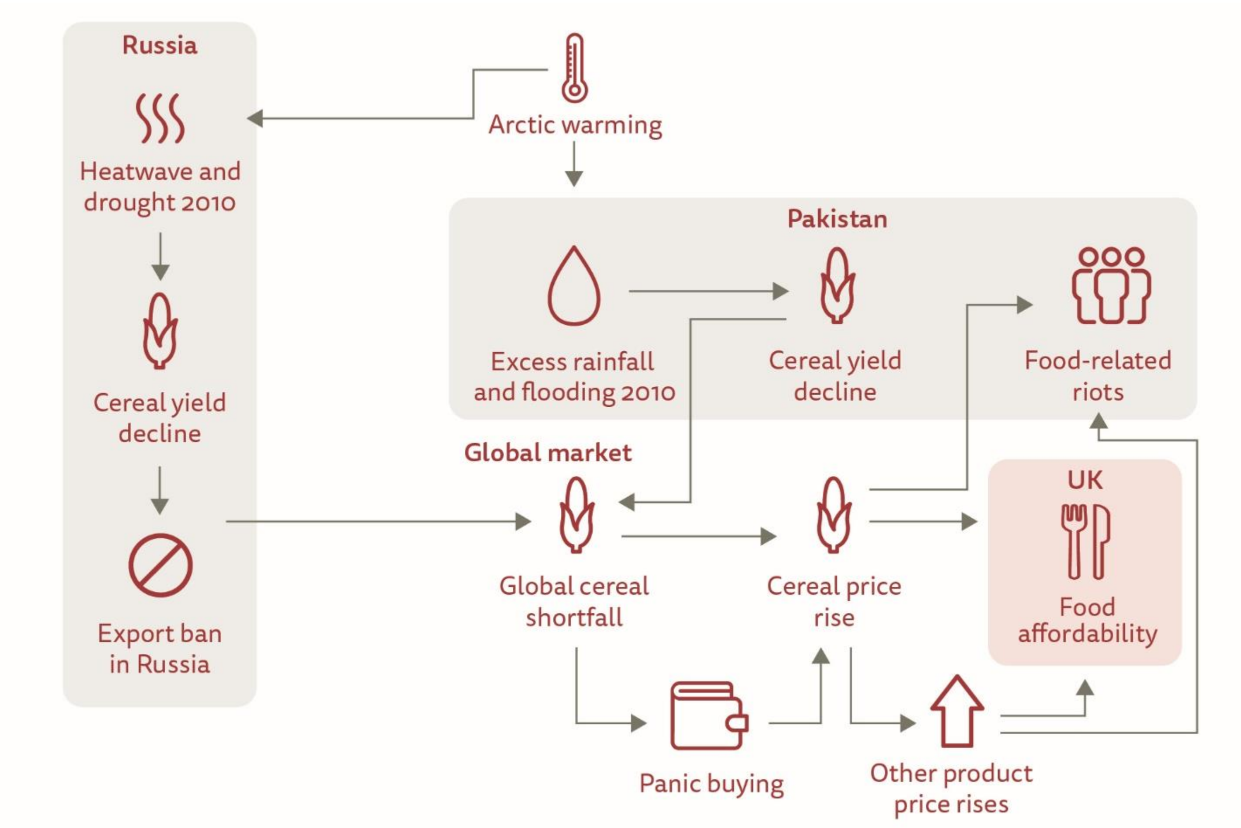

Figure 22 Example of cross-border impacts: drought and food prices. *Source: image created by Hilden et al., 2020 based on Challinor et al., (2018)*

The Finnish National Risk Assessment (2018) considers the combined impact of climate change, extreme weather conditions and water supply issues on food production systems abroad and the impacts on food supply for Finland (see Figure 23). They further recognize that population growth, unregulated groundwater and land use as additional pressures which together can create the context for escalating risks. Finland expects an increase in the likelihood of disruptions in food supply and impacts on the economy, infrastructure, and security of food supply, as well as indirect negative impacts on the functional capacity of the population and services and psychological resilience (Finnish Ministry of the Interior 2019).

