1
Disaster Threats in Europe

1.1 Disaster Risk Landscape in Europe

The core objective of this book is to give an overview of Disaster Risk Reduction policies, networking and mostly research activities that have been carried out (some still running at the time of publication) in the period from 2013 to 2025. To set the scene, it was found essential to provide background information about disaster threats. In this respect, this chapter has been based essentially on a Communication by the European Commission published in 2020 giving an *Overview of natural and man-made disaster risks the European Union may face* (European Commission 2020a) and a report on *Cross-border and emerging risks in Europe* (EC Joint Research Centre 2024).[1] Further background information about natural hazards within disaster management may be found in a Book Series produced in the framework of an EU project coordinated by the University of Vienna (Marr et al. 2025).

1.1.1 Lessons from the Past

Over the last few years, Europeans have faced multiple emergencies that have caused devastation of human life, property, environment and cultural heritage. Disaster events occurred across the EU; some of them were more extreme than ever or had affected locations that have not seen similar threats before. The biggest emergency event to hit Europe in decades was certainly the coronavirus disease 2019 (COVID-19). Caused by a novel virus unknown to infect humans before December 2019, this developed into a global pandemic in a matter of a few months, killing thousands of people across the world and the EU, overwhelming national healthcare systems, disrupting all public life and presenting a major shock to economies.

While the COVID-19 pandemic is the worst health crisis seen in the European Union (EU) history, it is not the only adverse event witnessed in recent years. Europe has also grappled with extreme weather and other disasters caused by natural hazards, some of which manifested themselves with new intensity and pattern. Regions from north to south experienced episodes of life-threatening heat, with historic temperature records broken several years in a row. Heatwaves caused death, disrupted critical infrastructure and exacerbated drought and forest fires. Since 2021, dramatic wildfires have been blazing throughout the continent, including in such unusual locations as the Arctic or

1 In accordance with the authorisation to reuse Commission documents under the Creative Common Attribution 4.0 International Licence, implying that reuse is allowed, provided that appropriate credit is given and any change indicated.

wetlands. They killed more people and burnt more land than ever and overwhelmed national and EU response capacities. Storms, extreme rainfall events and floods continued causing damage, with washed-away roads and inundated city streets making news headlines. Examples of dramatic flash floods are those which hit Belgium, Luxemburg and Germany in July 2021, and more recently Spain (in particular the surroundings of the city of Valencia), in October 2024.

An ever-present seismic risk sent a reminder through some of the strongest earthquakes to hit the EU and neighbouring countries in years. A series of quakes that shook central Italy in 2016–2017 were the most destructive, killing hundreds of people, reducing historic buildings to rubble and causing over EUR 22 billion of physical damage.[2] In March 2020, in the midst of the ongoing COVID-19 crisis, Croatia was struck by its biggest earthquake in 140 years, which triggered the evacuation of hospitals and put additional pressure on the already strained emergency services – illustrating the complexity of managing simultaneous or consecutive disasters.

In addition to adverse events caused by natural hazards, Europe also had to deal with threats posed by actors with malevolent intentions. European cities were the target of terrorist attacks, though thankfully fewer lives have been lost compared to the tragic events of 2015–2016. The 2018 attack on civilians in Salisbury, United Kingdom, involving the military-grade nerve agent Novichok drew attention to the potential threats linked to the use of chemical, biological, radiological and nuclear (CBRN) materials by hostile actors. Recent years have also seen some of the most harmful cyberattacks to date that targeted European democratic processes and government systems, affected critical infrastructure such as hospitals and brought billions of euros of losses to businesses.

Some of these adverse events overwhelmed national response capacities and put considerable pressure on public budgets, prompting Member States to seek assistance from the EU solidarity instruments, such as the Union Civil Protection Mechanism (UCPM) and the EU Solidarity Fund (see Chapter 2 of this book). The next section provides insights on types of events that tended to strain national capacities and caused the biggest damage, both in recent past and longer-term historical perspective.

1.1.2 The Toll of Past Disasters

The full impact of disasters experienced in recent years remains to be seen, as there is usually a time lag between the occurrence of an adverse event, the consequences it generates and availability of disaster loss data. The COVID-19 pandemic has been the costliest disaster event to hit Europe in decades, killing more about two million people in Europe and tipping the EU economy into sharp recession. Another hazard that contributed to substantial loss of life in the past is heat.

The European Environment Agency (EEA) collects information on fatalities and economic losses from disasters caused by natural hazards. The data is provided by the NatCatSERVICE of the Munich Reinsurance Company and EUROSTAT. It covers geophysical events (earthquakes, tsunamis, volcanic eruptions), meteorological events (storms), hydrological events (floods, mass movements) and climatological events

2 Damage estimation based on data provided by Italy in the application for the EU Solidarity Fund assistance.

(cold waves, heatwaves, droughts, forest fires).[3] Collected data show that heatwaves accounted for 85% of 91,455 fatalities caused by weather-related and geophysical disasters in the EU in the period 1980–2017. The majority of these fatalities were recorded during two heatwaves that occurred in 2003 and 2013 (European Environment Agency). On another type of threat, 426 persons have been killed in terrorist attacks perpetrated in the EU since 2006. According to EUROPOL, the majority of deaths from terrorism were caused by mass-casualty attacks witnessed in 2015 and 2016.[4]

In terms of economic impact of disasters, more systematic and comparable data is only available for weather-related and geophysical events. Total economic losses from aforementioned events exceed EUR 500 billion over the period 1980–2017. The largest share of all recorded losses is attributable to storms and floods. Most of the damage – approximately 70% – was caused by relatively few (3%) high impact events, such as the 2002 flood in Central Europe or 2016–2017 earthquakes in Italy. Although damage varies significantly from year to year and by geographical location, a general trend of increasing losses from extreme weather events can be observed over time. Only a third of losses incurred were insured.

Disasters often cause serious or even irreversible damage to natural environment and cultural heritage, but these impacts are more difficult to express in monetary terms and thus are not reflected in the available loss statistics. However, recent adverse events in Europe that brought significant damage to natural ecosystems, the environment and cultural heritage have highlighted again the importance of safeguarding these invaluable resources from disasters. For example, every year, forest fires destroy protected areas under the European Natura 2000 network[5] (aiming to safeguard Europe's most valuable threatened species and habitats) or national protected sites, wiping out the achievements of decades of preserving valuable habitats, species and landscapes for future generations.

Natural and man-made hazards are also persistently putting the European cultural heritage under pressure and compounding conservation challenges. Evidence suggests that protecting cultural heritage from disasters still receives insufficient attention in risk management strategies and planning across the EU. The recent European Court of Auditors' report on EU investments in cultural sites also recommended stepping up actions aimed at preserving heritage sites by identifying risks and planning mitigation measures (European Commission 2020a).

An example of disaster affecting cultural heritage is the Venice flooding, which occurred in November 2019, the second worst flood in the city's recorded history. Due to high tide, heavy rain and sirocco wind, the water rose to 187 cm above sea level – the highest since record levels reached in 1966. This left more than 85% of the city flooded and caused a damage of at least EUR 1 billion, according to estimations reported in the Press.[6] Water brought harm to numerous historic artefacts and sites: museums, churches and palaces, including the St. Mark's square, St. Mark's Basilica and Doge's Palace. UNESCO representatives warned that the city could lose its status as a World Heritage Site if it does not protect itself adequately from flooding.

3 https://www.eea.europa.eu/data-and-maps/indicators/direct-losses-from-weather-disasters-3/assessment-2
4 https://www.europol.europa.eu/activities-services/main-reports?rt[0]=282
5 https://ec.europa.eu/environment/nature/natura2000/index_en.htm
6 https://www.lapresse.it/politica/venezia_brugnaro_danni_inestimabili_almeno_un_miliardo_-2042386/video/2019-11-17

In summary, while measures put in place to address various disaster risks have played an important role in protecting Europeans, the damage caused by disaster events has been on an increasing trend, challenging national and European response capacities and public budgets. In the past, based on the available data, infectious diseases and heatwaves were the biggest 'killers', while storms, floods and earthquakes were the costliest natural hazards in terms of economic losses caused. The fact that most of the damage harm was brought by a few relatively rare high-impact events draws attention to the importance of prevention and preparedness for this type of scenarios.

It has to be emphasised that while available data on past disasters provide useful insights, it should be viewed with caution, as the picture it portrays is not complete. We know more about certain types of impacts and certain types of risks than about the others. Moreover, the experience of the past cannot be the (only) indication of what lies ahead in terms of disaster risk, as there are powerful forces at play shaping hazards, our exposure and vulnerability. The following section takes a closer look at some of the key drivers behind the developments in the risk scenery which sheds light both on the historic trends and projections for the future.

Disaster risk is a dynamic phenomenon which evolves over time and space due to changes in hazard characteristics, exposure and vulnerability of persons and assets and/or coping capacity. For example, climate change modifies patterns of extreme weather events, technological developments change the face of man-made threats, urbanisation is one of the factors behind the growing exposure to hazards, while environmental degradation or ageing societies contribute to a reduced resilience. The remainder of the section focuses on several 'mega forces' – namely climate change, urbanisation, environmental degradation, the changing security paradigm and technological developments – with a special focus on their implications for disaster risk in the European context. Though the aforementioned risk drivers are discussed individually, they should not be seen in isolation, as they interact with each other, amplifying existing or leading to the emergence of new risks. In this context, 'emerging risk' appears in the risk landscape due to changes in one or several of its components: hazard, vulnerability and/or exposure. New or emerging risks can manifest themselves due to novel types of hazard (new process or phenomenon not considered before), increases the vulnerability and/or exposure, or decreases in the coping capacity. Emerging risks have a high degree of uncertainty regarding the probability of occurrence and potential damage. The next sections provide a snapshot of risk drivers and occurrences for different types of disaster.

1.2 Climate Change

1.2.1 Introduction

Global average temperature is now around 1 °C higher compared to the pre-industrial era (1850–1899). The years 2019–2024 were the hottest since records began. Despite the target of the Paris Agreement on Climate Change[7] to keep global warming well below

7 https://unfccc.int/files/meetings/paris_nov_2015/application/pdf/paris_agreement_english_.pdf.

2 °C compared to pre-industrial temperatures, greenhouse gas emissions worldwide are still growing. Recent projections estimate global warming of up to 4 °C by 2,100 under current climate policies, and around 3 °C if all countries meet the Nationally Determined Contribution targets of the Paris Agreement.

According to the Intergovernmental Panel on Climate Change (IPCC) (2018), global temperature changes are already having consequences in terms of melting of polar ice caps, sea level rise and weather patterns. In Europe, the 2020 State of the European Environment report concludes that climate change has increased the occurrence of weather extremes. This ranges from unprecedented forest fires and heatwaves above the Arctic Circle to increasing droughts in the Mediterranean region, accelerating coastal erosion on the Atlantic coast to more severe flooding and decimated forests in Central and Eastern Europe. While not all-weather extremes can be attributed to global warming, there is increasing consensus that the emissions of greenhouse gases caused by human activities are influencing the climate and the earth's temperature. Our ability to detect whether the extreme events we experience are linked to climate change is improving, with better understanding of the climate system and higher computing power.

Despite considerable progress in the last years, the science of attributing specific disasters to human activities is still contested, and further work and research is needed to ensure, on the one hand, the robustness of the results to inform policymaking and, on the other hand, to broaden the scope of the analysis – in terms of geography, spectrum and impacts of disasters covered. What is however undisputed is that, in the absence of decisive climate action, global warming will continue, with severe consequences for people and their assets, as well as for ecosystems.

In the EU, economic losses from weather extremes are on average already EUR 12 billion per year. Looking forward, a series of PESETA (Projection of Economic impacts of climate change in Sectors of the European Union based on bottom-up Analysis) research projects led by the Joint Research Centre (JRC) of the European Commission were dedicated to the better understanding of future implications and costs of climate change, specifically for the EU. Project findings concluded that the burden of climate change shows a clear north–south divide, with southern regions in Europe much more impacted in terms of extreme heat, water scarcity, drought, forest fires and agriculture losses (Feyen et al. 2020). The project estimates that, in a scenario where global warming is 3 °C or more above pre-industrial temperature, the EU could face the following impacts:

- **Ecological domains** would shift northwards, resulting in severe changes of the prevailing domains in southern Europe and Boreal areas and the encroachment of the tropical domain in Europe. The alpine tundra domain would contract by 84% and practically disappear in the Pyrenees. The natural climatic tree line would shift vertically up by up to 8 month/year.
- Each year nearly 300 million individuals in the EU and the United Kingdom would be exposed to deadly **heatwaves**, resulting in a 30-fold rise in deaths from extreme heat (90,000 annual deaths compared to around 3,000 each year today).
- **Wildfire and pest outbreaks** would become more frequent and severe, increasing biomass loss and carbon release. An additional 15 million Europeans living in the

proximity of wildland would be exposed to high-to-extreme fire danger for at least 10 days/year.[8]

- Availability of **water resources** would drop by up to 40% in southern regions of Europe that already suffer from water scarcity. During summer, the majority of people and economic activities in these regions would face water scarcity. **Droughts** would happen twice as often in most of southern and western Europe and increasingly affect agriculture, energy and water supply sectors. Total drought losses for the EU and the United Kingdom would increase to nearly EUR 40 billion/year with 3 °C warming in 2100 compared to EUR 9.4 billion/year at present.
- Almost half a million people in the EU and the United Kingdom would be exposed to **river flooding** each year, or nearly three times the number at present, and river flood losses would rise sixfold in magnitude, reaching nearly EUR 50 billion/year with 3 °C in 2100.
- **Coastal flood** losses in the EU and United Kingdom would grow by two orders of magnitude and climb to EUR 250 billion/year in 2100, while 2.2 million people would be exposed per year to coastal inundation compared to 100,000 at present.
- If 3 °C global warming occurred in today's economy, **annual welfare loss** in the EU and the United Kingdom could represent 1.4% of GNP, when considering a limited set of climate impacts (river and coastal flooding, agriculture, droughts, energy supply, mortality from temperature extremes and windstorms). With 4 °C global warming annual welfare loss would be 1.9% of GDP. The magnitude of welfare losses in southern regions of Europe is estimated to be several times larger compared to that in the north. Welfare loss due to heat and cold-related fatalities dominate the (incomplete) aggregated welfare loss. River and coastal floods are the second most significant source of welfare loss in the EU and the United Kingdom, particularly in northern and central EU regions. Changes in droughts impacts lead to an increase in welfare in northern Europe, but become a source of welfare reduction in southern EU regions.

Europe is also affected by climate impacts occurring outside its territory: in an interconnected global economy, spillover effects can be felt through trade, supply chains, geopolitics and security, migration or spread of diseases. International spillover effects could increase the internal EU welfare loss by approximately 20% (Feyen et al. 2020).

The magnitude of future weather-related risks and impacts will depend on a variety of factors, including levels of development and vulnerability, and on the choices and implementation of adaptation and mitigation options. The way we live – the environmental, socio-economic, political and technological context – will also play a role and may contribute to our vulnerability to the effects of climate change. For example, urbanisation of coastal flood plains, deforestation of hill slopes or constructing buildings in risk-prone areas increase the risk of disasters. Future risks and impacts can be reduced by scaling up and accelerating climate mitigation, and by both incremental and transformational adaptation.

