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URBAN SHIFT

Urban Shift for green innovations

EXTREME WEATHER

2023

MCRIT

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Contents

Foreword

Urban Shift (UShift) is an experimental, impact-based, and transdisciplinary education programme that focuses on creating lasting change by bringing together students from Higher Education Institutions (HEI), a Vocational Education Institution (VET), urban experts, and business partners. This is to be achieved by combining intersectional environmental education, knowledge exchange, transdisciplinary collaboration, and sustainable innovation.

By providing the learners with the necessary GREEN LABOUR MARKET SKILLS (digital, green, business and transdisciplinary/resilient skills), UShift is creating a LIVING ECOSYSTEM for 80 learners from diverse backgrounds (urban design, environmental engineering, media and business) that fosters the development of solutions to pressing urban challenges. The learners, divided into two batches, will create 10 startup teams working on urban challenges linked to urban heat islands (UHI)/cooling, and food waste/circularity, or climate/extreme weather predictability and mobility/circularity. Thus, the project allows students to successfully transform into change makers and EU GREEN DEAL AMBASSADORS by equipping them with the knowledge and experience needed to become green entrepreneurs and/or future employees of green jobs on the global market.

The culmination of this education programme are two sets of LIVING EXHIBITIONS (8 separate exhibitions) spread across Barcelona, Genoa, Copenhagen, Stuttgart, and Vienna. Their purpose is to showcase the solutions and success stories that flourished from the UShift project lifetime in order to raise public awareness for humanity's biggest challenges (i.e., pressure on planetary boundaries, resource scarcity, persistent poverty, social injustice, exponential population growth, urbanization boom, global pandemics, etc.) and interest in the UShift LIVING LABS curricula, the European Green Deal, and the United Nations (UN) Sustainable Development Goals (SDGs). This will be done through an interactive exhibition programme made up of panel and roundtable discussions, media discourse, artistic events, workshops and knowledge exchange via the exhibition of the developed courses and start-up prototypes. The goal is to inspire individual stakeholders such as NGOs, consumers, green start-ups, policy makers, and incubators to take part in the global Urban Shift as active change makers.

Even after the project's lifetime, UShift will continue to have a positive impact via the establishment of an easily adaptable LIVING CURRICULUM template and OPEN ONLINE TRAINING sessions that will be made available on YouTube to inspire future transdisciplinary collaboration. Furthermore, the establishment of an ALUMNI NETWORK serves as a tool to foster sustainable project outputs and the continuation of the start-up teams, as well as serves as a channel for peer-to-peer learning, support, knowledge and expertise exchange, collaboration, co-creation, and mentorship between the learners, start-up teams, business partners and urban expert during and after the project.

Urban Shift is a project developed by Wirtschaftsuniversitat Wien - WU (Austria), Institute for Advanced Architecture of Catalonia - IAAC (Spain), Hochschule Der Medien - HdM, (Germany), Wirtschaftskammer Österreich - WIFI (Austria), Multicriteria- MCRIT (Spain), Terra Institute - TERRA (Italy), Pretty Ugly Duckling - PUD (Denmark), Green Innovation Group A/S - GIG, (Denmark), and co-funded by the Erasmus+ Key Action 2 Partnerships For Innovation Alliances For Innovation 2021 Programme of the European Union.

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1. What is Extreme Weather?

1.1 Defining the Challenge

The climate is constantly at flux, warming and cooling over the passage of millennia, but in the past century, these changes have increased significantly, putting ecosystems, human health, and economies, at risk. In addition to a general increase in temperatures worldwide, the Earth has experienced more frequent, more intense, and longer extreme weather events. **Extreme weather events (EWEs) are natural occurrences**, seen across the globe since before anthropogenic times.

Definition
Extreme weather events (EWEs) are individual weather events that are rare at a particular place and time of year.

Table 1: Definition of extreme weather event. Source: IPCC, 2021.

Types of EWEs include temperature extremes (e.g., heat waves and cold snaps), heavy precipitation, storms, floods, and wildfires. Although wildfires are not a type of weather event, they are often included in the discussion of EWEs due to their similar relationship with climate change, their increase in frequency and intensity, and their potential destructive impact on society (IPCC, 2021). See Table 2 for further information on each EWE.