Threat scenario/disruption	Trend of likelihood	Impacts of the threat scenario/disruption on vital functions						
		Leadership	International and EU activities	Defence capability	Internal security	Economy, infrastructure and security of supply	Functional capacity of the population and services	Psychological resilience
Disruptions in food supply	↑	*	*	*	*	**	**	**

Figure 23 The trend of likelihood for the disruption in food supply

*Yellow colour signals indirect impact, while Red colour signals direct impact. * signals minor impact, ** signals other negative impact, *** represents preventing or severely compromising impact. Source: Finnish Ministry of Interior (2019), key on p22.*

2.5.2 Migration caused by climate related displacement

Another type of transboundary cascading effect relevant to European countries is climate related displacement of people and the resulting potential migration (Hilden et al., 2020). Here, climate change impacts which make some areas uninhabitable forces people to migrate. In other instances, negative climate impacts on agricultural production in lower-income countries, such as Africa, drive migration from rural to urban areas. Due to the limited capacity of African cities to absorb all internal migrants, some people continue their migration to places such as Europe as economic migrants (European Commission 2017b).

The European Commission does not see sudden large-scale international migration from developing regions to Europe as likely due to the resources required for this to transpire (European Commission 2017a). However, both the Finnish and Danish NRAs recognize this as a climate related risk. The latest Finnish NRA estimates that globally there are already 200 million refugees resulting from environmental and climate change. They consider it likely that Europe will encounter larger future waves of migration, compared to the past (Finnish Ministry of the Interior 2019). BSR cities also found climate refugees as one of the potential long-term social risks from climate change (Paju 2019). Figure 24 shows the extent to which a country had migrants arriving into the country from climate vulnerable countries using 2010 and 2012 data. Among the impacts of such migration at the local level in the BSR can include the need to integrate new populations into societies (Finnish Ministry of the Interior 2019).