8 Statistics based on available data for countries in EU, UK and EFTA, candidate countries and potential candidates.

When estimating climate change developments and impacts, there are important factors for which there is still limited knowledge, e.g. tipping points. Tipping points are thresholds that, if passed, could send the Earth into a spiral of runaway climate change. For instance, the thawing of arctic permafrost due to increased temperature could in turn release vast amounts of greenhouse gases in the atmosphere, thus further exacerbating the problem of global warming. Similarly, the unprecedented summer of 2019 arctic wildfires released the same amount of CO_2 into the atmosphere as the total of arctic wildfires in the same month from 2010 to 2018. This could in turn trigger unforeseen changes in the Arctic or the climate system. Science is making progress in identifying early warning signals of tipping points, but uncertainty about their probability and effects remains high. From this perspective, climate tipping points fall in the category of a low or unknown probability but high impact risk. The unpredictability and unknowns related to tipping points do not justify inaction – the potential impacts are too dangerous. Disaster risk management (DRM), climate change mitigation and adaptation and resilience-building efforts should further define what is needed to address these events and make the case for the right policies, actions and investment decisions.

1.2.2 Extreme Weather Events

Climate change is already affecting the frequency and severity of extreme weather events, and this trend is projected to increase. The state of play related to hydrometeorological extreme events and links to research actions have been subject to several books of the Wiley Series to which the present book belongs, including science-policy aspects (Quevauviller 2015), governance issues (La Jeunesse and Larrue 2020) and responses (Sempere et al. 2024).

One of the key climate change signals is extreme heat. The hottest summers in Europe over the past 500 years have all come in the past 17 years. As the planet continues to warm, the whole of Europe will be affected by more frequent and longer periods with extreme high temperatures (European Environment Agency 2017). With climate change, heatwaves are expected to happen more frequently and become more intense. In a climate that is 3 °C warmer compared to pre-industrial times, a current 50-year heatwave may occur almost every year in southern Europe, whereas in other regions of Europe such events may happen every 3–5 years (Feyen et al. 2020).

The projected changes in the heatwave hazard leads to a large increase in the number of people exposed to extreme heat as well as mortality. This increase is most pronounced in southern European countries, and the highest number of fatalities are predicted to occur in France, Italy and Spain. Research aspects related to hydrometeorological extreme events and health impacts have been subject to one of the books of the present Series (Matthies-Wiesler and Quevauviller 2022).

Regarding precipitation, moderate changes are projected in the 2 °C global warming scenario. However, with 3 °C global warming, more significant differences are expected, with increases in north-central-eastern Europe and a decline in most parts of the Mediterranean. Winters will generally be wetter in most of Europe, except for its most southern parts, where reductions of up to 25% in winter precipitation are projected. Southern Europe is also expected to see a decline in summer precipitation. The latter trend can also affect western Europe and parts of central and eastern Europe, despite

the overall increase in annual average precipitation in these regions (Feyen et al. 2020). The impacts of climate change on hail are more difficult to predict, as the trends and projections of hail events are still subject to a high degree of uncertainty.

Despite the recent advances in climate modelling techniques, there are many uncertainties in predicting future storm trends due to knowledge gaps around storm formation and incomplete historical records. Nevertheless, there is general agreement on the fact that over the 21st century, the strongest, most devastating storms are likely to increase, both in autumn and winter, in most European regions, particularly in the North Atlantic region and in northern, north-western and central Europe. Recent studies on changes in winter storm tracks generally project that the North Atlantic storm track will extend eastwards towards central Europe and Britain and Ireland (European Environment Agency 2017). Mediterranean Sea hurricanes (otherwise known as 'medicanes') are predicted to decrease in frequency but increase in intensity in the Mediterranean area.

The effects of extreme weather events are determined not only by the severity of the event but also by the exposure and vulnerability of the population and economic assets. Looking forward, the continued trend of population ageing in Europe is a vulnerability factor that could aggravate the effects of extreme weather events, in particular extreme temperatures. Further, continued urbanisation could amplify the urban heat island effect. The combined effects of heatwaves and air pollution might further exacerbate human stress in densely populated areas. All EU capital cities will become more vulnerable to extreme heat in the coming decades. The cold wave hazard may remain a significant threat locally in certain regions (Smid et al. 2019).

The climate in Europe varies from maritime to polar and can be split into four main groups: subtropical, temperate, cold and circumpolar. The different climatic conditions across the continent mean that Europe faces a variety of different extreme weather risks, from storms and heavy precipitation to heatwaves. Extreme weather events frequently occur in Europe and have significant human and economic consequences. The impacts differ depending on the type of extreme weather event: for example, heatwaves predominantly impact on humans, while storms and heavy precipitation lead to a high level of economic damage. Between 1980 and 2017, weather and climate-related extremes caused 87,391 fatalities across the EU, up to 77,637 of them due to heatwaves, the majority a result of the 2003 heatwave. Based on data in the NatCatSERVICE database, in the same period, extreme weather events led to economic losses of EUR 426 billion, with storms alone causing EUR 163 billion in damages (Feyen et al. 2020).

1.2.2.1 Storms, Strong Wind and Hurricanes Windstorms are characterised by continuous strong winds and are often accompanied by intense precipitation. Large storms in mainland Europe are extra-tropical cyclones (or hurricanes). In northern and north-western Europe, severe cyclones can take place throughout the whole year, while in central Europe, they occur mainly in autumn and winter. Regions closer to the coast are particularly vulnerable (European Environment Agency 2017). The EU's outermost regions[9] are affected by tropical cyclones, which can be particularly damaging, as

9 Guadeloupe, French Guiana, Martinique, Saint Martin, Réunion, Mayotte (France); the Canary Islands (Spain) and the Azores and Madeira (Portugal).

seen in September 2017, when category 5 hurricanes Irma and Maria caused massive devastation in the French Caribbean outermost regions of Saint-Martin, Guadeloupe and Martinique. In terms of knock-on or concurrent events, storms, especially when combined with heavy precipitation, may lead to floods, storm surges and coastal erosion and can cause serious risks to health, transportation and infrastructure. Coastal storms are also addressed under Section 1.2.3.2 in relation to coastal flooding. In terms of changes in frequency or severity of storms, historical trends vary substantially, and therefore no significant long-term trends are apparent. EU research aspects related to coastal storms have been subject to one of the books of the present Series (Ciavola and Coco 2017).

1.2.2.2 Heatwaves and Cold Waves The length, intensity and frequency of heatwaves in Europe are rising. A heatwave is generally defined as a period of excessively hot temperatures, lasting for several days. The severity of a heatwave depends on a number of factors, including its duration, its relative intensity (how much hotter than normal) and its absolute intensity. Extreme temperatures are often connected to droughts, as dry soil reduces evaporative cooling[10] and thus increases the scale of a heatwave (Mueller and Seneviratne 2012). Heatwaves can also worsen droughts, as they exacerbate soil moisture deficits and low flows in rivers. Extreme heat can also conversely be linked to the increased frequency and intensity of heavy precipitation events (including hailstorms); warmer air can hold a greater quantity of water (Kendon et al. 2014). People in the EU are particularly vulnerable to heatwaves as three-quarters of the EU-28 population lives in urbanised areas (UN-Habitat 2016). The 'urban heat island' effect, caused by the built environment absorbing more heat than its rural surroundings, exacerbates the impacts of heatwaves. Cities in central and north-western Europe are being increasingly affected (European Environment Agency 2017), worsened by built environments that are not adapted to such temperature extremes. Additionally, having a high proportion of elderly people makes cities sensitive to heatwaves and other climatic hazards. In addition to the elderly, those with chronic diseases and disadvantaged groups also have a heightened risk of heat-related mortality. In terms of impacts on life and health, there is some debate over whether extreme highs are more dangerous than extreme lows.

Temperature extremes can disrupt critical infrastructure networks, particularly transport and energy supply. Extreme heat is detrimental to water availability, and consequently, the energy sector, which depends on a secure water supply for cooling and for energy production. The repeated heatwaves of 2019 across Europe, with record-breaking temperatures, led to several nuclear power plants in various parts of Europe temporarily closing and affected hydropower output and stocks in France, Spain, the Balkans and Scandinavia. Existing transport networks (roads, railways and bridges) are also vulnerable to heatwaves, particularly in southern and eastern Europe, as they are not designed to withstand extreme heat, while still being faced with cold conditions in

10 Evaporative cooling is the conversion of liquid water into vapour using the thermal energy in the air, resulting in lower air temperature.

the winter in some places. Transport infrastructure in northern Europe is in turn affected by cold spells and snow (European Environment Agency 2018).

1.2.2.3 Heavy Precipitation The intensity of heavy precipitation events, both in summer and winter, has increased in northern and north-eastern Europe since the 1960s. However, different studies and indices show diverging trends for south-western and southern Europe (European Environment Agency 2018). Heavy precipitation events have considerable impacts on society, including agriculture, industry and ecosystem services (i.e. direct and indirect contributions of ecosystems to human well-being). Hail events in particular are among the costliest weather-related extreme events in several European regions, causing substantial damage to crops, vehicles, buildings and other infrastructure. The highest number of hail events occur in mountainous areas and pre-Alpine regions. However there have been increases in hail in southern and central Europe.

In other words, ecosystem services are the direct and indirect contributions of ecosystems to human well-being. These services include provisioning, regulating, cultural and supporting services on which societies and economies depend, including food and water provision, climate regulation, flood control, air and water purification, erosion control, etc. This is due to a warming and more unstable atmosphere (European Environment Agency 2017). In terms of concurrent or cascading risks, heavy precipitation can lead to floods, which is also addressed in the following section on flooding.

1.2.3 Flooding

According to the 6th IPCC (IPCC 2023), the frequency and intensity of heavy precipitation events have likely increased in Europe. This has led to an increased number of riverine floods in Europe for the last three decades and to high reported economic flood damages (Feyen et al. 2020). In July 2021, several EU Member States were affected by severe floods, causing deaths and widespread damage. Other major events occurred in September 2022 in Italy and in October 2024 in Spain.

Increased flooding is likely to be one of the most serious effects of climate change in Europe over the coming decades. Trends that have been previously observed are continuing, whereby climate-related extreme events are rising, with particularly sharp rises in hydrological events (EASAC 2018). A high-emissions scenario could lead to manifold increases in the socio-economic impact of floods in Europe by the end of the 21st century, especially as regards damages from coastal flooding.

For a number of European river basins, including the Po, Duero, Garonne, Ebro, Loire, Rhine and Rhone, an increase in extreme floods with a current return period[11] above 500 years is projected. As mean sea levels and the intensity of storm surges are

11 Return period is a metric for the occurrence of natural hazards such as floods or earthquakes. It describes how likely a hazard event is to occur at, or above, a specific intensity within a time frame defined by a probability. A longer return period suggests a lower probability that an extreme hazard will occur in any single year. For example, the return period of a flood of 100 years can otherwise be expressed as its probability of occurring 1/100, or 1% in any one year. Source: Global Facility for Disaster Reduction and Recovery, https://www.gfdrr.org/en/100-year-flood

expected to rise in the coming decades, these factors are expected to increase the frequency of coastal flooding across the EU.

Damage from coastal flooding is projected to rise sharply for all EU countries with a coastline and the United Kingdom if current levels of coastal protection are not raised. The largest absolute damage levels are projected for Germany, Denmark, France, Italy, the Netherlands and the United Kingdom. For some countries the damage represents a considerable proportion of future national GDP, e.g. 4.9% for Cyprus, 3.2% for Greece and 2.5% for Denmark by 2100 (high emissions scenario) (Feyen et al. 2020).

Pluvial floods and flash floods are also likely to occur more frequently throughout Europe, as they are triggered by intense local precipitation events, which are predicted to increase due to climate change (European Environment Agency 2017). The projected changes are strongest in Scandinavia and eastern Europe in winter. Given that river flooding due to extreme precipitation, as well as storm surges and sea levels, are expected to increase as a result of climate change, it is likely that the likelihood of compound flooding will increase as well (see Section 1.2.3.4). The west coast of the United Kingdom, northern France, the coastlines of countries to the east and south of the North Sea and the eastern half of the Black Sea are projected to be particularly affected (Bevacqua et al. 2019). While floods are a natural phenomenon, human choices have a significant effect on how often they occur and their impact. An increase in the likelihood and adverse impacts of flood events can result from building on floodplains or near the coast, the reduction of water-retaining surfaces and interventions to watercourses or their surroundings.

About 1.2 million km of rivers and more than 18,000 lakes exist in the EU. There are 177 river basin districts in the EU, of which 94 lie across country borders (European Commission 2019g). The Danube, for example, has a catchment shared by 19 countries in central Europe, the Balkans and the EU's eastern neighbourhood. Countries with long coastlines tend to have relatively smaller river catchments and shorter rivers, and their populations tend to be located in towns along the coast. Overall, nearly half of the EU population lives within 50 km of the coast. On the other hand, most European cities have at least one river or lake crossing their urban landscape, while roughly three-quarters of the total EU and United Kingdom population live in cities, towns and suburbs (Eurostat 2016).

Considering this proximity to water, flooding remains as one of most frequent and economically damaging disasters in the EU. Flood events occur in Europe most commonly in the form of:

- river, or fluvial, flooding;
- coastal flooding and storm surges;
- pluvial flooding, which can take the form of flash floods in urban areas

In mountainous or hilly areas, secondary or associated hazards include landslides, as both flooding and landslides events can be caused by heavy rainfall. River and coastal flooding have affected millions of people in Europe. Since 1870, there has been an increase in the area flooded annually and the number of people affected, although this is contrasted by a substantial decrease in flood fatalities (Paprotny et al. 2018a,b). While floods result in comparatively lower numbers of fatalities compared to other natural

hazards, they can still be lethal. Between 1980 and 2017, more than 3,000 people lost their lives in floods. In addition to fatalities, floods also cause many negative effects on people's health, including injuries, infections, exposure to chemical hazards and mental health problems (European Environment Agency 2017). The economic impact is also substantial, though estimations vary. Based on data in the NatCatSERVICE database (Munich Reinsurance Company), over 1980–2017, hydrological events (floods and landslides) have caused a total of EUR 159.55 billion in damages across the EU-28 or on average EUR 4.3 billion/year (European Environment Agency 2017). Besides economic losses, flooding events can lead to disruption of critical services, including health services, safe water, sanitation and transportation (Feyen et al. 2020).

1.2.3.1 River Floods River floods are a common natural disaster in Europe and – along with storms – are the most significant natural hazard in terms of economic damage. The PESETA IV study estimates that on average, river flooding causes EUR 7.8 billion of economic losses per year (Feyen et al. 2020). The number of very severe river flood events in Europe increased over 1985–2016 (EASAC 2018), but with large variability between the years in question. This increase has been attributed to better reporting, land-use changes and increased heavy precipitation in parts of Europe, but it is not currently possible to quantify the importance of these factors (European Environment Agency 2017). Additionally, there has been an increase in economic losses from river flooding since the 1970s. This trend can be attributed to socio-economic factors, such as increasing wealth located in flood zones. Increases in heavy precipitation in parts of Europe may also play a role.

1.2.3.2 Coastal Floods and Storm Surges Nearly half of the EU's population lives less than 50 km from the sea; the majority is concentrated in urban areas along the coast (Eurostat 2013). Coastal flooding has had an impact on low-lying coastal areas in north-western Europe in the past. Most often, it is caused by a combination of storm surge and high tidal levels, which lead to extremely high-water levels along the coast. The most intense surge events typically occur during winter in Europe and are caused by coastal storms (storms have also been covered under Section 1.2.2.1 and are considered as extreme weather events). Extreme high coastal water levels have increased at most locations along the European coastline. This appears to be predominantly due to increases in mean local sea level (European Environment Agency 2017). This trend in turn has increased the risk of coastal flooding. The PESETA IV study estimates the economic losses in the EU from coastal flooding to be on average EUR 1.4 billion/year, with France and the United Kingdom accounting for half of this loss (Feyen et al. 2020).