		
Heat Wave	**Heavy Precipitation**	**Wildfires**
A period of three or more days when a region experiences abnormally hot temperatures.	When the amount of rain or snow fall in a location substantially exceeds what is normal (EPA, 2021).	An unplanned fire that burns in a natural area such as a forest, grassland, or prairie (WHO, Floods).
		
Droughts	**Storms**	**Floods**
When a region experiences significantly low precipitation over a long period of time resulting in an imbalance in the water cycle.	A deep and active area of low pressure with associated strong winds and precipitation, including tropical cyclones, tornados, and hurricanes (Met Office).	Floods are the most frequent type of natural disaster and occur when an overflow of water submerges land that is usually dry (WHO, Wildfires).

Table 2: Definitions of each type of EWE.

Since climate varies regionally, the definition of an extreme weather or climate event and its threshold will differ from location to location. When discussing EWEs, words such as "severe," "rare," "high-impact," and "extreme" are often used interchangeably, causing confusion on the meaning of each term.

The severity of an event usually refers to the losses endured, including lives, financial capital, and environmental quality lost to the event. A weather event becomes rare when it has a low probability of occurring, for example, an event that happens only once every 500 years. A high-impact event, on the other hand, would be one that has a lasting impact, such as a prolonged heat wave or drought, regardless of how long the event itself is in duration.

Finally, a weather event's extremity is based on how unusual the event is in comparison to the pre-existing threshold (See Table 3) (Stephenson, 2012). In general, extremes are defined based on fixed or percentile-based values. A fixed value, for example, would monitor how many times the atmospheric temperature in a given area hit 35° C whereas a percentile-based value would measure how much more intense or frequent the occurrence is than the average for that environment on that calendar day (e.g. 90th percentile warmer than usual) (IPCC, 2021). Knowing how to evaluate EWE is helpful in gaining a better understanding of their potential impacts.

Term	Definition
Severe	Severe events are events that create large losses in measures such as number of lives, financial capital, or environmental quality (e.g., loss of species). The severity can be measured by the expected long-term loss, which is known as the risk. Risk depends on the product of the probability of the event (the hazard), the exposure to the hazards (e.g., how many people are exposed), and the vulnerability (i.e., how much damage ensues when someone is hit by the event). In other words, severity is a function of not only the meteorological hazard but also the human state of affairs. For example, the severity of United States landfall hurricanes has increased considerably in recent years, mainly owing to increased numbers of people settling in the United States Gulf states (increased exposure).
Rare	Rare events are events that have a low probability of occurrence. Because of the rarity of these events, human societies (and other ecosystems) are often not well adapted to them and so suffer large amounts of damage when they do occur. Hence, despite their rarity, the large vulnerability associated with such events can often lead to large mean losses (and hence they are a type of severe event).
High-impact	High-impact events are severe events that can be either short-lived weather systems (e.g., severe storms) or longer-duration events such as blocking episodes that can lead to prolonged heat waves and droughts. The World Meteorological Organization (WMO) program THORPEX uses the phrase "high-impact weather" rather than "severe weather" to help people avoid confusing the term severe with only short-lived events such as individual storms (D. Burridge, personal communication).
Extreme	Extreme events are events that have extreme values of certain important meteorological variables. Damage is often caused by extreme values of certain meteorological variables, such as large amounts of precipitation (e.g., floods), high wind speeds (e.g., cyclones), high temperatures (e.g., heat waves), etc. Extreme is generally defined as either taking maximum values or exceedance above pre-existing high thresholds. Such events are generally rare; for example, extreme wind speeds exceeding the 100-year return value, which have a probability of only 0.01 of occurring in any particular year.

Table 3: Definitions of "severe," "rare," "high-impact," and "extreme" weather events. Source: Stephenson, 2012.