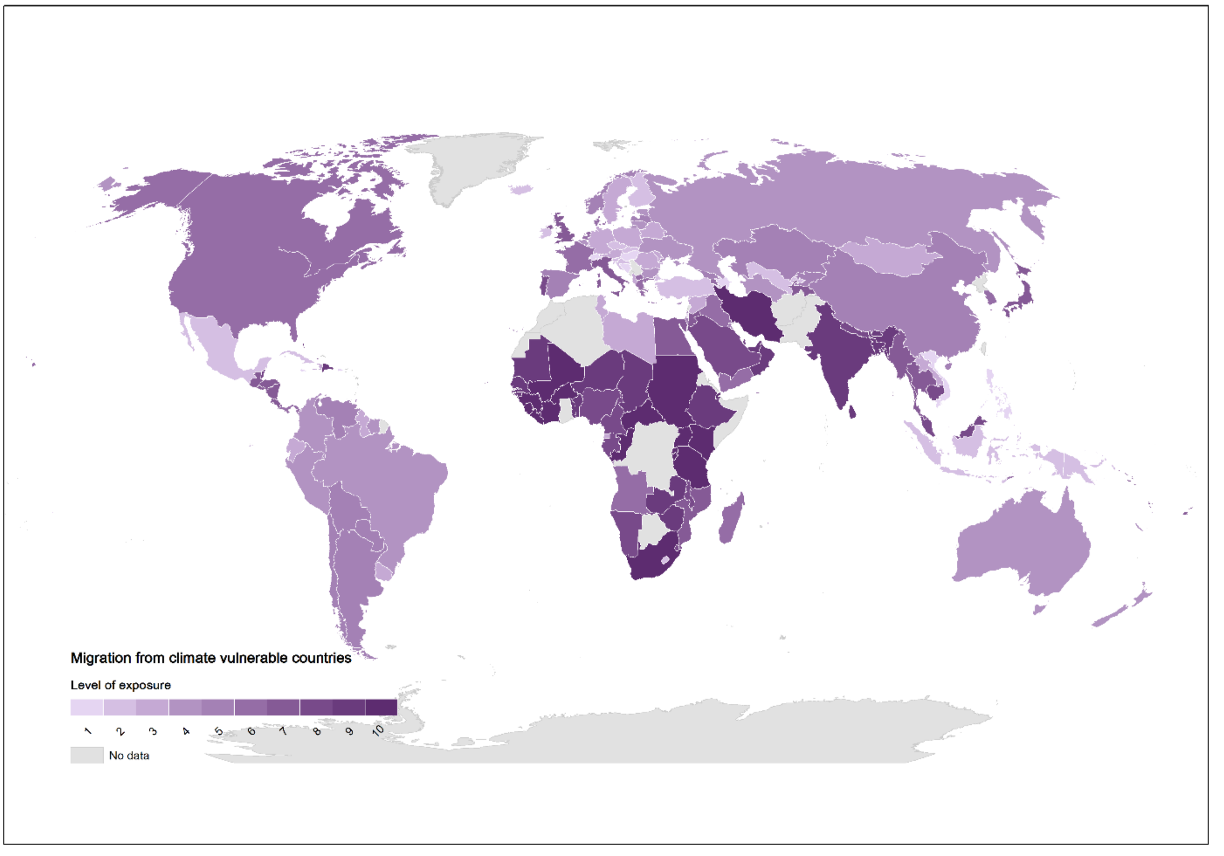

Figure 24 Exposure map for migration from climate vulnerable countries. *This shows the extent to which a country has in-migration from climate vulnerable countries, data from 2010 and 2012. Source: Benzie and Carlsen* ***(2016)***

2.5.3 Supply losses and business disruptions

Climate change can cause disruptions in global supply chains. Similar to food, markets for other internationally traded goods can also be impacted by hazards. Human diseases can affect the workforce needed for operating various components of the supply chain, e.g. operations, management, logistics, etc. Heavy storms may damage production or transport infrastructure in other countries, impacting the supply and prices of energy and materials (European Commission 2017a). For example, as more than a third of oil refineries are coastal, damage to ports or refinery facilities (or both) can disrupt oil supply and oil prices globally (European Commission 2017a; Nicholls and Kebede 2012). In addition to the local impacts, loss of services from transport hubs to shipping products can result in business interruptions and economic losses globally (Tsionis et al. 2016).

These cascading effects can even take place regionally in the BSR. For example, CI is sometimes networked or serving a larger area, and thus disruptions have cross-border impacts (Infrarisk 2015). Therefore, even if a local CI is not itself exposed to directly to hazards, it might be vulnerable if it is dependent on energy from a neighbouring country (Abajo et al. 2015; EEA 2016). Electricity grid connectedness can both mitigate and spread cascading effects (EEA, 2016).

The complexity of supply chains makes risk assessment across the supply chains resource-intensive and challenging. A study of fourteen major Swedish export-oriented corporations showed that climate change related risks are often not prioritised because the cascading effects on their business are not recognised (Tenggren et al. 2019).

2.5.4 Financial instability

Climate change impacts, such as extreme weather events can disrupt **global financial markets and global financial flows** (e.g. investments, remittances from one country to another or insurance) (Benzie and Carlsen 2016). For example, a country which suffers from an extreme weather event may have difficulty securing international private investment or insurance for rebuilding its economy if it is perceived as high-risk. Figure 25, which is based on data from 2008-2012 shows that Poland has historically invested in climate vulnerable countries and thus, as an investor, may also be exposed or impacted by climate impacts in those countries.