1.2.3.3 Pluvial Flooding and Flash Floods Pluvial flooding is the flooding of land directly from rainfall water falling on or flowing over it. A flash flood is a characteristic of a flood that rises and falls quite rapidly, with little or no advance warning, usually as a result of intense rainfall over a relatively small area (European Commission 2013c). Since the 1960s, the intensity of heavy precipitation events in summer and winter has increased in northern and north-eastern Europe (this has also been addressed under Section 1.2.2 on extreme weather phenomena). More extreme precipitation events,

combined with increasing soil sealing,[12] due to urban sprawl have amplified the risk of urban flooding. In most cities, the level of soil sealing is between 40% and 60%, with some cities having soil sealing as high as 80%. This means excess water from extreme rainfall cannot drain into the ground and is instead led into sewage systems, which often are not designed to cope with such amounts of water (European Environment Agency 2017).

1.2.3.4 Compound Flooding Compound flooding occurs when large run-off from heavy precipitation, leading to river flooding, is combined with high sea level (storm surge). Low-lying coastal areas are therefore at a particularly high risk. The resulting impact of the combined hazards can be worse than when they occur individually (Bevacqua et al. 2019). Nevertheless, they are rarely analysed as interacting phenomena. The recently released pan-European HANZE (Historical Analysis of Natural Hazards in Europe) database (Paprotny et al. 2018b) lists 24 co-occurrences of storm surges and river floods along the Irish, United Kingdom, Belgian and Polish coasts, the French Atlantic and Mediterranean coast and the Italian Adriatic coast. In the present climate, the highest compound flooding probability is concentrated primarily along the Mediterranean coast (Bevacqua et al. 2019). Floods can also occur as a result of the failure of infrastructure, notably hydropower dams or flood defences.

1.2.4 Droughts

Drought is a systemic natural hazard with important repercussions in almost all sectors of natural and socio-economic systems (EC Joint Research Centre 2024). Estimates of drought impacts done in 2021 were in the order of 9 billion euros per year, with climate change projections indicating that, in the absence of climate action (4 °C in 2100 and no adaptation), annual losses in the EU and the United Kingdom are projected to rise to more than 65 billion euros per year (EC Joint Research Centre 2024). Droughts are not only sources of economic concerns, they can also lead to impacts on ecosystems and societies, e.g. decreasing food security. This complex phenomenon requires a multidisciplinary approach to holistically assess its risks, including the potential transboundary effects in the EU and elsewhere (EC Joint Research Centre 2024).

Over the 21st century, droughts are projected to increase in frequency, duration and severity across Europe, particularly in the Mediterranean, but also across large parts of western and central Europe (European Commission 2020a). In recent years, northern Europe has also experienced water shortages (EDO 2017, 2018, 2019; Toreti et al. 2018).

In combination with an increasing likelihood of severe heatwaves, droughts pose a significant threat for Europe. The extreme drought conditions that affected the 2018 spring and summer growing season in central and northern Europe, and led to unprecedented wildfires in Scandinavia, could become the norm within 25 years (EDO 2019). In southern Europe, the availability of water resources could drop by up to 40%.

12 Soil sealing is the covering of the soil surface with impermeable materials like concrete and stone, as a result of new buildings, roads, parking places and other public and private space. Depending on its degree, soil sealing reduces or completely prevents natural soil functions and ecosystem services on the area concerned.

Water scarcity and drought would increasingly affect ecosystems, agriculture, energy production and water supply in regions that already suffer from water stress. In the absence of international market adjustments, crop yields would drop by more than 10% in southern Europe. Average annual drought losses are also expected to increase significantly. The Mediterranean and Atlantic regions will see the largest losses, with Belgium, Greece, Ireland, Portugal and the United Kingdom showing the highest increase in losses relative to now (Feyen et al. 2020). In addition to a changing climate (e.g. increased temperatures and precipitation deficits), human decisions can significantly affect the occurrence and impacts of droughts. While droughts are considered as natural phenomena, water scarcity is a direct result of human activities (where demand exceeds available resources) and has a direct effect on vulnerability and response to drought episodes. Over-abstraction of water resources, leading to water scarcity, soil compaction and soil erosion, which result in the soil column having reduced water-holding capacities, and in the reduction of water-retaining surfaces, all contribute to an increasing likelihood of drought events, accompanied by their adverse impacts. Water stress already affects one-third of EU territory all year round. This trend is expected to continue, with water scarcity affecting most of Europe over the 21st century, with a 40–80% increase in the severity of water deficit events by 2050, except in northern European regions. In most regions around Europe, projected increases in water consumption will further aggravate river flow droughts (Feyen et al. 2020).

Drought has been a recurrent feature of Europe's climate, not only limited to southern Europe or some EU outermost regions. Droughts have severe consequences for people and for most economic sectors, including agriculture, forestry, energy production, industry, river transport (waterways) and public water supply. Compared to other natural disasters that unfold over a matter of hours, drought is a natural phenomenon characterised by a slow onset and can often last a long time. It can have a variety of possible impacts that can last for months or years after the event ends (Spinoni et al. 2017). Droughts can be meteorological, agricultural, hydrological or socio-economic, occurring on different time scales and with different impacts. Meteorological droughts can begin and end relatively quickly and occur when dry weather dominates an area, leading to low soil moisture. They may be exacerbated by high temperatures (heatwaves). Hydrological droughts are more severe and long lasting and usually occur after many months of meteorological drought, taking place in areas with low groundwater levels and affecting watercourses, water resources and natural ecosystems. Water scarcity can be affected by the rate of abstraction for agriculture and different socio-economic needs. The severity and frequency of droughts have increased in Europe: in summer and autumn in southern and eastern Europe and in winter and spring in northern Europe (Spinoni et al. 2017).

A decrease in summer soil moisture content has also been observed in most of the Mediterranean region, particularly in south-eastern Europe, south-western Europe and southern France (European Environment Agency 2017). There has also been a decrease in summer low flows of European watercourses over the second half of the 20th century (Stahl et al. 2010). However, current data are insufficient to attribute the latter trend to global climate change. From 2006 to 2010, 15% of EU territory has been affected by meteorological droughts each year (European Environment Agency 2017). Since 2011, Europe has experienced a severe drought almost every year, except for

2013 and 2016. Additionally, Europe's freshwater resources are under increasing stress, with a mismatch between the continuously increasing demand for, and the limited availability of, water resources across the EU. This has had significant impacts on many economic sectors. The PESETA IV study estimates current annual losses from drought to be around EUR 9 billion, with the highest losses in Spain (EUR 1.5 billion/year), Italy (EUR 1.4 billion/year) and France (EUR 1.2 billion/year). Depending on the region, between 39% and 60% of these losses relate to agriculture and 22–48% to the energy sector. Public water supply accounts for between 9% and 20% of the total damage. Losses in the transport sector relate only to inland water transportation and on average represent 1.5% of total losses, while subsidence damage to infrastructure accounts for around 8% of total losses. Drought also affects the environment in many different ways, yet these impacts are difficult to evaluate (Feyen et al. 2020). For example, forests at the lower altitudes of mountains in Europe are already suffering from decreased precipitation and increased temperatures, which is altering the suitability of locations for specific species. Drought and heatwaves can decrease the annual growth of the trees, which means less carbon sequestration, wood production and less carbon storage in the long term. In a vicious circle, these changes are also making forest tree species highly susceptible to damage from biotic and abiotic sources – those caused by pest attacks, more frequent droughts, heatwaves, windstorms and forest fires (European Commission 2013c). For instance, between 2017 and 2019, over 270 million m^3 of drought-weakened standing timber in central Europe was destroyed by windstorms and spruce bark beetles. While the damage is spread across many countries, the greatest losses are seen in Germany, Czechia and Austria. Large-scale drought has caused forest decay, meaning that large areas of forests will have to be regenerated with other drought/climate tolerant and site-adapted tree species, according to sustainable forest management principles. As regards mitigating human impacts, civil protection authorities may need to intervene when droughts lead to water shortages or even crises. These may require, for example, the distribution of water for civil use through tankers or trucks or even restrictions on use and rationing. As droughts are often exacerbated by heatwaves, their secondary effects include wildfires, which are a particular concern for civil protection authorities in southern Europe (see following section).

Research aspects related to droughts have been subject to one of the books of the present Series (Iglesias et al. 2019).

1.2.5 Wildfires and Forest Fires

The term 'wildfires' includes forest fires and other fires out of control that may burn land cover types other than forests. Approximately 40% (182 million ha) of the EU territory is covered by forest and other wooded land. European forests and human activities in the vicinity are regularly threatened by fires, which burn on average circa 0.4 million ha of the natural landscape on an annual basis (EC Joint Research Centre 2024). In addition to the economic and environmental damage, wildfires are the cause of human casualties. For example, between the period of 2017 and 2018, Europe experienced the most devastating wildfires of the decade, which killed more than 200 people and injured over a thousand (San-Miguel-Ayanz et al. 2018). The

environmental impacts of wildfires include the loss of biodiversity, damage to ecosystems and the destruction of soils. Areas affected may be prone to other damages such as soil erosion, landslides and desertification. The economic damages caused by wildfires were estimated at around 10 billion euros in 2017 and 2.5 billion euros in an average year (San-Miguel-Ayanz et al. 2018 cited in EU Joint Research Centre 2024). In the first half of 2024, the number of fires mapped in the European Forest Fires Information System (EFFIS) was higher than that of the previous seasons in the period 2006–2023 (EC Joint Research Centre 2024).

Wildfires can be caused either by natural phenomena (e.g. heatwaves, increased temperature and lightning) or human activity. The likelihood of a fire igniting and spreading depends on the type of vegetation, fuel on the ground, topography and weather conditions. The impact depends on the (i) amount of fuel that is available to burn, (ii) weather conditions that determine the fire spread, (iii) fire intensity, (iv) assets that may be subject to damage (i.e. the proximity of population or infrastructure) and (v) capacity to suppress the fire. In Europe, approximately 95% of wildfires are directly or indirectly caused by human behaviour and activities, including negligence and arson (Ganteaume et al. 2013; European Commission 2018e). Socio-economic developments and changes in land use have helped create structural conditions conducive to human-induced wildfires. The movement of people from rural to urban areas, the abandoning of traditional land uses and unsustainable forest management practices (e.g. lack of proper management and vegetation control) have resulted in a large accumulation of combustible fuels and made forests more prone to fires. At the same time, urban sprawl and the growing urban–wildland interface have led to more frequent and dangerous disasters, sometimes with human casualties (European Commission 2018a).

Along wildland–urban or wildland–industrial interfaces, wildfires can affect hazardous infrastructure or industrial zones, leading to major accidents with toxic releases, fires or explosions (known as Natech accidents, see Section 1.5.6). Fires can affect industrial facilities via thermal radiation (heat), ember flight or direct flame impingement affecting vulnerable industrial equipment. The transformation of the areas surrounding industrial facilities, as well as climate change, raises concerns about future industrial plant safety in wildfire risk zones. To date there is no integrated European fire management system that would meet the requirements to prevent Natech accidents triggered by wildfires (Kern and Krausmann 2020). Overall, the weaknesses in forest and fire risk management practices have played a role in, and indirectly contributed to, the creation of fire risks. A recent overview of the research on the topic concludes that there is insufficient and fragmented attention being paid to preventing wildfires in Europe, with the main focus and resources placed on suppression. Policies on spatial planning, national forestry strategies and others have not sufficiently integrated considerations on fire prevention. Preferred firefighting strategies (e.g. early initial attack) have contributed to fuel accumulation and landscapes being more prone to large and intense fires. Action to raise risk awareness and people's preparedness also needs to be stepped up (European Commission 2018e). In future, wildfire risk is projected to increase due to climate change. Warmer temperatures and longer periods without rain will help fires to ignite and spread, leading to more frequent and intense fires. The PESETA IV study estimates that the probability of high-to-extreme danger of wildfires will rise nearly everywhere in Europe (Feyen et al. 2020). Only in scattered

parts of northern Europe (the area around and south of the Baltic Sea) is the number of high-to-extreme fire danger days projected to decrease slightly. Fire danger will worsen, especially in southern regions of Europe, where fires already occur more often and are more intense (Feyen et al. 2020).

Climate change will also affect wildfire risk through changes in forest growth and productivity, tree species composition and ecosystems' evolution and health. Already over the last two decades, the combination of rising temperature and changes in precipitation has reduced plant defence mechanisms and increased their vulnerability to insect outbreaks, particularly in high-latitude regions. In the future, southern Europe and the Boreal areas are expected to experience significant changes in the prevailing components of ecological domains. The transformation of bioclimatic conditions is likely to outpace the time required for vegetation to adapt, making the latter more vulnerable to fires and affecting recovery afterwards (Feyen et al. 2020). In a vicious circle, forest fires themselves contribute to climate change, both due to greenhouse gas emissions from burning forests and as a result of forest degradation.

The EU is one of the most forested regions in the world, with a forest cover of nearly 160 million ha, representing 36% of the EU's territory according to the Forest Information System for Europe (FISE). Approximately 38 million ha of forest are included in the Natura 2000 network protecting EU's most valuable species and habitats. Forests provide society with a multitude of social, environmental, economic and cultural benefits. They also help mitigate climate change and protect biodiversity. One of the major hazards threatening European forests as well as other landscapes is fire, which causes significant social, economic and environmental damage. Over the past decade, fires in Europe have burnt more than 4 million ha of forest and other wooded land – an area larger than Belgium. In the same period, more than 400 people (firefighters and civilians) lost their lives due to fire according to the annual UCPM report (see Chapter 2) on forests fires in Europe for 2008–2018. The environmental impacts of wildfires are difficult to estimate in monetary terms, but they can be devastating and sometimes irreversible, such as degradation or loss of natural ecosystems, functions and services and changes in biological diversity. There are also cascading effects, since burnt areas become prone to post-fire flash floods, soil erosion, landslides and desertification. 2017 and 2018 were particularly dramatic in terms of fire activity (number, magnitude and severity) and human casualties (EC Joint Research Centre 2018c). In those two years, wildfires killed more than 200 people. More than a million hectares of territory was burnt, a quarter of which was in protected areas under Natura 2000. The economic damage caused by fires was estimated at around EUR 10 billion in 2,017,339 and EUR 2.5 billion in 2018 (EC Joint Research Centre 2019b). The 2019 wildfire season was also unusual. The year started with a large number of winter (off-season) fires, which in a few months destroyed more forests than during the whole of 2018. In 2017, Portugal experienced an extremely devastating fire season. A total of 112 people lost their lives. Almost 6% of the country's surface was burnt, exceeding the yearly average by five times. Another example is the 2018 Attica forest fires in Greece, which killed 102 people and burnt 1,276 ha. These have been the second deadliest wildfires of the 21st century so far, after the 2009 Black Saturday bushfires in Australia that killed 180 people. The same year, Sweden fought unprecedented fires that burnt an area 10 times larger than the yearly average. Other parts of Scandinavia, the United Kingdom, Ireland,

Latvia and Germany also witnessed higher than usual fire activity (EC Joint Research Centre 2018c).

While the Mediterranean region is the most affected by wildfires, the risk is a cause of concern also in other parts of the EU. Recent years have shown that extreme wildfire events are happening in new locations, such as northern Europe and even the Arctic. The burnt areas mapped in EFFIS represent, on average, about 80% of the total area burned by wildfires, since only fires larger than 30 ha are mapped. The area burnt by fires smaller than 30 ha represent about 20% of the total burnt area in each country, but this area is not mapped in EFFIS. Another trend observed in recent years is that wildfire seasons are starting earlier than usual and lasting longer. Moreover, the frequency and severity of fires have increased, triggering reflections on how to deal with the phenomenon of 'megafires' (EC Joint Research Centre 2019b).

1.3 Geophysical Hazards

For the purposes of this chapter, geophysical risks encompass natural hazards caused by geological conditions, notably earthquakes, volcanic eruptions and tsunamis. Other geological risks (such as landslides, ground instability, cavity collapse, erosion) are not covered in this section.