1.2 Background

Climate monitoring has demonstrated that **since 1950, EWEs** – such as storms, droughts, heavy precipitation, wildfires, cold freezes, and heat waves – **have increased in frequency, intensity, and duration**. In July 2021, Germany, Belgium, Luxemburg, and the Netherlands experienced intense floods, resulting in the loss of around €40 billion worth of damages and the death of 200 people (Barclays, 2023). Just five months prior, Texas and northern Mexico underwent the longest documented cold freeze in their history (a total of almost nine days), resulting in a region-wide loss of power, an economic loss of an estimated €120 billion in Texas alone, and 246 fatalities (NCEI, 2021; ERSS, 2021; Click 2 Houston, 2022). Floods in China have also disrupted product production and transportation, causing a toll on world trade and economy (Barclays, 2023). With such hefty costs on society, it continues to become even more of a priority to address these changes in weather patterns and come up with solutions to mitigate their influence on the ecosystem, society, and cities.

Changes in extreme weather and climate events, such as heat waves and droughts, are the primary way that most people experience climate change. Human-induced climate change has already increased the number and strength of some of these extreme events. Over the last 50 years, much of Europe has seen increases in prolonged periods of excessively high temperatures, heavy downpours, and in some regions, floods and droughts. These incidences are natural, but the recent increase in frequency, duration, strength, and number of regions effected by them is primarily a **result of human influence** and **threatens our economy, infrastructure, agriculture, health, and security.**

Figure 1: Thirty-two climate indices for the sixteen climate extreme weather typologies, grouped into six hazard types, as identified by the Intergovernmental Panel on Climate Change (IPCC) in its Sixth Assessment. Source: European Environment Agency, 2023.

1.3 How are extreme weather and climate change related?

> *"A better understanding of the underlying causes of extreme weather events gives society a powerful tool for anticipating risks and making informed choices. Sadly, a tragic experience with an extreme weather event may be a citizen's most personal encounter with the consequences of climate change, and what ultimately spurs collective action" (Marcia McNutt, President of the National Academy of Sciences).*

The increase in EWEs worldwide is largely influenced by the same increase in global temperatures, which are a direct result of anthropogenic emissions. For the past 800,000 years, carbon dioxide concentration in the atmosphere has always remained between 180ppm and 280ppm, but in the last century alone carbon concentration has increased by another 100ppm, currently at 420ppm (NOAA, 2023). This change has resulted in an increase in sea level rise, temperature, weather extremes, biodiversity loss, etc. The Keeling Curve, seen in Figure 2, demonstrates this rise in carbon dioxide. When juxtaposed with the trends in extreme weather over the same time period, the correlation between the two developments becomes evident: climate change is influencing the rise in EWEs.

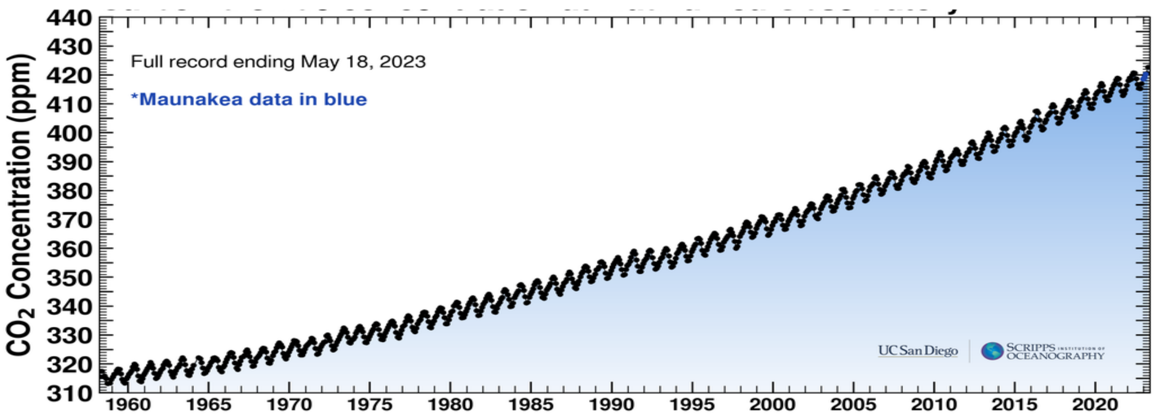


Figure 2: Carbon dioxide concentration at Mauna Lao Observatory. 1960-2020. Source: USCD, 2023.