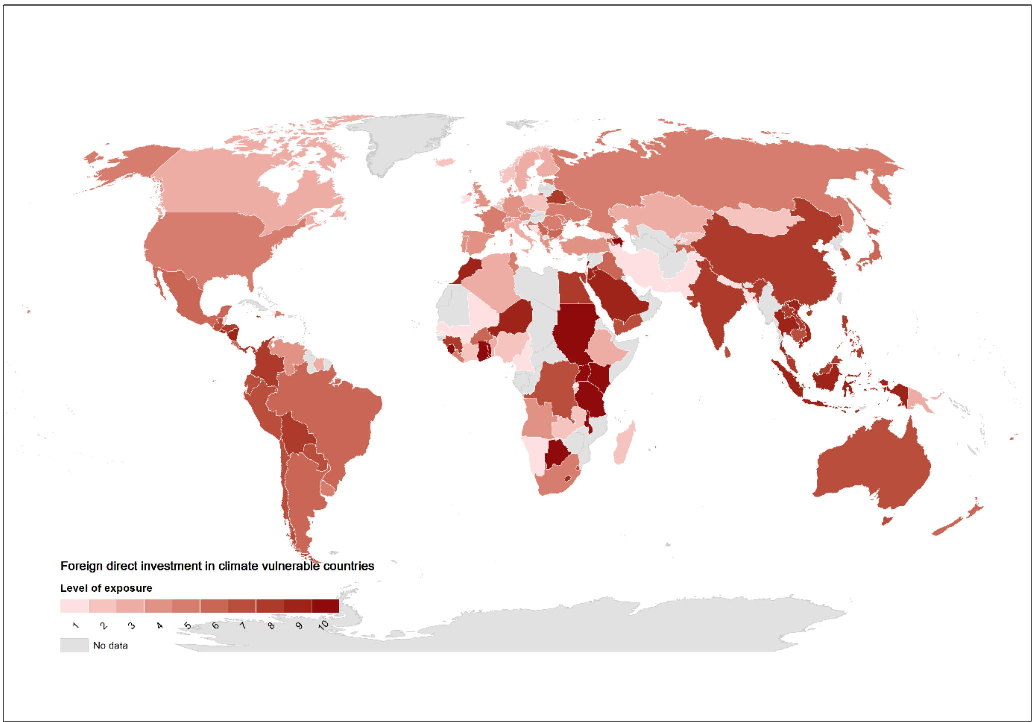

Figure 25 Exposure map for bilateral climate weighted foreign direct investment. The extent to which a country invests in climate vulnerable countries, data from 2008-2012. *Source: Benzie and Carlsen* ***(2016)***

Also, some countries are dependent on remittances, or transfers of money from often family members or relatives working in other countries. Figure 26 shows the extent to which a country is dependent on the flow of remittances, based on data from 2012 (Benzie and Carlsen 2016). From here it is visible that within the BSR region, the Nordic countries have the least relative extent of dependency on remittances, followed by Germany and Poland, and then the Baltics with the highest relative dependency. However, it is unknown what the current levels of remittances are as well as whether they are coming from countries that are vulnerable to climate impacts. It should be noted that remittances can also be impacted by indirect climate related impacts, such as pandemics. This was observed with the COVID-19 pandemic, which was not climate related, but which influenced the ability of (foreign) workers to earn money and thus also their ability to send remittances back to family across the border.