Seismic risk refers to the potential for damage, loss or harm to people, buildings, infrastructure and the environment due to the occurrences of earthquakes. It encompasses the likelihood of an earthquake of a certain magnitude occurring in a specific area (i.e. seismic hazard), as well as the vulnerability of the built environment and population exposed to the effects of the earthquake (i.e. exposure). The seismic hazard includes surface faulting, ground shaking, landslide, liquefaction, tectonic deformation, tsunamis and seiches (USGS Earthquake Hazard Program, cited by EC Joint Research Centre 2024).

Exposure and vulnerability are the main drivers of evolving earthquake risk. In Europe, between 1975 and 2015, the population potentially exposed to earthquakes increased by 7%, while the exposed built-up environment increased by 142%. In 2015, approximately a quarter of the EU's population and a quarter of the built-up area were potentially exposed to earthquake scenarios with a return period of 475 years. In terms of vulnerability, the gradual improvement of seismic standards in buildings in almost all EU Member States has been an important development (European Commission 2020a). However, despite the progress achieved, seismic resilience of buildings remains a serious concern. The size of the built-up area in the EU is about 25 billion m^2. Of the current residential building stock, 80% was built before the 1990s, with 40% built before the 1960s (Ehrlich et al. 2018). A considerable amount is even older and often classified as cultural heritage. JRC analysis shows that the majority of buildings in the seismic-prone regions of Europe were designed without provisions for earthquake resistance or following moderate-level seismic codes (Capes and Teeuw 2017; Palermo et al. 2018; Sisti et al. 2018; Tsionis et al. 2017).

The Earth is a constantly evolving system. The movements of the tectonic plates cause strain and energy to accumulate deep underground. When an earthquake occurs, the freed energy travels through the earth in the form of waves that, having reached the surface, manifest themselves as rapid movements of land that strike people, buildings

and the surroundings. Strong earthquakes with an epicentre in the sea or near the coast may cause a tsunami – a sudden displacement of a large mass of water that in extreme cases can reach over 30 m in height. Tsunamis may also be caused by coastal or submarine landslides, volcanic activity in the sea or near the coast and, more rarely, by meteorites falling into the sea. The collision of the Eurasian and the African plates is responsible for earthquakes in the southern part of Europe and the Eastern Mediterranean region, in countries such as Portugal, Spain, France, Italy, Croatia, Slovenia, Serbia, Montenegro, Albania, Bulgaria, North Macedonia, Greece, Cyprus and Turkey. Consequently, the Mediterranean coasts are also exposed to tsunami risk that is intensified by the presence of multiple volcanoes in the area. Movements of smaller plates also occur within Europe, for example in the Vrancea region in Romania. As major active seismic zones in Europe cross country boundaries, an earthquake may affect more than one country (Pagani et al. 2018).

The impacts of earthquakes can vary from localised effects to dramatic consequences on a wider scale for communities, infrastructure, the economy and the environment. Similarly, volcanic eruptions may have a limited impact or lead to disastrous events with consequences felt not only in the surrounding area, but potentially at a regional or even global level. Seismic risk is determined by the combination of seismic hazard, exposure of people and physical assets and vulnerability of the built environment. Ground shaking caused by small earthquakes frightens people and may cause minor property damage, but moderate to severe ground motion could cause moderate to heavy damage in structures, including their partial or complete collapse. The collapse of buildings is one of the main causes of death during an earthquake. To reduce fatalities, buildings and infrastructure must be designed, constructed or retrofitted according to modern anti-seismic provisions, such as the Eurocodes.[13] Earthquakes can trigger secondary effects, such as landslides, damage to vital infrastructure, liquefaction of the soil, tsunamis, debris avalanches and fires that sometimes cause more damage than the tremor itself. They can also lead to damage to vital infrastructure and Natech events, such as the release of hazardous materials from damaged industrial facilities. Based on the NatCatSERVICE database (Munich Reinsurance Company), geophysical disasters (earthquakes, tsunamis, volcanic eruptions) that took place between 1980 and 2017 killed more than 3,600 people and caused EUR 86 billion in losses. The sequence of quakes that struck central Italy in 2016–2017 was one of the most disastrous events seen in Europe in recent years.

1.4 Health and Plant Hazards

1.4.1 Epidemics/Pandemics

Besides the COVID-19 disease, there are multiple other emerging and re-emerging infectious diseases requiring increasing attention from the European health authorities. Emerging diseases include the Venezuelan equine encephalitis, Mayaro and severe

13 The EN Eurocodes are a series of 10 European Standards, EN 1990 – EN 1999, providing a common approach for the design of buildings and other civil engineering works. Available at https://eurocodes.jrc.ec.europa.eu/

fever with thrombocytopenia syndrome (SFTS). New developments have also been observed regarding multiple vector-borne diseases, which are transmitted by bites of vectors such as mosquitoes, ticks and sandflies that can carry pathogens from person to person and place to place. While the incidence of vector-borne diseases in Europe is much lower than in some other regions of the world, they are rising and their distribution is spreading. The most common vector-borne diseases in Europe are tick-borne encephalitis and Lyme disease. Approximately 85,000 cases of Lyme disease are reported each year, with an increasing number of cases witnessed in Northern Europe (European Commission 2020g). This trend is linked to (i) milder winters, (ii) warmer summers, (iii) lower seasonal variation of temperatures, (iv) longer vegetation seasons and (v) human or agricultural factors, such as land-use pattern. As regards mosquito-borne diseases, outbreaks of chikungunya, dengue, malaria and West Nile virus have occurred in recent years. In addition to imported cases, local transmission of these diseases has also been observed in continental Europe. Trade and travel play a significant role in the introduction and dispersion of vectors and viruses (Semenza et al. 2014). Moreover, it is anticipated that warmer temperatures and changes in precipitation brought by climate change will create further favourable conditions for outbreaks of vector-borne diseases, with the risk of these diseases becoming endemic in some areas of Europe (European Commission 2020a; Semenza et al. 2014).

Besides emerging diseases, 'old' infections are making a comeback. One prominent example is measles. Measles is one of the most contagious of all known infectious diseases: 90% of non-immune people exposed to an infected individual will contract the disease. Despite the availability of a vaccine and despite being a disease 'under elimination', measles is now considered a major threat to health across Europe. A large epidemic of measles has affected the region in the past few years (Semenza and Suk 2018). In total, some 150,000 cases of measles have been reported by EU/EEA Member States over the last decade (ECDPC 2018a). The risk of contracting measles is mainly driven by suboptimal vaccination rates in most European countries and a large pool of susceptible individuals. A vaccination coverage of 95% for both doses of measles-containing vaccine is necessary in order to obtain herd immunity and to, eventually, eradicate the disease. In 2018, only five countries achieved this target compared to 14 countries in 2007 (ECDPC 2018b). The intense movement of people enables the disease to spread. Data shows that most measles outbreaks in Europe are imported from another European country (Gossner et al. 2018). There is a high risk of continued widespread circulation of measles in the near future, as long as gaps in vaccination coverage and immunity remain (ECDPC 2019).

There are a number of reasons for insufficient and decreasing vaccination coverage in Europe. One important factor is vaccine hesitancy (ECDPC 2019), in reference to the reluctance or refusal to vaccinate against vaccine-preventable diseases despite the availability of immunisation services. Opposition to vaccination is not restricted to measles; it also concerns other vaccine-preventable diseases. A survey carried out in 2018 revealed that the Europeans have among the lowest levels of confidence in the safety and effectiveness of vaccines in the world. Misconceptions about vaccination have shifted the public focus away from its benefits towards distrust in science and fear of possible side effects (Larson et al. 2018). Besides vaccine hesitancy, suboptimal organisation of vaccination services and vaccine supply have also been a challenge for

national immunisation programmes. Member States have encountered multiple vaccine shortages (EU Council 2018). Production capacities in the EU are limited. Unpredictable demand and insufficient incentives for the pharmaceuticals industry to make the necessary investments hinder the research, development and production of new and existing vaccines.

A public health emergency on an international scale could also occur as a result of an outbreak of a foodborne disease. One example was the outbreak of *Escherichia coli* infection in 2011, which killed 55 people and made nearly 4,000 individuals from 16 countries in Europe and North America sick (WHO 2019a). Foodborne diseases are contracted through consuming food or liquids that have been contaminated with bacteria, parasites, viruses or toxins that may be produced by some bacteria during their growth. In Europe, the reported causes of foodborne diseases are most often bacteria because they are commonly subjected to surveillance, for example, *Campylobacter*, *Salmonella*, *Yersinia*, *E. coli*, *Listeria* and monocytogenes. Each year, over 350,000 cases of these infections are reported in the EU, but the real number is likely to be higher (European Food Safety Authority 2019). Some cases are fatal: in 2018, listeriosis and salmonellosis caused nearly 350 deaths. While there had been significant progress over recent years in reducing the burden of foodborne illnesses in the EU, this positive trend has recently stalled. A number of factors help spread foodborne illnesses: (i) increased international food and animal trade, (ii) the growing complexity of the food chain, (iii) increased travel opportunities, (iv) changes in agricultural practices, (v) new methods of food production and (vi) changes in consumer behaviour. A special concern is foodborne outbreaks with antibiotic-resistant strains. Data shows that antimicrobials used to treat common foodborne illnesses are becoming less effective (European Union 2018).

In general, antimicrobial resistance is a major public health issue both in the EU and globally. Antimicrobial resistance occurs when microorganisms such as bacteria, viruses, fungi and parasites change in ways that enable them to withstand the action of antimicrobial drugs. As a result, the medications used to cure the infections become ineffective, and infections with antimicrobial-resistant microorganisms persist and may spread to others (WHO 2019b). Such infections often result in worse patient outcomes and sometimes death. The main cause of antimicrobial resistance is the misuse and overuse of antimicrobials in humans as well as in animals, especially those reared for food production. Other causes include deficiencies in infection prevention and control in healthcare settings, and international travel, which can help disseminate antimicrobial resistance (Maris et al. 2017). In Europe, the antimicrobial resistance situation varies widely depending on the bacterial species, antimicrobial group and geographical region. In general, lower resistance percentages are reported by countries in northern Europe while higher percentages are reported in southern and eastern Europe. In the EU, resistance to key antimicrobial groups increased between 2005 and 2015. Some 33,000 people die every year as a direct consequence of infections with antibiotic-resistant bacteria. It is estimated that antimicrobial resistance in the EU costs EUR 1.5 billion/year in healthcare costs and productivity losses. Incidences of infections resistant to multiple antimicrobial drugs and last-resort treatments have been rising. The consumption of specific antibiotics used for treating multidrug-resistant bacterial infections almost doubled between 2010 and 2014. Projections suggest that if no effective action

is taken, antimicrobial resistance to second-line antibiotics in the EU/EEA will be 72% higher in 2030 compared to 2005.

At any time, there can be dozens of infectious disease outbreaks happening around the globe (WHO 2018). In an increasingly interconnected world, they can quickly spread from one country to another and evolve into large-scale health emergencies. There has been a renewed focus on infectious disease due to recent outbreaks of emerging and re-emerging infectious diseases, such as COVID-19, severe acute respiratory syndrome (SARS), Middle East respiratory syndrome (MERS), the Ebola virus disease, measles, avian and pandemic influenza, dengue and Zika virus disease.

1.4.1.1 Emerging or Re-emerging Infectious Diseases

An emerging or re-emerging infectious disease is one that (i) arises through evolution or change in existing pathogens, (ii) was previously unrecognised or (iii) is already known but spreads to new geographic areas, or new populations, or reappears after having been eradicated. Worldwide, novel pathogens continue to emerge: since 1970, over 1,500 new pathogens have been discovered (WHO). A large proportion of them are detected in animals and can subsequently be transmitted to humans.[14] Zoonotic diseases have long been a source of particular concern due to their potential to cause an epidemic. The possibility of a new zoonosis emerging is high, as an increase in the global population, human intrusion into natural ecosystems and intensive agriculture are driving increased rates of interspecies contacts and the interchange of pathogens (FAO 2011; Brown 2013; Wang and Crameri 2014; Carrasco-Hernandez et al. 2017; WHO 2017).

Whichever the causative agent, urbanisation, intensive travel and trade flows facilitate the spread of infections nowadays, enabling them to be imported and become endemic in new locations facilitated by climate and environmental changes. At the same time, decreasing vaccination rates and widespread antimicrobial resistance witnessed across the globe, along with an ageing population in Europe, contribute to the increased vulnerability of people to infectious diseases. The capacity of healthcare systems to detect and control epidemics differs widely; however, in the interconnected world, 'global health security is only as strong as its weakest link' (European Commission 2020a). While scientific and technological developments offer new solutions to address public health issues, they also create the possibility for disease-causing microorganisms to be engineered or recreated in laboratories and used for malicious purposes (WHO 2002, 2019b). Experts estimate that future terrorist threats are likely to come from the use of biological and chemical weapons (European Parliament 2018). All of these factors contribute to the increasing likelihood of epidemics and pandemics (Johns Hopkins Center for Health Security 2019). In 2018, a report prepared for the Global Preparedness Monitoring Board[15] concluded that there was a 'very real threat of a rapidly moving, highly lethal pandemic of a respiratory pathogen killing 50–80 million people and wiping out nearly

14 Scientists estimate that more than 6 out of every 10 known infectious diseases in people can be spread from animals, and 3 out of every 4 new or emerging infectious diseases in people come from animals.

15 The Global Preparedness Monitoring Board (GPMB) was convened in 2018 by the World Health Organization and the World Bank Group. The GPMB's mandate is to apprise key policymakers and the world of system-wide progress towards increased preparedness and response capacity for disease outbreaks and other emergencies with health consequences.

5% of the world's economy' (WHO 2019b). Europe and the world were already confronted with the manifestation of this risk – the COVID-19 pandemic. The following section takes a closer look at this unprecedented public health emergency event.

1.4.1.2 A Global Pandemic: The Case of the COVID-19 Disease Coronaviruses are a large family of viruses known to infect various animals and humans. In people, they can cause illness ranging from the common cold to more severe diseases. Zoonotic (i.e. transmitted between animals and humans) coronaviruses have in recent years caused human outbreaks, such as SARS in 2003 and MERS since 2012 (ECDPC 2023). At the end of December 2019, a novel coronavirus (SARS-CoV-2), not previously known to infect humans, was identified in Wuhan, China. It is believed to have been originally transmitted to people from an animal, but the source had not been established at the time of writing (WHO 2019b). The virus can be transmitted from person to person via droplets and fomites, i.e. objects or materials likely to carry infection, such as clothes, utensils and furniture. As there is no pre-existing immunity in the population against the new coronavirus, potentially everyone is susceptible to infection. For most infected people, the disease is mild, but in more severe cases, it can lead to pneumonia and death (ECDPC 2019). The likelihood of hospitalisation, severe illness and death is significantly higher in people over 65 and those with pre-existing health conditions. At the time of writing, neither specific treatment nor vaccines were available to fight against SARS-CoV-2 infection. It was also not yet clear what the long-term effects of the disease on infected patients would be. By 11 March 2020, when the World Health Organization (WHO) declared a global pandemic, the virus has spread to 114 countries, infected more than 118,000 people and caused 4,281 deaths. By that time, Europe had become the new epicentre of the disease. The number of cases and deaths was growing exponentially in all Member States. Confronted with the rapid spread of the infection and the threat of exceeding the capacity of healthcare systems, Member States introduced social distancing measures as well as travel and trade restrictions. In some Member States, the public health emergency coincided with other disaster events and concurrent pressures. In Croatia, the strongest earthquake in 140 years hit in the midst of the pandemic, triggering the evacuation of hospitals. In the Mediterranean, increased migration flows at the time of the pandemic posed further challenges for containing the spread of the virus. In some countries, the ongoing influenza season (ECDPC 2019) and dengue epidemic in several EU outermost regions put an extra strain on hospitals and intensive care units. Even in advanced healthcare systems, and with special measures taken, the pandemic created immense stress. The capacity of intensive care units was exceeded in some of the hardest-hit places. Countries struggled with widespread disruptions in supply of critical resources such as ventilators, testing materials and personal protective equipment. Ensuring occupational safety for medical staff has been a challenge, as COVID-19 cases have been identified among healthcare workers (ECDPC 2019). Faced with the shortages of personal protective equipment and medicines, some Member States have taken national measures restricting their export, thus preventing essential goods from reaching other affected areas across Europe (European Commission 2020h).