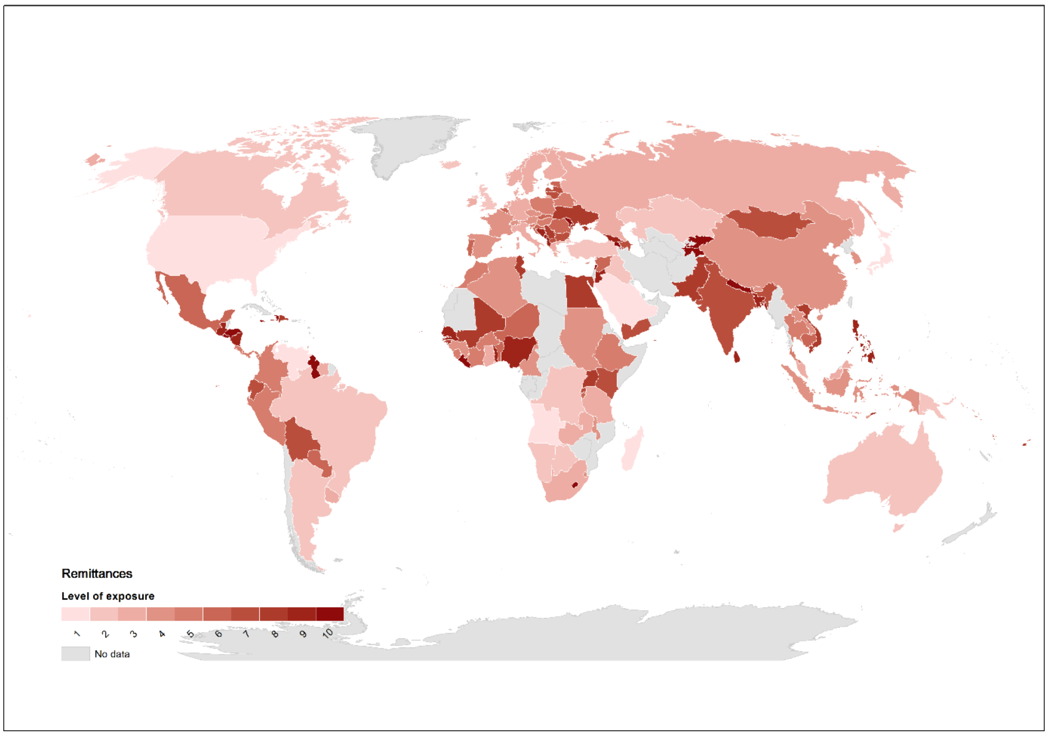

Figure 26 Exposure map for remittances. *The extent to which a country is dependent on the flow of remittances, data from 2012. Source: Benzie and Carlsen (2016)*

APPENDIX CASCADING EFFECTS FROM CLIMATE RELATED DRIVERS AND HAZARDS

Climate change drivers and hazards	Examples of consequences and cascading effects	Systems involved	References
Hurri-canes, ty-phoons, and high winds	• Health risks and injury or death due to flying/falling objects, collapsing structures, as well as traffic accidents • Flooding • Blocked or closed traffic routes, including air, land and water • Risk of maritime vessel accidents from high waves • Risk of power failures due to infrastructure damage, e.g. above-ground electrical wiring • Disruptions in IT and telecommunications services due to overloads/high use • Limited capacities of emergency response due to the extreme weather itself, the resulting power failure, traffic and transport related obstacles • Blocked waterways with litter and debris • Industrial accidents, including fires, explosions and release of hazardous materials caused by winds causing objects (internal or external) to float into or hit industrial facilities, pipe-lines, or offshore platforms • Damage to wind and hydropower generation plants • Infiltration of freshwater with saline water impacts waterworks or groundwater caused by a combination of more frequent extreme weather, a rise in sea levels, and changes in wind patterns making it unusable as for water supply for drinking or irrigation for agriculture • Damage to forestry and/or recreation/tourism • Port closures due to high winds; difficulty for sea rescues	• Public health sector • Transport sector (land, air and water) • Power sector • Waste management sector • Emergency response • Forestry • Tourism	DEMA (2018), DRB (2015); MSB (2012)
Heavy pre-cipitation events, cloud bursts and flooding	• Health risks due to traffic accidents due to weather conditions, malfunctioning signals, peo-ple wading through deep water or climbing onto higher objects, surface water contamina-tion by sewage • Disruption of infrastructure related services due to damage to or destruction of infrastruc-ture equipment • Overflow of sewage systems and surface flooding from higher pressure on drainage and wastewater systems; congestion of pipes for wastewater can lead to basement flooding and increased need for wastewater treatment and associated health risks.	• Public health • Transport sector (land) • Power and heating • Telecommunication • Waste management sector • Emergency response • Fire service • Building & construction • Water management	Deppisch et al. (2015); Łabuz T.A. (2015); EMA (2018) DRB (2015); DEMA (2018); MSB (2012); Finnish Ministry of In-terior (2019); EC (2017); Necci et al.

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	• Inflow of saline water into the sewer and wastewater treatment plans due to heavy precipitation combined with sea-level rise in the coastal cities, heavy rainfall might also cause inflow into sewerage systems and wastewater treatment plants; this can affect water quality • Power failures due to infrastructure damage, e.g. water intrusion damage the grid or electrical equipment • Power failures can lead to telecommunications failures which limit rescue services especially in a time where they are needed; inability for people to work or go to school due to traffic and transportation problems; challenges in communicating about how to organise basic society during time of crisis, including the status and limited ability of hospitals (generators only working to supply critical functions) and evacuation centers if needed. • Disruption in heating or hot water due to flooded steam wells and heating pipes • Disruption in IT systems and mobile phone networks and / or electrical fires due to water and moisture damage of IT equipment • Damage to water pipes from flooding • Limited capacities of emergency response due to the extreme weather itself, the resulting power failure, traffic / transport related obstacles • Blocked waterways with litter and debris, including marine litter • Soil erosion and run-off, including impacts on road banks • Increased road wear and need for maintenance • Local flooding in low lying areas, mudslides from underwashing of treeroots, streets become waterways which create property and asset damage; landslides • Severe consequences on tourism, the local economy, and local recreational possibilities from the disappearance or retreating of beaches and coastal areas • Congestion in pedestrian and road traffic and traffic accidents • Technological disasters triggered by natural hazards (Natech) Damage to control rooms of industrial facilities relying on electricity or electrical equipment which can be damaged by water intrusion. Power loss alone can trigger Natechs. • Stagnated water on agricultural areas • Diseases spread through stagnating water, including via insect vectors, animals, and humans, especially under circumstances of multiple drivers of climate change (precipitation, temperature, and destruction of ecosystems); potential epidemics • Damage to local infrastructure (public and private) can cause disruptions to supply chains (potential global implications) • Disruptions in mobility and potentially tourism depending on the extent of damage • Deterioration of older chemical-toxic landfills from flooding leading to human health risks. For example, poisoned water intake causing very serious illnesses of sufficient fraction of population • Damaged power plant causing long term blackout and malfunctioning of health care system threatening human life and health. • Spoiled edibles due to flooding and as a result direct and indirect huge economic losses.	• Land management • Tourism & recreation • Infrastructure • Agriculture • Supply chains • Industrial facilities and infrastructure	(2018); EU (2017); (DSB 2019a)

Climate change drivers and hazards	Examples of consequences and cascading effects	Systems involved	References
Average increased precipitation	• Accelerated ridge growth in roads and decreased load capacity of roads due to higher groundwater levels from increased rain • Increased port flooding and thus port closures due to higher water levels • Ground cables for electricity can be damaged by the increase of water in soils.	• Transport sector (land) • Power and heating • Telecommunications • Forestry	Finnish Ministry of Interior (2019); MSB (2012)
Wintertime heavy precipitation, snowstorm,	• Disruptions to power supply from fallen trees or packed snow, which can leave several power grid companies without power in the case of a strong storm across an extensive area. Can lead to power losses for days or weeks in winter when electricity is required for heating. • Disruption of transportation • Threats to electrical power systems and electrical supplies • Threats to buildings due to loads of snow • Secondary hazards, including snow avalanches • Floods from snowmelt in the spring • Damage to forests due to large quantities of wet snow	• Transport sector (land) • Power and heating • Telecommunications • Forestry	Finnish Ministry of Interior (2019), DRB (2015)
Extreme heat temperatures	• Damage to transport infrastructure, such as railroad lines affected by heat distortion* • Disruption to functionality of critical infrastructure as, for example, servers and data processing centres could have problems with cooling* • Efficiency of solar power production is decreased • Increased mortality among animals, increased infections among animals*	• Transport sector • Agriculture • Energy sector • Critical infrastructure	Deppisch et al. (2015); MSB 2013; MSB (2012)
Extreme cold temperatures	• Loss of life and damage to buildings from cold temperatures • Disruptions to electrical supplies, fuel supplies, limitations in the gas supply, disturbance of telecommunications systems • Inland shipping difficulties	• Buildings • Energy supply • Transport	RCB (2014)
Increased average temperatures (water and air)	• Reduced winter tourism due to reduced snow cover • Damage of roads (impairing the load-bearing capacity) due to reduced ground frost • Damage on roads (increased holes in the roads) and eroded pavements due to higher frequency of melt-freeze cycles • Trees have increased exposure to damage due to the reduction of ground frost. Damaged trees can fall and disrupt transportation routes as well as power supply. • Higher resources on road maintenance due to increased damage to road superstructures, wearing of coatings, challenges of winter maintenance, damage to concrete structures, roadblocks and bridges destroyed by flowing water, and flooding	• Ecosystem • Local economy • Local recreation, tourism • Public health • Forestry • Transportation systems • Power systems	Finnish Ministry of Interior (2019); Viitasalo et al. (2015), Schneider et al. (2015); Stein et al. (2013); Gaia Consulting (2018); MSB (2012)