Despite challenges and frictions encountered, the EU, Member States, regions and cities also showed solidarity by helping each other to deal with the crisis. Within the

Union Civil Protection Mechanism (UPCM) framework (see Chapter 2), Member States donated medical and personal protective equipment, took on patients from neighbouring countries into intensive care and sent medical staff to the worst affected places. The Commission and Member States joined forces to procure medical and protective equipment. As a safety net, the European reserve of medical equipment – the rescEU stockpile – was created under the UCPM (European Commission 2020a). The EU Emergency Support Instrument was activated to support the healthcare sector during the emergency with EUR 2.7 billion in funding. The EU Solidarity Fund was revised to include public health crises within the scope of intervention. Funding was allocated to research projects on coronavirus vaccines, diagnosis and treatment. Last but not least, the UCPM helped with repatriating thousands of EU citizens stranded abroad. Looking forward, the EU has invested EUR 9.4 billion in strengthening preparedness for major cross-border health threats and resilience of healthcare systems through its new health programme EU4Health 2021–2027. At the time of writing, the coronavirus pandemic has not receded. The number of infections and deaths have continued to grow, with new outbreaks seen in Europe and across the world, notwithstanding the mitigation measures taken and the capacity of strengthened health systems to tackle the disease. By the end of August 2020, the number of infected people globally exceeded 25 million, and more than 800,000 deaths were recorded. In the EU, the human toll included nearly two million infected people and more than 130,000 fatalities (European Commission 2020a). In addition to its dire impacts on life and health, the coronavirus outbreak has also been a major shock to the EU and global economies. The spread of the virus and stringent containment measures caused disruption to global supply chains, volatility in financial markets, consumer demand shocks and negative impacts in key sectors like travel and tourism. The GDP outturn for the first quarter of 2020 showed that the European economy had slipped into contraction after almost seven years of uninterrupted growth. A lot of uncertainty surrounds the outlook, as the duration and scale of the pandemic remain unpredictable. To soften and counterbalance the economic and social effects of the COVID-19 outbreak, the Commission put forward the recovery instrument – Next Generation EU – offering Member States financial support of EUR 750 billion for action to recover, repair and emerge stronger from the crisis. The COVID-19 pandemic is a worst-case disaster scenario. Unfortunately, it might not be a unique event. There are numerous pathogens with the potential to cause a pandemic, and there is always a possibility that the next global health crisis could be caused by an agent that is currently unknown (European Commission 2020a). In many respects, the COVID-19 pandemic is a typical example of emerging risks and the challenges that such new risks pose for DRM. The pandemic is also a litmus test of our general preparedness for large-scale disaster events. There will be many lessons that need to be learned about:

- the fitness of existing national/EU/global instruments
- readiness and resilience of critical healthcare infrastructure
- production, supply and stockpiling of critical medical equipment
- protection of the most vulnerable groups in society
- multi-sector and multilateral cooperation in complex emergencies
- communication in times of disinformation
- the role that new technologies can play in managing disasters.

1.4.2 Animal and Plant Diseases

There are many factors behind the entry, establishment and spread of animal and plant diseases in a region. The key drivers include globalisation, climate change and changes in land management and agricultural practices. The increase in movement of people, animals, plants and products has accelerated the redistribution of pathogens and diseases. In addition, changes in climate are altering geographical and temporal distribution of pests, weeds, parasites and diseases. For example, there is evidence that midges – vectors of bluetongue disease – advanced from Africa into southern Europe because of increased humidity and temperature. The movement of blood-feeding flies, mosquitoes and ticks is responsible for the spread of lumpy skin disease from the Middle East to southeast Europe (European Commission 2020f).

Animals and food production can be exposed to a variety of serious infectious diseases. Some animal diseases are confined to a single species, while others can spread from one species to another. A distinction is made between epizootic diseases, which cannot be transmitted to humans (e.g. foot-and-mouth disease), and zoonotic diseases, which can be transmitted naturally from animals to humans (e.g. avian influenza). Since some animal-borne diseases can be transmitted to humans and because of food safety concerns, animal diseases are considered to be a major threat to public health. Besides human and animal health implications, disease outbreaks can have many other negative effects, such as (i) costs to livestock farmers and related industries, (ii) business disruption, (iii) loss of markets, (iv) potential changes in consumption patterns and (v) high public sector costs related to disease eradication and monitoring action. Highly transmissible animal diseases easily spread across borders and can lead to an international emergency. Countries with an industrialised agricultural sector are highly vulnerable to the spread of diseases. Many animal diseases affect wildlife and may have a negative impact on the environment (e.g. biodiversity loss). Infected wildlife, in turn, can play a role in the recurrence of outbreaks and in transmitting pathogens to both domestic animals and human beings. The type and incidence rate of infectious animal diseases vary across the EU, depending on climate conditions, farm types and management, veterinary and agricultural practices and animal movements. The unpredictable occurrence and behaviour of animal disease epidemics makes forecasting their frequency and impact difficult (European Commission 2013e). The most severe epidemic livestock diseases requiring priority attention across the EU are listed in the relevant EU legislation (European Union 2016a). Based on current levels of veterinary preparedness, the greatest risks for the EU are presented by: (i) the classical and African swine fever (viral infections affecting porcine animals), (ii) foot-and-mouth disease (a highly-contagious viral infection affecting ruminants and pigs), (iii) avian influenza (a viral infection affecting birds, Brown et al. 2017), (iv) lumpy skin disease (a viral disease affecting cattle), (v) peste des petits ruminants (a viral disease affecting goats and sheep) and (vi) sheep and goat pox.

Avian influenza virus is primarily a bird disease, but elsewhere in the world there have been cases of affected humans who came into close contact with infected birds. Therefore, the disease is a threat not only to poultry production, but also to public health. While in the 2016–2017 epidemic, no transmission to humans occurred, the general concern is that avian influenza viruses have the potential to mutate into a

strain which could be transmitted to humans, and subsequently between humans. This in turn could lead to a human influenza pandemic. Besides animal diseases, Europe's agricultural, forestry and food production sectors are also under threat from pests and diseases that attack agricultural crops, trees and other plant species. They could potentially eradicate crops and could result in food security risks and nutrition crises. Recently, 20 quarantine pests were identified as priority pests requiring increased action from public authorities due to the severity of economic, social and environmental impacts they can cause. Some prime examples are Moroccan and Italian locusts, the grapevine flavescence dorée (affecting vine plants), the *Xylella fastidiosa* (affecting olive trees), the pinewood nematode (Portugal) and the bark beetle (Germany, Czechia and Slovakia); these are all capable of extreme levels of breeding on a regional scale.

1.5 Societal Risks and Accidental Threats

1.5.1 Urbanisation

Urbanisation is understood here as movement of people to urban areas and/or increase of urban areas, population and processes (European Commission 2020a). Urban areas are places where the majority of population now reside: cities, towns and suburbs are home to three-quarters of Europeans (European Union 2016b). Future projections suggest that by 2050, the overall level of urbanisation in Europe will exceed 80% (European Union 2019a). Urban areas are also centres of economic activity and growth. For example, in 2014, metropolitan areas generated 47% of the EU GDP (EUROSTAT 2019). Due to high concentration of population, infrastructure, economic activity and cultural heritage, urban areas take the brunt of damages and losses whenever a disaster event hits.

Urbanisation dynamics and patterns are important determinants of whether and how disaster risk is affected. In Europe, the urban population is increasing, but at a slower pace than in other regions of the world. However, the built-up area is growing faster than the population is growing. Urban and land-use planning in EU Member States is a highly regulated field, providing the framework for an integrated urban development. A range of EU policy initiatives and legislation also promote balanced land use, sustainability and safety of cities. Notwithstanding this, urban growth has not been without challenges and negative side effects in terms of disaster risk.

In Europe, the surface area of cities and the share of built-up areas have been increasing, in particular in the main metropolitan and coastal zones (EC Joint Research Centre 2017). Spatial expansion has brought people and assets closer to hazards. Urbanisation along the European coast, boosted by the increasing demand for recreational activities, has exposed more people and assets to coastal flooding. Simultaneously, sea levels and extreme high coastal water levels have been growing. An interplay between these developments is likely to lead to major increases in losses from coastal flooding in the future if measures are not taken. Another example is increasing risk of wildfires with human casualties and damage to properties resulting from an urban sprawl into forested areas.

Growing cities have also not been immune to the urban sprawl phenomenon that is associated with harmful effects. Despite efforts to address the problem, urban sprawl has been increasing in all European countries (European Environment Agency 2016). Sprawling cities consume larger amounts of land, demand more energy and transport and emit higher amounts of greenhouse gases compared to more compact settlements. As the built environment expands in a sprawling manner, it fragments landscapes, leading to the deterioration of ecosystem services and aggravates impacts of risks such as floods, droughts and heatwaves.

A recent JRC research project estimated that almost half (46%) of Europe's urban area had a low capacity to mitigate floods, mostly due to soil sealing. Impervious surfaces not only prevent rain from being absorbed into the ground, but they also inhibit the replenishment of underground water supplies. This worsens water scarcity problems, especially where consumption of water is increasing due to the growth in population and economic activities while drought episodes become more common (EC Joint Research Centre 2018a).

During heatwaves, the built environment and imperviousness create favourable conditions for the 'urban heat island' effect – a microclimatic phenomenon whereby urban settings experience higher temperatures than their rural surroundings. This phenomenon is one of the major concerns for urban authorities across Europe, given its detrimental effects on human health and projected increase in the frequency and intensity of heatwaves (European Commission 2020a).

The design and characteristics of urban fabric – the built and the 'green' environment – are important determinants of a city's resilience or vulnerability to hazardous events. In European cities, ageing building stock and infrastructure pose significant challenges. The size of the built-up area in the EU is about 25 billion m^2, of which about 10 billion were constructed before the 1960s. Buildings built more than half a century ago often do not meet evolving resilience needs or standards. One major concern is earthquake resistance. JRC analysis shows that most buildings in the seismic-prone regions of Europe were designed without provisions for earthquake resistance or following moderate-level seismic codes (EC Joint Research Centre 2018b; Tsionis et al. 2017). Another issue is resilience of infrastructure in the context of a changing climate – its ability to cope with impacts of intensifying extreme weather events, especially in the areas where they were not common in the past.

Green infrastructure[16] and nature-based solutions play an important role in mitigating weather-related disaster risks (European Commission 2013b). In overall terms, European cities perform relatively well in terms of the share of green infrastructure: the JRC study of nearly 700 urban areas in the EU found that, on average, 40% of their surface was covered with green spaces. However, the percentage varies widely across EU cities, as does the distribution of green spaces within a city. Moreover, as population grows, urban planners are increasingly facing difficult trade-offs: how to contain cities within their boundaries, avoid sprawling and densify while at the same time maintaining or enhancing green spaces (EC Joint Research Centre 2019).

16 Green infrastructure is defined as a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas.

Besides the challenges discussed in this section, there are also some positive messages. Throughout Europe, sustainable urban development and resilience to disasters have been climbing higher on the municipal agenda. Cities are front-runners in formulating, testing and exchanging innovative solutions for a more balanced growth and safe urban environment. The pace of land take for urban development has slowed down in the recent decade. That being said, countervailing pressures will not dissipate. In addition to pressures from urban population growth, other disaster risk drivers like climate change are strengthening. Addressing vulnerabilities, such as ageing or outdated infrastructure, requires substantial financial resources and is a long-term endeavour. Resources and powers to take action vary across European cities. Against this background, both the importance and the challenge of keeping urban communities and assets safe are evident.

1.5.2 Disruption of Critical Infrastructures

The risks to critical infrastructures may increase in the future as new threats emerge. Climate change is expected to heavily affect infrastructure through heatwaves, floods and droughts (Forzieri et al. 2015). Due to climate change alone, annual damage to Europe's critical infrastructure could increase 10-fold by the end of the century under business-as-usual scenarios, from the current EUR 3.4 billion to EUR 34 billion (European Commission 2020a). The highest losses would be borne by the industry, transport and energy sectors. Southern and south-eastern European countries will be most affected. Energy blackouts, due to the vulnerabilities of critical infrastructure networks, affect all sectors of European societies, with immediate negative effects on populations and economies. The unlawful use of drones is an emerging threat, as demonstrated in December 2018 by the disruption to air traffic at the Gatwick airport in the United Kingdom. The overall increase in the terrorist threat in the EU also applies to the critical infrastructure environment. Individuals or groups with malevolent intent might seek to attack critical infrastructure networks as a part of a broader hybrid influencing strategy that might combine physical attacks and cyberattacks with disinformation campaigns. The operation and security of critical infrastructure may also be affected by changing ownership structures or by the deployment of foreign-sourced components. The landscape of critical infrastructure protection is rapidly evolving. In the coming years, the discussion will probably be more about critical infrastructure systems, even systems of systems and their interaction. Another expected trend is a shift in focus from protection to resilience, reflecting an increase in the number of threats and their complexity, such that threats cannot always be predicted and incorporated in a pure risk management approach (Bordin et al. 2019).

Critical infrastructures are complex, interconnected systems that are subject to a wide range of hazards and threats. Man-made threats include terrorism, cyberattacks and sabotage by internal (insider) or external perpetrators. Accidental risks include technical breakdowns, air, rail or road accidents and fires and explosions. Natural hazards include storms, floods or epidemics/pandemics. In this time of rapid climate change and intensifying natural disasters, infrastructure systems are under pressure to deliver resilient and reliable services. The disruption of critical infrastructure can affect the

delivery of essential services, including the provision of energy, transport, water, food, communications, health, emergency response services and payments/financial operations. The final impacts depend on the duration of the disruption, the time of year, the resilience of the service and the response by the authorities. They may involve human casualties, severe social effects and negative economic consequences. As interdependencies increase, the potential for systemic failures is increasing. With the interdependence of essential services, the failure of one critical infrastructure may trigger cascading effects, disrupting the operation of other key services. The increasing complexity, interdependency and scale of infrastructure networks can make them more difficult to protect. While technological developments have improved the quality of essential services, this progress itself creates new vulnerabilities. The growing challenges associated with understanding and protecting complex, interdependent infrastructure networks mean that the resilience of critical infrastructure networks – their ability to recover from incidents – is becoming ever more important.

1.5.3 Chemical Industrial Accidents

The EU is one of the most highly industrialised regions of the world. Highly industrialised economies are by nature intense users of all kinds of chemicals and therefore have a significant exposure to chemical accident risk. Some of the most versatile substances for industrial use are hazardous substances such as chlorine, ammonia and hydrogen fluoride. Substances that are considered high hazard are mainly those that are flammable, explosive, toxic to humans or toxic to the environment, and several substances belong to more than one of those categories. Although, there may be a reduction in carbon-based fuels in future, toxic and flammable petrochemicals such as ethylene, benzene and toluene are likely to continue be essential to the modern economy unless suitable replacements are found (EC Joint Research Centre 2024). Most chemical accidents in the world occur on fixed sites, and the vast majority of legislation and data are hence associated with fixed hazards rather than transport, pipelines and offshore exploration. EU exposure to cross-boundary chemical accident risks is discussed in the EC Joint Research Centre (2024) report.