	• Earlier and longer blue-green algae blooms* due to higher summer air temperatures and increased water temperature, especially in combination of Nitrogen and Phosphorous nutrients in the water. Algae blooms can pose health risks related to water use and limits on recreational water use. This can negatively impact the local tourism-based economy as well as recreation. • Disruption of power due to the increased temperatures of waters, which are needed for cooling power plants.		
Forest, bush and landscape fires	• Health risks, such as possible death or injuries from coming into contact with the fire itself. • Health risks due to air pollution from fires, especially for high-risk groups. People can be hurt by the smoke and inhalation of the particulate matter in the air close to the fires and areas farther away due to winds carrying particles from one area to other. • Loss in property • Increased societal exposure to wildfires when urban settlements are alongside wildland habitats. Fire management around nature-urban interfaces is also more complicated. • Disruption of transport systems and critical infrastructure (airports, power lines, etc.) due to forest fires result in economic losses for property owners, and a loss of recreational areas for the public. • Impact on local biodiversity	Various critical infrastructure	Stein et al. (2013); EC (2017); Finnish National Ministry of Interior (2019)
Maritime ice sheet	• Economic impacts to countries dependent on sea cargo from a disruption in maritime logistics due to the limited capacity of newer environmentally friendly maritime vessels to perform in icy conditions, together with the lack of an accessible ice-breaking fleet	• Logistics (sea cargo) • Economic actors dependent on logistics	Finnish National Ministry of Interior (2019)
Drought	• Negative impacts on agriculture (crop-losses), which can result in eradication of crops and local food crisis • Negative impacts on forestry • Increase the risk of forest fires and peatland fires, which then increase air pollution and concentration of heavy metals in rivers • Impacts on the water supply for domestic and industrial use, negatively impact hydroelectric power generation as well as the possibilities of power control in the national grid in case of longer drought	• Agriculture • Forestry • Power generation	Finnish National Ministry of Interior (2019); Lithuanian Fire Protection and Rescue Department (2018)
Sea level rise	• Erosion and flooding of coastal facilities can cause damage to infrastructure • Cable damage from increased instability of the seabed due to eroding currents and waves	• Communications • Infrastructure	MSB (2012)
	Examples of transnational cascading effects		
Extreme weather	• Global food supply decreased due to damage to transportation infrastructure, large crop losses, presence of pests, reduced fertility of agriculture. • Hampered extraction, production, and transport of critical products such as oil, gas, and other industrial inputs due to damage to infrastructure and transport abroad • disrupted global financial markets and thus global financial flows (e.g. Investments, remittances from one country to another, or insurance). For example, a country which suffers	• Transportation • Food systems • Society – locally • Society - globally • Financial markets/flows	WEF (2016); Finnish Ministry of Interior (2019); EEA (2017); Abajo et al. (2015); MSB (2012)

	from an extreme weather event may have difficulty securing international private investment or insurance for rebuilding its economy if it is perceived as high-risk. • Increased insurance premiums and decreased coverage/eligibility, as some assets may become uninsurable. • Further opportunities for insurance companies to widen their insurance coverage or create new products. • Higher risk on local critical infrastructure if it is dependent on critical infrastructure across the border (energy, transport, etc.). • Economic shocks, increased poverty, regional instabilities and even mass migration. • Increased tension globally, increased risk of armed conflicts created by global social unrest related to climate change	• Insurance • Infrastructure	
Temperature and precipitation changes and land-use changes	• Increased spread of diseases from climate change. Due to global mobility, the diseases can spread to become international epidemics and pandemics, which also distribute the societal impacts, including economic ones. This can also impact the tourism industry which relies on mobility of people. • Financial implications and affected societal functioning due to epidemics and pandemics caused by human- or animal-spread diseases • Significant economic impacts through global networks such as supply chains which are impacted due to gaps in supply induced by climate change. • Eradication of crops and local food crisis due to animal and plant diseases, or other negative climate impacts on agriculture, such as drought • Increased burden on public sector economy and possibly eroded faith in authorities due to climate change induced damage to international supply chains or mass migration to the BSR. • Higher risk of foodborne diseases due to climate change related scarcity of water and changes in production methods and trade patterns.	• Health system • Global trade • Tourism/travel • Agriculture • Critical infrastructure and other services	EC (2017), MSB (2012), DSB 2019

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