As long as chemicals and chemical processing remain important for our societies, accidents will continue to happen. The use and application of chemicals are actually growing rather than decreasing. The expansion of urban areas and their proximity to high-risk industrial establishments increase their exposure to risk, as well as the potential for human and economic consequences should there be an accident. The risk may further be exacerbated by climate change. More frequent extreme weather events, such as floods, droughts and heatwaves, could damage or weaken infrastructure, triggering the release of dangerous substances, explosions, industrial fires or aggravating the effects of such accidents. Moreover, some technological adjustments due to climate change, such as a switch to alternative fuels, including hydrogen and lithium batteries, may also introduce new risks or exposure to new risks. One recent example is an explosion that occurred at a hydrogen filling station for fuel cell cars in Norway in 2019. The ageing of hazardous installations is another area of concern, receiving increasing attention over the past decade, both from public authorities and industry. Everything

associated with an installation and its processes can age: equipment, procedures and technologies (OECD 2017a).

While fast economic and technological developments could provide new resources for strengthening the safety and security of industrial sites, they also generate new vulnerabilities. For example, process automation helps reduce the 'human error', but brings challenges related to programming errors or software glitches. Shortcomings in risk management can themselves lead to disasters. The 2017 Chemical Accident Risks Seminar identified several factors affecting the effectiveness of chemical accident risk management (Wood 2017): (i) the insufficient use of safety performance indicators, (ii) weaknesses in maintenance and mechanical integrity, (iii) IT security and safety challenges and (iv) organisational change and fragmentation of expertise over several (sub) contractors increase the possibility of large-scale accidents occurring. Another area that calls for special attention is the use of new substances, for example, biobased chemicals, liquefied natural gas, compressed natural gas, nitrogen and nanoparticles (OECD 2017b). These new substances and nanotechnology offer new possibilities for the industry, economy and society. However, the knowledge of related risks to public health and the environment is still relatively limited. Lastly, malicious activities, such as cyberattacks, can target industrial sites. However, knowledge and tools to support inspections and oversight of cyber safety and security at EU Seveso sites are not widely available (Wood et al. 2017).

Disasters that result from chemical accidents are unforeseen events involving hazardous substances. Hazardous industries include: (i) petroleum oil refineries, (ii) chemicals manufacturing/storage (including liquefied natural gas), (iii) fireworks and explosive manufacturing/storage, (iv) fuel storage and distribution, (v) processing of metals, (vi) production of pharmaceuticals, (vii) waste treatment and (viii) small and medium-sized businesses and non-chemical-based businesses that use dangerous substances. The transporting of dangerous goods through a country's territory also presents a risk of a chemical accident. The risk of an accident depends on the industrial site's activity and the volume and types of dangerous substances involved. The likelihood of an accident occurring depends on how well the risks are understood and managed. The interface between technology and humans adds complexity to risk management. Chemical accidents can have a wide variety of causes, such as human error, insufficient safety measures, deliberate malicious acts and natural hazards. The technological accidents caused by natural hazards are called 'Natech' accidents (see Section 1.5.6). Historical accidents like Seveso (Italy, 1976), Bhopal (India, 1984), Schweizerhalle (Switzerland, 1986), Enschede (the Netherlands, 2000), Toulouse (France, 2001), Buncefield (UK, 2005) and Gorni Lom (Bulgaria, 2014) showed that such accidents can have serious consequences. The impacts of industrial accidents, irrespective of their cause, may include: • fatalities and injuries of workers on-site and the surrounding population; • damage to property and infrastructure on-site and in the surrounding area; • disruption of essential services and transport networks; • environmental contamination and potential cross-border pollution; • health hazards (e.g. caused by the release of acute toxic substances); • physical hazards (e.g. highly flammable substances, hazards caused by the release of explosives); • substantial economic losses that may lead to bankruptcy or job losses; and • transboundary environmental and health impacts. When major accidents take place, ecological and economic

costs are borne not only by the establishment affected, but also by the local community, the Member State concerned, and, potentially, neighbouring countries.

Overall, the number of chemical incidents in Organisation for Economic Co-operation and Development (OECD) countries, representing the world's most industrialised economies, is high compared to non-OECD countries (European Commission 2020a). At the same time, the severity of these accidents in terms of fatalities is much lower. This is an indication that action taken to control the risks of chemical accident has been successful in reducing deaths and injuries (Wood and Fabbri 2019). While small-scale industrial accidents are common, the likelihood of major industrial events with a high impact remains low in the EU. This is largely thanks to the effectiveness of preventive government and industry interventions, or, in some countries, a relatively low presence of hazardous activities.

1.5.4 Nuclear and Radiological Accidents

Nuclear accidents are critical events involving nuclear facilities or activities which can lead to the release of radioactive material in the atmosphere and may also have transboundary implications (IAEA Safety Glossary). Releases of radioactive materials can settle and contaminate people, buildings, food, water and livestock through inhalation and exposure to the traveling plume and deposited material, which poses a significant health risk that should be anticipated in order to provide with adequate protective measures to decrease the risk of occurrence and mitigate the consequences through appropriate countermeasures (EC Joint Research Centre 2024). These facilities include nuclear power plants, but also installations handling nuclear material (e.g. nuclear fuel re-processing plants), storage facilities for used nuclear fuel, nuclear-powered vessels and research facilities. Radiological accidents can also take place while radioactive material is being transported, as well as during other activities involving industrial, research, or medical radiation sources. Nuclear power reactors are the most common nuclear facility. There were 124 nuclear power reactors in operation in the EU (situation at the end of 2019), grouped on 55 sites in 14 Member States.[17] Their safety record is such that although incidents have occurred, the engineered safety systems designed with significant redundancy[18] to prevent escalation of incidents have ensured that no major accidents have ever taken place.

In general, there is an extremely low probability of nuclear accidents occurring, but when they do, they have a high impact. Due to the potentially high human, economic and environmental impact of a severe nuclear accident, nuclear power plants are subject to strict safety and security checks and strict prevention and mitigation measures are in place. Climate change and more frequent extreme natural events could potentially lead to an increased risk of accidents in nuclear power plants or facilities containing radioactive substances. However, this is considered in safety assessments, taking account of their projected lifetimes (European Commission 2020a).

17 Belgium, Bulgaria, Czech Republic, Germany, Spain, France, Hungary, the Netherlands, Romania, Slovenia, Slovakia, Finland, Sweden and the United Kingdom.

18 Redundancy is the duplication of critical components or functions of a system with the intention of increasing reliability of the system, usually in the form of a backup.

1.5.5 Environmental Degradation

Environmental degradation,[19] in particular the damage to ecosystems and biodiversity loss, is aggravating disaster risk. Ecosystems provide multiple services and benefits, including those highly relevant for disaster risk reduction and mitigation, such as regulation of climate, pests and diseases, water retention and flood control, prevention of landslides, coastal protection and others. The ability of ecosystems to deliver ecosystem services is linked to their condition. Regrettably, biodiversity and ecosystems face immense pressures at a global and European scale. Worldwide, about 75% of the terrestrial environment and 40% of the marine environment are now severely altered (European Environment Agency 2019). The great majority of indicators show a rapid decline due to changes in land and sea use, exploitation of natural resources, climate change, pollution and invasive alien species (IPBES 2019).

The report on the 'European environment – state and outlook 2020' published by the EEA concludes that Europe continues to consume more resources and contribute more to environmental degradation than other world regions. In the past 10–15 years, deteriorating trends dominated the state of ecosystems and services. Policy responses have been insufficient to halt biodiversity loss and the degradation of ecosystem services, and the respective 2020 targets set in the EU Biodiversity Strategy will not be met (European Environment Agency 2019). The EEA warns that the overall outlook for Europe's environment in the coming decades is discouraging, as ecosystem degradation and biodiversity loss, climate change, pollution loads and other global environmental challenges are feeding each other through numerous feedback loops at multiple scales (European Environment Agency 2019).

Degraded or disturbed ecosystems do not only have the reduced capacity to provide essential services and protect against adverse events; they are also less resilient to disasters. For example, forests stressed by drought and high temperatures may be more vulnerable to insect attack, which in turn leads to large numbers of dead trees that are susceptible to fire (De Rigo et al. 2017). In a vicious circle, disasters further contribute to damage in the natural environment, disturbing ecological balance. Environmental degradation can also lead to new risks, such as new infectious diseases. Globally, growing human expansion into wildlife areas, sweeping changes in land use and ecological disruption are important factors driving diseases, in particular zoonoses – those that spread from animals to humans (Alonso Aguirre 2017). Even if a new infectious disease were to emerge in a remote area, in the current globalised world, it can quickly spread to new locations. The COVID-19 pandemic, caused by a coronavirus that is deemed to have spilled over from an animal source to humans (WHO 2019b), has raised attention to the threats originating from an increased interaction between humans and the natural world (Carrington 2020).

19 Environmental degradation is a process through which the natural environment is compromised in some way, reducing biological diversity and the general health of the environment. This process can be natural in origin, or it can be accelerated or caused by human activities. Source: The European Environment Information and Observation Network (Eionet) https://www.eionet.europa.eu/gemet/en/concept/15154

1.5.6 Natech Events

Soaring industrialisation and human development increasingly put natural and technological hazards on a collision course. When natural hazards, such as earthquakes, floods, storms etc. impact industrial activities that process storage or transport hazardous substances, they may result in damage to facilities and equipment which can cause releases of toxic chemicals, fires or explosions. The consequences of such natural hazard-triggered accidents can be significant, with potentially long-term social, environmental and economic effects (EC Joint Research Centre 2024). In addition, natural hazards can cause multiple releases of hazardous substances at the same time, destroy safety barriers and down lifelines needed for accident prevention and mitigation. Natech risks are expected to increase with climate change, which is bound to affect the frequency and severity of hydrometeorological accident triggers (Krausman et al. 2017).

Analyses of industrial accident databases showed that 2–6% of accident records were caused by natural hazards (Suarez Paba et al. 2020). Considering that there is a reporting bias towards severe accidents, it is very likely that the real number of Natech accidents may be more severe in monetary terms that those of accidents triggered by non-natural causes (EC Joint Research Centre 2024; Girgin and Krausman 2016). In the past few years, a number of major Natech accidents made the headline, for example the Fukushima nuclear power plant meltdown further to the Great East Japan earthquake and tsunami in 2011, the chemical releases and oil spills due to Hurricane Harvey in the USA in 2017 and the fires at an oil storage terminal in Cuba due to lighting in 2022. Although significant progress in Natech risk management has been made globally over the past decade, gaps persist that require continued action from authorities, industry and academia. Challenges pertain mainly to awareness raising, risk governance and communication and knowledge creation (EC Joint Research Centre 2025).

1.6 Security Threats

1.6.1 The Changing Security Landscape

From a security point of view, Europe is facing an increasingly uncertain and unsettled world. To the east, countries are struggling with military, economic, political and energy-security related threats and vulnerabilities. In North Africa, the Sahel region and the Middle East, armed conflicts and political instability are escalating. The spread of ungoverned spaces has left a vacuum for terrorists and criminals to thrive. Intensifying regional rivalries, climate change and resource scarcity, coupled with demographic growth and state fragility, drive conflict and instability around the world (European Commission 2020a). They have led to a dramatic rise in civilian victims and refugees. By the end of 2018, more than 70 million people were displaced (UNHCR 2018a). Against this bleak backdrop, Europe has also witnessed the biggest influx of migrants and refugees since the Second World War, with more than two million people arriving on its shores since 2014 (UNHCR 2018b).

While turmoil in different regions of the world persists, multilateralism and rules-based global order are under severe strain. Great power competition is now a leading

trend in world politics (EUISS 2019). New powers are seeking their place on the global stage, while existing powers are behaving less predictably. Tendencies to pursue national interests are intensifying, alliances are shifting, making it harder to take concerted action and pursue crisis resolution through diplomacy. Instability abroad and developments on the international scene have an impact on the security environment in Europe. Without aiming at a comprehensive security policy analysis, this section takes a look at how external and internal driving forces interact and shape security threats for the EU, in particular terrorism, hybrid, cyber and CBRN threats.

1.6.2 Terrorism Threat in Europe

Conflicts in different regions of the world are a major driver of terrorist activity (Institute for Economics and Peace 2018). Turmoil in the Middle East and North Africa over the last decade, in particular, has played an important role in shaping the terrorist threat globally and in Europe. Protracted crises in the region facilitated the rise of ISIS/Daesh and the establishment of the Islamic State in 2014. The terrorist group attracted an unprecedented number of followers from around the world. Between 2011 and 2016, more than 42,000 persons from over 120 countries have travelled to Syria and Iraq to join ISIS/Daesh (Radicalisation Awareness Network 2017). It is estimated that around 5,000 European nationals followed suit to become foreign terrorist fighters (Europol 2018). ISIS/Daesh became one of the four deadliest terrorist organisations in the world, killing more than 27,000 people in the years 2015–2019 (Institute for Economics and Peace 2019), including tens of persons in the EU.

The military defeat of the Islamic State in 2019 was an important achievement in the fight against terror. However, it has not put an end to the jihadist terrorism threat. ISIS/Daesh remains active and there are signs of it trying to rebuild itself. The number of affiliates outside of Iraq and Syria continue to rise, as does the number of non-affiliate groups that have pledged allegiance to the group. Moreover, Al-Qaeda has been reconsolidating its influence and actively encouraging terrorist attacks in the EU (Europol 2018). Multiple other actors are plotting alone or conspiring with others. Terrorist organisations and threats persist beyond the Middle East, in particular in Afghanistan, parts of Africa and South-East Asia. As long as these regions suffer from instability, violence and weak governance, the threat of terrorism is unlikely to subside.

The setbacks experienced by ISIS/Daesh in Syria and Iraq had several implications for the jihadist terror threat in Europe. They have incentivised the European jihadist movement to shift the focus from travelling to fight in the conflict areas towards taking retaliatory action and spreading of the jihadist message in the EU. The loss of territory by the Islamic State has also triggered the return of the European foreign terrorist fighters from battlefields to their home countries. It is estimated that approximately 30% of them have already come back (Europol 2018), alone or with families, while hundreds remain in detention in Iraq and Syria and could be returning in the future. Radicalised individuals with combat experience and international terrorist connections are perceived as a security threat, as they may be ready to commit new atrocities or could serve as role models, propagandists, recruiters, or fundraisers for terrorist organisations (Europol 2018).

People born and raised in the EU have not only been joining ISIS/Daesh ranks abroad, they were also the main perpetrators of the recent jihadist attacks on the European soil. Some of these terrorists were guided by jihadist organisation, while others acted as 'lone wolves', inspired by the propaganda (Europol 2018). This brings to the forefront the 'domestic' dimension of the threat and poses difficult questions about home-grown terrorism and radicalisation. While the jihadist ideology, networks and recruitment strategies play an important role, they do rely on finding a susceptible audience. In Europe, this audience has been young second- or third-generation immigrants from socio-economically disadvantaged Muslim communities, with a criminal history or those who have socialised in a criminal environment (European Policy Centre 2017). Research into root causes of jihadist radicalisation in Europe points to such factors as poor integration into the society, perceived or real socio-economic grievances, perceptions of injustice, a sense of alienation and resentment, personal problems and a search for a cause or belonging. It also highlights the importance of crime–terrorism nexus and the role prisons play in radicalising individuals.

The problem of radicalisation and violent extremism, however, is not limited to the jihadist terrorism and can occur at any end of political spectrum. In fact, Europe has decades-long history of ethno-nationalist/separatist terrorism, left-wing and anarchist terrorism. One of the worrying trends that has emerged over the last years is the rising extreme right-wing sentiment and the number of arrests related to right-wing terrorism. Far-right extremist parties and movements have been mobilising support by exploiting recent jihadist terrorist attacks, anxieties related to migration, fears of perceived attempts to Islamicise society and grievances linked to the alleged loss of national identity. While the vast majority of these groups have not resorted to violence, they nevertheless help entrench a climate of animosity against minority groups. Such a climate, built on xenophobia, anti-Semitic, Islamophobic and anti-immigration sentiments, may lower the threshold for some radicalised individuals to use violence against persons and property of minority groups (Europol 2019a).

Terrorism is a serious threat to Europe not only because it poses a direct danger to citizens and infrastructure in the form of attacks. It has wider repercussions: creating the feeling of insecurity, fuelling distrust among different groups in the society and towards the government, feeding prejudices and extremist views. This poisonous atmosphere can lead to a vicious cycle of radicalisation, where right-wing extremists and radical Islamists feed off each other, becoming even more radicalised in the process. As different groups spin divisive 'us' versus 'them' narratives in the context of various pressures, social cohesion erodes and societies become more polarised. Domestic and foreign actors can exploit these divisions in order to pursue their agendas and sow instability (European Policy Centre 2017).

The terrorist threat in the EU remains high, although the level varies across Member States. While the number of fatalities from terrorist acts has fallen since 2016, the number of failed, foiled and successful attacks, as well as the number of arrests, highlight the continued threat (EUROPOL 2020a). The threat is rapidly evolving and is multifaceted due to the complex and fragmented nature of the global terror threat. Jihadist terrorism is one of the main threats to the EU through the activities of structured terrorist groups or cells and home-grown individuals who act alone, inspired by jihadist propaganda. The military defeat of the so-called IS Caliphate in Syria and Iraq has not

necessarily resulted in the threat diminishing; rather, it has made the situation regarding threats more complex and fragmented. In addition to the risk posed by returning foreign terrorist fighters, the EU is confronted with the threat posed by home-grown radicalised individuals who follow IS and Al-Qaida propaganda that calls for more attacks.

Besides jihadism, other forms of terrorism are also a threat to the security of people in the EU. There is still ethno-nationalist and separatist terrorism in some Member States, as well as left-wing/anarchist terrorism and right-wing extremism. Although extreme right-wing terrorism is not a new phenomenon, recently there has been an increase in its frequency and lethality of attacks. While the violent right-wing extremist scene is very diverse across EU Member States (EUROPOL 2020b), all right-wing extremists prey on fears of perceived attempts to Islamicise society and the loss of national identity.

So far, most of the terrorist attacks and plots have relied on non-sophisticated weaponry and methods (bladed weapons, car ramming) and targeted public spaces (concert halls, public venues, transport hubs, supermarkets). Such methods, in particular car ramming in mass events, can and have caused mass casualties. The use of vehicles as a weapon is expected to continue, as such attacks are easily planned and require minimal expertise, and a variety of vehicles can be easily accessed (Bordin et al. 2019). The availability of new technologies (e.g. encrypted communications, drones, 3D printing) increase the terrorists' capacity to mount attacks. The emerging risks are associated with terrorists' access to technologies and substances which can significantly increase their capabilities and the impact of terrorist attacks, such as: • access to CBRN agents; • use of unmanned aerial systems for planning and carrying out attacks against either soft or hard targets. The likelihood of more complex attacks involving CBRN agents remains low, but they cannot be excluded. In recent years, an increase in CBRN terrorist propaganda, tutorials and threats has been observed online (EUROPOL 2019b). There were also cases of terrorists planning and sometimes even producing material for non-conventional attacks. These attempts have relied on low-technology methods, using precursors that are relatively easy to obtain and simple production processes. Chemical substances (plant-based toxins, toxic industrial chemicals, gas-forming chemicals) are the main substances of concern (Zammit 2017). In the coming years, new technologies might make a difference when it comes to biological agents. There is a risk that novel gene-editing technologies (e.g. CRISPR [clustered regularly interspaced short palindromic repeats])[20] and synthetic biology could be used to develop destructive biological weapons, such as new infectious viruses. While this is unlikely at present, the biohacking[21] movement is developing quickly; technical barriers and manufacturing costs are also lowering. Regarding the radioactive substances, there are no

20 Gene editing or genome editing is a group of technologies that give scientists the ability to change an organism's DNA. These technologies allow genetic material to be added, removed, or altered at particular locations in the genome. Several approaches to genome editing have been developed, one of them being CRISPR. Source: MedlinePlus, available at https://medlineplus.gov/genetics/understanding/genomicresearch/genomeediting/

21 Biohacking – also known as DIY biology – can be defined as the attempt to manipulate human brain and body in order to optimise cognitive or physical performance, outside the realm of traditional medicine, often using opportunities offered by new technologies.

recent indications that terrorists are interested in using them. However, there are some vulnerabilities that can be exploited (e.g. radioactive sources in medical facilities). Unmanned aerial vehicles (e.g. drones) can be used as a delivery mechanism for CBRN agents, as in 2015, when a drone carrying traces of radioactivity was found on the roof of the Japanese Prime Minister's official residence. Moreover, numerous cases of drones flying over nuclear plants highlight the vulnerability of this type of infrastructure to conventional attacks, with drones used as a delivery device for explosives. In the future, a number of challenges are expected, related to (i) the return of foreign fighters from Syria, Iraq and Libya, (ii) extremist preachers, (iii) Internet propaganda, (iv) extremist content on satellite TV, (v) radicalisation of second- and third-generation migrants due to a failure to include them in society, (vi) culture shock experienced by non-integrated first-generation migrants and (vii) an increase in violence and hate speech by far-right groups.

1.6.3 The Increasingly Hybrid Nature of Threats

The security environment in Europe is further shaped by the geopolitical rivalry combined with the ever-increasing opportunities provided by digital technologies. The EU and Member States are confronted with hybrid threats that permeate different domains of societal life and increasingly blur the distinction between internal and external security, peace and war, civilian and military, physical and virtual, partners and adversaries/competitors (European Policy Centre 2017; Treverton et al. 2018).

The term 'hybrid threats' refers to a mix of coercive and subversive activity, conventional and unconventional methods (i.e. diplomatic, military, economic and technological), which are used in a coordinated manner by state and non-state actors to pursue their strategic objectives. The 'arsenal' of hybrid influencing techniques is versatile and can include cyberattacks on critical infrastructure, disinformation[22] campaigns, interference in elections, financing of anti-establishment parties, espionage, leaks of stolen data, economic pressure, investments in strategic industries and military incursions. Hybrid operations are deliberately designed to be difficult to detect and attribute and remain below the threshold of formally declared warfare. It is often challenging to differentiate between individual incidents and coordinated campaigns. Hybrid campaigns target and exploit vulnerabilities. The ultimate goal is to weaken and destabilise the adversary by causing economic damage, meddling in decision-making processes, creating confusion, amplifying divisions and undermining public trust in government institutions, mainstream media and democratic processes (European External Action Service 2019). Hybrid threats are not a new phenomenon, and many of the influencing techniques have existed since a very long time. However, the threats are evolving with the developments in geopolitics, technology and social trends.

22 Disinformation is understood as verifiably false or misleading information that is created, presented and disseminated for economic gain or to intentionally deceive the public and may cause public harm. Communication on tackling on-line disinformation. Source: COM(2018) 236.

1.6.4 Cyber Threats

The cyberspace and social media have become the new battleground for state and non-state actors. In the cyber domain, hostile and illicit operations can be implemented at a distance and with a high level of anonymity. They require limited investment, while the impact can be enormous. Digital transformation of the EU's economy and society, increasing reliance on information systems, cloud computing, big data, the rise of Internet of Things, automation of industrial processes, the roll out of 5G technology open new possibilities that can be exploited by malevolent actors. The Internet and social media are used as powerful tools for spreading disinformation, terrorist propaganda and extremist content. Terrorist groups and extremists take advantage of social networking sites, online video channels and radical chat rooms to engage with disaffected youth and recruit new followers. States propagate disinformation with the help of online troll-farms, bots and real and fake accounts. Growing polarisation in Europe provides an enabling environment for influencing campaigns that can range from election debates (EU vs DiSiNFO 2019a) to migration (EU vs DiSiNFO 2019b) or such topics as vaccination (EU vs DiSiNFO 2018) or the COVID-19 pandemic (EU vs DiSiNFO 2020). Rapidly advancing machine learning techniques such as deep fakes are likely to bring disinformation campaigns to the next level – by allowing to create alternative realities through fabricated images, audios and videos that humans cannot distinguish from authentic ones. With the increasing availability of data and algorithms, the focus can also be expected to shift from manipulation of the content to the back-end manipulation (Meessen et al. 2020). Artificial intelligence (AI) is a game-changer and a double-edged sword when it comes to cybersecurity: it can facilitate the detection of malicious activities, but it will also help craft and disguise more sophisticated attacks (Bordin et al. 2019).

As societies are increasingly dependent on electronic networks and information systems, the protection of cyber space has become a major concern for European countries. All forms of cybercrime have been significantly increasing and evolving over recent years. According to the EUROPOL's 2019 Internet Organised Crime Threat Assessment (IOCTA), cybercrime is becoming more aggressive and confrontational across various its forms, including high-tech crimes, data breeches and sexual extortion (EUROPOL 2019b). The latest trends, as discussed in the IOCTA 2020, include the amplification of existing cyber threats during the COVID-19 crisis (EUROPOL 2020b). Ransomware and banking trojans remain the top malware threats, a trend unlikely to change for the foreseeable future. The 2017 WannaCry and NotPetya attacks not only happened on an unprecedented scale affecting a wide range of key industries and critical infrastructures worldwide, but also resulted in a high cost to the global economy. According to the European Union Agency for Cybersecurity (ENISA), the WannaCry ransomware campaign affected more than 150 countries and over 230,000 systems. Distributed Denial-of-Service (DDoS) continues to be a threat for businesses and public organisations. This situation is aggravated by the fact that 'crime-as-a-service', connecting specialist providers of cybercrime tools and services (ransomware, DDoS, etc.) with organised groups, has become the leading model of the digital underground. Data remains a key commodity for cyber-criminals. It is procured for immediate financial gain in many cases, but, increasingly, it is also acquired in order to commit more

complex fraud, encrypted for ransom, or used directly for extortion. Social engineering remains one of the main methods used for committing cybercrime. Phishing aimed at high value targets, for example, refined variants of spear phishing such as CEO fraud, have become a key threat. EMV522 (chip and PIN), geo-blocking and other industry measures continue to reduce card-present fraud within the EU, but logical and malware attacks directly against ATMs evolve and proliferate. Organised crime groups are starting to manipulate or compromise payments involving contactless cards. The production and distribution of child sexual exploitation material continue to increase. The use of end-to-end encrypted platforms for sharing media, coupled with the use of largely anonymous payment systems, has helped the live streaming of child abuse to escalate. The increasing number of young children with access to the Internet and its social media platforms increases the risk of online sexual coercion and extortion.

The dark net continues to facilitate criminals involved in a range of illicit activities, such as the exchange of child sexual exploitation material. The extent to which extremist groups currently use cyber methods to conduct attacks is relatively limited, but the availability of cybercrime tools and services provides them with the opportunity to use these techniques. Furthermore, the dark net can be used to purchase illicit commodities such as firearms. Digital currencies are used to pay for criminal products and services in the digital underground economy and the dark net. Digital currencies have also become the standard payment solution for extortion payments. Cryptojacking (the exploitation of Internet users' bandwidth and processing power to mine cryptocurrencies) has emerged as a new trend, creating revenue for attackers, further motivating them to hack legitimate websites. Economic damage caused by cybercrime can only be estimated due to the under-reporting of cybercrime, different perceptions of what cybercrime is and difficulties in quantifying damages. The WannaCry attacks alone are estimated to have cost global economies roughly USD 4 billion (Beer 2017). There has been increasing concern over semantic attacks such as disinformation and its role in hybrid threats and actions that challenge the integrity of democratic processes. For example, the East StratCom Task Force (European External Action Service 2018), launched in 2015 by the European Union External Action Service (EEAS) to address Russia's disinformation campaigns, reported 1,000 cases of disinformation detected between January and June 2019. This is compared to 434 cases reported for the same period in 2018.

1.6.5 CBRN Threats as a Growing Concern

Besides the cyber-enabled threats, concerns have been growing in Europe about the potential use of CBRN materials for malicious purposes. It is known that terrorist organisations are interested in and capable of using CBRN materials inside and outside the EU. In Syria, ISIS/Daesh used toxic chemicals as weapons on several occasions. In the EU, law enforcement authorities disrupted several terrorist plots involving chemical materials. Online, an increase of CBRN terrorist propaganda, tutorials and threats has been observed over the last years (Europol 2019a). The concerns about hostile actors using CBRN substances were further reinforced in 2018 in the aftermath of the Novichok attack, which involved the use of a military-grade nerve agent against individuals in Salisbury, United Kingdom.

CBRN threats by nature are multifaceted and they are developing rapidly. Technologies are advancing, and the barrier for gaining knowledge on the use of CBRN materials is decreasing (Europol 2019a). The Internet facilitates access to know-how and substances. Some of the chemical materials have dual-use and are readily available. The advent of molecular biology techniques allows for easier manipulation of bacteria and viruses. Cyber tools and new technologies such as drones can be used in attacks against nuclear facilities.

The security landscape is ever evolving and increasingly complex. Threats originate from state and non-state, foreign and domestic actors. New technologies, cyber space and social media add a new dimension to the setting, posing new challenges as well as opportunities. Internal and external security are more intertwined than ever (European External Action Service 2019). Understanding and countering malicious threats requires taking into consideration developments on the international scene alongside domestic tensions, grievances and vulnerabilities. The complexity of challenges calls for a comprehensive response, based on cooperation across sectoral and territorial boundaries and the whole-of-society approach. The respite from malicious threats might not be within reach any time soon, but their impact will depend on the resilience of European societies. Resilience against radicalisation, violent extremism and disinformation, resilience of critical infrastructure and supply chains and cybersecurity are important elements in this respect, as are efforts to promote conflict resolution and stability abroad.

1.7 Emerging Risks

1.7.1 Defining Emerging Risks

In accordance with the EC Regulation 178/2002, the European Food Safety Authority (EFSA) defines emerging risks (to human, animal and/or plant health) as a risk arising from a newly identified hazard that may lead to significant exposure, or from an unexpected new or increased significant exposure and/or susceptibility to a known hazard. An evaluation of emerging risks involves the early detection of relevant facts derived from research and/or monitoring programmes or episodic observations. The assessment of emerging risks must be adaptable to accommodate changes in the conditions affecting the risks and advancements in detection methods. It should be noted that the assessment of emerging risks is distinct from the assessment of risks under emergency (or crisis) conditions, as the latter are managed through established EC procedures (European Commission 2004).

The 2014 OECD Recommendations on Governance of Critical Risks defines them as 'threats and hazards that pose the most strategically significant risk', as a result of (i) their probability or likelihood and of (ii) the national significance of their disruptive consequences, including sudden onset events (e.g. earthquakes, industrial accidents, terrorist attacks), gradual onset events (e.g. pandemics) and steady-state risks (notably those related to illicit trade or organised crime). Emerging Critical Risks are any risks that meet those criteria and are also 'either new risks or familiar risks that are evolving due to new or unfamiliar conditions' (quoted from EC Joint Research Centre 2024).

The overview of cross-border and emerging risks in Europe (EC Joint Research Centre 2024) describes in depth the main emerging risks in the EU in the Food security sector (in relation to food availability, sanitation, healthcare), the use of alternative fuels (in particular biofuels, hydrogen, lithium batteries and solar energy), hybrid threats, biodiversity loss, climate change and environmental degradation (that are discussed in the above sections). The section below discusses some further emerging risk aspects related to technological developments, including digital transition, armed conflict risks and disinformation.

1.7.2 Technological Developments

The risk panorama across the EU is increasingly diversifying from more 'traditional' risks linked to natural hazards to include technology-driven risks, in particular those related to cyber space. The overall picture of technology- and cyber-enabled threats is becoming more complex and interlinked with wider societal and geopolitical developments. New technologies have the potential to both intensify threats and to offer new solutions for addressing them.

Fast-paced advancement of digital technologies is transforming the European society, economy and public administration. Digital technologies are changing our daily life, way of working and doing business, travel and communication. Digital communication, social media interaction, e-commerce and digital enterprises are generating an ever-increasing amount of data, which, if pooled and used, can lead to a completely new means and levels of value creation. Digital solutions such as communications systems, AI or quantum technologies can enrich our lives in many ways. However, these benefits do not come without risks that can threaten citizens' well-being, businesses, critical infrastructure and wider security interests (European Commission 2020b).

The more digitalised and interconnected we are, the more exposed we may become to malicious cyber activity. Cybersecurity threats are continuously on the rise and becoming more diverse and sophisticated. Both non-state and state actors use cyber space and tools to pursue their interests ranging from financial gain to hacktivism or hybrid influencing. These actors exploit unpatched vulnerabilities in existing technologies and make use of the opportunities offered by emerging technologies (Europol 2019b). The increasing deployment of new technologies, such as the 'fifth generation' of telecommunication systems (5G), cloud computing, Internet of Things, Next Generation Internet and AI, is bringing along new challenges from a security point of view.

AI and quantum computing, like every technology or tool, can be used to malicious ends. AI is facilitating intelligent and automated decision-making that might open up new avenues for manipulation and attack methods. Cybersecurity experts also caution that sometime in the future, quantum computers might be able to break encryption that currently helps protect everything from e-commerce transactions to health records, rendering today's cybersecurity virtually powerless (Giles 2019).

The Internet of Things is blurring the boundaries between physical and virtual worlds, with more objects and people interconnected through communication networks. Thousands of connected devices already surround us: virtual assistants, thermostats,

wearable health and fitness monitoring devices, cars, smart TVs or refrigerators. Such devices are not only facilitating daily life, but are also increasingly applied in industry, healthcare and public services in cities ('smart cities'). In the coming years, Internet of Things and 'smart living' will be further boosted through 5G connectivity.

The 5G will enable more devices to be connected to the Internet, at the same time increasing the amount of data generated. The 5G will become the backbone of many IT applications, including in critical sectors such as energy, transport, banking and health, as well as industrial control systems that contain sensitive information and support safety systems. As many critical services will depend on 5G, ensuring the security of these networks is a strategic goal (European Commission 2019b).

Growing connectivity across societies, economies, industries and countries, physical and virtual systems create more incentives as well as points of access for malicious actors while simultaneously increasing the damage potential. Moreover, the threats stem not only from adversarial acts but also from technical accidents. In increasingly interconnected systems, any disruption – be it triggered by an intentional or unintentional act – is likely to have cascading effects.

Digital technologies are not the only ones changing the threat picture. Other developments in science, technological innovations beyond digital, together with their falling costs and easier access to knowledge are also affecting the nature of threats. For example, 3D printing can and has been used to fabricate homemade weapons in recent terrorist attacks in Europe (Dearden 2019); drones can be used to remotely attack nuclear facilities (Reuters 2018) or kill people; and biotechnology would be a dangerous instrument in the hands of terrorists, etc.

It is not only new technologies which may give rise to new threats. Ageing IT and other infrastructure, legacy systems and technologies pose specific problems. They are more prone to failure or an easier target for cyberattacks. Ageing infrastructure has already been identified as a concern in Europe in relation to the safety of nuclear power plants and prevention of industrial accidents (European Commission 2019c).

Addressing this complex threat picture is a significant challenge for all DRM actors concerned. Technological developments are fast-paced, and keeping abreast in terms of their societal implications and regulation is not an easy task. Vulnerabilities and potential targets are multiple. The threats are asymmetrical. Perpetrators need relatively little investment to exploit vulnerabilities and cause large-scale damage, while anticipating threats and designing comprehensive defence strategies is a daunting and resource-intensive exercise. Europe is a net importer of cybersecurity products and solutions and largely depends on non-European providers. The risks are borderless in terms of geography and sector. They even extend to space, as satellites can also be the targets of cyberattacks. The impacts can range from billions of euros of economic losses to the shutdown of critical services, potential destabilisation of government or the loss of life.

Against this background, the continued strengthening of cybersecurity culture and capabilities remains an important priority. In terms of protecting critical digital and non-digital infrastructure from emerging threats, unconventional attacks and other risks, the thinking has been increasingly shifting towards the resilience paradigm: i.e. ensuring that infrastructure is equipped to recover from a disruption as quickly as possible rather than aiming at the reduction of all possible risks, as this might not be

feasible or cost effective. The complexity of threats calls for closer cooperation and synergies across sectoral, institutional and national borders.

Finally, besides threats and challenges, new technologies are also offering new solutions and tools that can be applied for more effective DRM. Technologies help spread critical information more quickly, improve understanding of the causes of disasters, enhance early warning systems, assess damage in new ways and add to the knowledge base of the social behaviour and economic impact after a crisis (Minges 2019).

1.7.3 Armed Conflict Risks

Armed conflict remains one of the biggest threats of our time. Following a relative decline in violence in the early 2000s, the number and intensity of violent conflicts have increased in recent years. The ongoing war in Ethiopia, Russia's invasion of Ukraine and the Gaza war have led to a sharp rise in conflict-related fatalities, making 2022 the deadliest year since the Rwandan genocide of 1994 (Davies et al. 2023). Beyond the tragic losses of human life and the destruction of infrastructure, violent conflict can have other far-reaching effects, including economic devastation, social disruption, famines, health crises, mass migration and environmental damage (EC Joint Research Centre 2024). Additionally, large-scale violence can spread across regions, potentially destabilising nearby states or drawing them into the conflict. The best way to avoid these outcomes is to prevent emerging conflicts before they descend into large-scale violence. This requires an understanding of the root causes of conflict, as well as the capacity to detect potential conflicts at an early state. These aspects are further discussed in the EC Joint Research Centre (2024) risk overview.

1.7.4 Disinformation

The exposure of citizens to large-scale disinformation, including misleading or outright false information used for economic gain or cause public harm, is a major challenge for Europe. While disinformation is not a new phenomenon, it became much more widespread in recent years thanks to social media, where anyone can create content and disseminate it on a much greater scale than ever before (EC Joint Research Centre 2024). The uncovering of information operations aimed at influencing democratic processes has shown that disinformation poses a substantial threat to democracy by hampering citizens' abilities to make informed decisions. Moreover, developments such as Russia's military aggression (and information war) against Ukraine and advances in generative AI have highlighted the dangers of disinformation to modern society. It erodes trust in institutions and in digital and traditional media and harms our democracies; it can polarise debates, create or deepen tensions in society and undermine electoral systems, with a wide impact on European security. In addition, it impairs freedom of opinion and expression. In this context, fighting disinformation in the era of social media and online platforms has to be coordinated among all relevant actors, from institutions to social platforms, from news media to single users. Facts and figures, and recommendations, are further discussed in EC Joint Research Centre (2024) risk overview.

1.8 Progress, Challenges and Prospects

1.8.1 Understanding Risks – Increasing Local Resilience

Identifying the most vulnerable people and areas is essential for prevention/preparedness purposes. Assessments and analyses of vulnerability are improved by better and more easily accessible data. When this data is converted into understanding and made available to DRM actors, decision-makers and the general public, they too can better understand the risks, anticipate them and make informed decisions to reduce these risks and prepare for disasters and crises. Collaboration between researchers and practitioners is therefore important. People must be empowered to reduce their vulnerability to the risks they are increasingly facing and have the skills and capacities in place to be able to respond immediately. In remote locations, resilience can be lifesaving. In threatening situations, it is part of human nature to help others. Europe, together with the rest of the world, has gained first-hand knowledge of the consequences of not being adequately prepared for the COVID-19 pandemic. Preparedness must look beyond expected risks, even if the requirements to prepare for such crises in concrete terms at personal, neighbourhood, society and global levels may be demanding. This is where science can also help.

1.8.1.1 Preparing for Expected and Unexpected Crises Being fully aware that something unexpected can happen is the very core of disaster preparedness. Yet, not all crises are unexpected. For decades, researchers have been warning about the emerging climate crisis, which is increasingly leading to devastating extreme weather and natural hazards that affect individuals, societies and nations on all levels. The consequences are the worst in risk-prone countries facing multiple threats, including poverty, war and conflict.

The future climate is a great cause for concern: there will be more heavy rainfall and surface water, rain floods, landslides and mudslides in all counties. Meanwhile, all coastal countries will experience increased sea levels and higher storm surge levels, and there will be significant melting in all countries with permafrost. Working in close cooperation with municipalities on emergency preparedness through cooperation agreements is key. Local authorities must take climate change into account systematically and ensure they have contingency plans. Authorities should focus on at-risk groups such as older people who may not be able to prepare for crises or get to safety. More regular training exercises with civil society organisations, and the right kind of equipment and competence to meet the new risks, will be other decisive elements for better managing upcoming crises. Collaborating with scientific partners is also crucial. For instance, better analyses and uses of data lead to better understanding of risks and vulnerabilities. Ultimately, risks can be reduced, and preparedness measures taken where they are most needed.

1.8.1.2 Anticipating and Acting Early Early alerts and warnings are powerful in reducing disaster risks and informing anticipatory and early action. It is therefore essential to monitor weather conditions and hazards and have early warning mechanisms and institutional arrangements in place. The collaboration between first responder

organisations and meteorological services ensures that forecasts, alerts and early warnings reach isolated people and allow them to take action before an extreme weather event occurs (Red Cross 2020). Volunteers' knowledge of the local conditions and individual situations of vulnerable people and those who may become vulnerable is important in meeting their needs and speeding up emergency response. While early actions are critically important, preventive measures and raising public awareness of risks are even more so.

1.8.1.3 Preparing for Changing Risks In the last decades, changes and increases in the type, scale and intensity of disasters and emergency situations have challenged first responders. They have also reconfirmed the need to further develop and reinforce preparedness and the operational capacities and effectiveness of response. Interconnection and interoperability between first responder organisations, the authorities and other civil protection actors are crucial in this effort: from cooperating on the development of response preparedness planning processes to ongoing fast and clear communications during complex emergencies. Local preparedness capacities and skilled staff and volunteers are at the core of response effectiveness. To ensure their capacities remain relevant to the changing risk landscape, National Societies develop these in partnerships with others (Red Cross 2020). Experiences of subregional collaborations show the added value of the local networks, while at the same time being able to scale up and use the available national, regional and global resources efficiently.

1.8.2 Strategic Foresight for Better Anticipation

Disaster resilience goals identify anticipation as one of the key areas to effectively manage disaster risks, including the identification and understanding of new and emerging risks, their potential impacts and scenario-building capacities (EC Joint Research Centre 2024). This comes with the recognition that the risk landscape is increasingly complex (climate change, multi-risk assessments, cascading effects), and so anticipation is not limited to individual risks but requires a broader set of tools and approaches that capture systemic aspects, complexities and diverse stakeholder positions. This is where foresight practices come in through a systematic participatory process to create collective intelligence about the medium- to long-term potential futures and provide strategic knowledge – its fundamental premise being that the future cannot be predicted but can be actively influenced and created (Störmer et al. 2020).

The most popular way of exploring the potential futures, also in DRM, is through exploratory or uncertainty scenarios (Jafari et al. 2019). Their broad scope and way of dealing with uncertainty help perceive alternative views on changes to and dynamics of risks and test the effectiveness of potential solutions (Ridell et al. 2019, 2020). However, scenarios are only one step in the process of foresight, starting from scoping the issue, detecting trends and signals of change, through analysis of uncertainties, understanding the evolution of drivers and trends and their implications, generating strategies to react to potential future developments, and finally monitoring current developments in view of the insights that were generated (EC Joint Research Centre 2024). It is therefore not only useful to consider the use of particular tools, but attempts are increasingly made to

integrate future-oriented processes and foresight principles into the framework of risk governance (Aubrecht et al. 2013; Ridell et al. 2020).

Given that the uncertainty and volatility in the increasingly connected world pose complex challenges for decision-making, this reality should be considered when designing and employing strategies and policies in all areas (EC Joint Research Centre 2024). Adapting to a reality of fast-paced and interconnected changes means moving beyond the idea that the future is a set trajectory to instead plan and prepare for a range of possibilities. Such a practice is part of strategic foresight, which applies the methods, practices and knowledge from foresight and future studies in the context of decision-making for a particular organisation, such as a company, government or ministry. In policymaking, foresight can, for example, be used to stress-test how given policies would fare in a range of possible futures, or to explore effective a given strategy would be in the face of a range of possible disruptions (EC Joint Research Centre 2024). Strategic foresight is an organised and systematic process to engage with uncertainty to support anticipation in policy or strategy decisions. It can help to improve resilience and agility of an organisation, and it is in this way an essential tool to support risk management and preparedness.

Strategic foresight starts with a better understanding of what are the emerging and novel elements on the horizon. Horizon scanning is a structured and continuous activity whose objective is to detect at an early stage and to analyse emerging issues that are at the margins and that could potentially have significant impact on society and policy. The overarching purpose of horizon scanning is to provide timely awareness of what is new or changing to allow early discussions on the intended and unintended consequences of these developments. It has both an alert and creative function, informing about observed marginal but also enabling reflection on potential future developments (Amanatidou et al. 2012; EC Joint Research Centre 2024).

Foresight has increasingly become a part of the EU's policymaking process (European Commission 2020l). Annual strategic foresight reports contribute to raising awareness on key areas of change in the future and provide a common ground for reflecting on EU policies with a systemic and forward-looking approach (EC Joint Research Centre 2024).

1.9 Conclusions

With attention moving towards managing disaster risks rather than disasters, it is critical to partner with different actors to gather data on increased or new risks. This allows for an improved assessment of where early warnings are most needed, and the best way to reach potentially affected people and to further raise their awareness of local risks. In a well-functioning system, National Societies, e.g. National Red Cross Societies, receive support requests and alerts from authorities, warn people about the dangers and activate their preparedness for the anticipated disaster. However, the system only works if people know how to act based on early warnings. National Societies' experience shows that increasing the awareness of disaster and climate change-related risks among the population has led to better preparedness. Technology, such as 112 alerts, web apps, platforms and SMS messages, can make a life-saving difference. Multi-hazard or complex situations such as the COVID-19 pandemic also require real-time

situational awareness to help find a coordinated, appropriate response to emergencies. National Societies have established emergency operation centres for more effective analysis and data sharing and linking with the authorities' systems. Improved information management has increased operational agility and speed for emergency response, enhanced coordination and enabled National Societies to play their role in the national crisis management system. To prepare for a coordinated emergency response, disaster management actors must know each other's systems, working structures, guidelines and standard operating procedures. Joint organisation of and mutual participation in each other's trainings and exercises, and investment in inter-agency cooperation – including by inviting civil society representatives to the civil protection coordination bodies at different levels – are useful. In conclusion, all actors must improve their multi-risk assessments and analyses, increase attention to prevention, disaster risk reduction and anticipatory action and adopt more inclusive and comprehensive systems approach to managing risks.

The EU's DRM system is being strengthened with an important opportunity to invest more in prevention to reduce the vulnerability of people and societies (see Chapter 2). Severe cross-border impacts are expected on climate change-related risks, future pandemics and others. Thus, collaboration between neighbouring countries and regions including the key actors must be done at larger scale. Better linking of scientific data, such as flood forecasts, between Member States and National Societies, and with civil protection and disaster management practitioners and at-risk people, is important. All actors must improve their multi-risk assessments and analyses, increase attention to prevention, disaster risk reduction and anticipatory action and adopt more inclusive and comprehensive systems approach to managing risks to prevent and reduce human suffering and losses.