As the climate warms and carbon emissions increase, natural fluxes in weather become even more intensified. Natural climate cycles – like El Niño Southern Oscillation, which is a two-to-seven-year cycle of normal to extreme cold or heat patterns in the eastern tropical Pacific Ocean – are magnified by Earth´s evermore sensitive climate (National Geographic Society, 2022). A study done by the Carbon Brief, an organization based in the United Kingdoms that publishes data, analyses, and summaries on climate and energy policy and science, showed that **of 152 heat events analysed, 93% were more severe due to influences from climate change** (Carbon Brief, 2022). Another study, run by The Proceedings of the National Academy of Sciences (PNAS), found similar trends, concluding that global warming has increased the intensity and probability of the hottest daily and monthly events in over 80% of the territory studied and around 50% when considering the driest and wettest events (PNAS, 2017). Climate change has also been shown to make storms, floods, and other EWEs more frequent and intense.

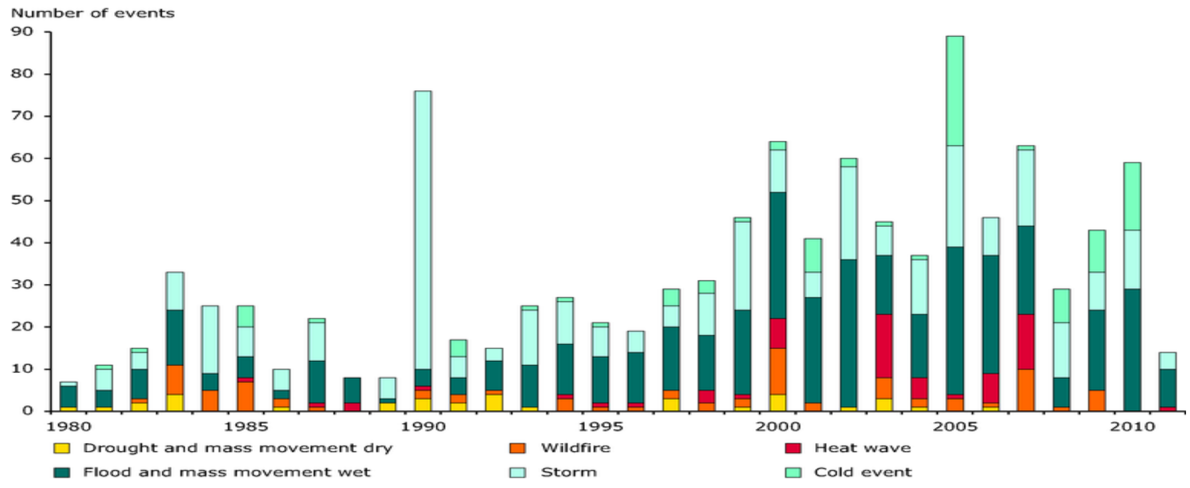


Figure 3: Number of reported extreme weather events and wildfire. 1980-2012. Source: EEA, 2016.

These influences extend beyond heightening weather abnormities and include increasing the impact of those occurrences on matters such as public health and safety. In 2003, a heat wave that plagued much of Europe caused the death of 735 people in Paris and another 315 fatalities in London. Just over 50% of these deaths are attributed to the intensification of the heat wave by climate change (Carbon Brief, 2016). A study done in 2021 "found that 37 percent of heat-related deaths [between 1991 and 2018] can be directly attributed to anthropogenic (or human-induced) climate change and that increased mortality is evident on every continent" (Emory News Center, 2021). Climate change can also intensify food crises resulting from floods and droughts. With the rise in sea level, also attributed to climate change, water contamination due to infiltration of salty or polluted water is more likely. In these ways, climate change can increase the intensity of EWEs, causing more damage and risk to society and the natural environment.

It is crucial to note, however, that **while climate change does influence EWEs, it is not the sole cause of their occurrence.** Their increase in frequency and severity are a result of a combination of many factors, climate change being one of them[1].

1.4 An urban focus on extreme weather and climate change adaptation in Europe

Climate change´s impact on extreme weather is of particular importance in the urban environment where weather is already under higher strain due to the denser population and insulating effects of the urban environment, also known as urban heat islands. Cities have an indirect responsibility for the observed global warming as the major contributor of green-house gases. More than half of the world's population currently lives in cities, releasing more than 70% of the total emissions of carbon dioxide (CO2) of anthropogenic origin and a substantial proportion of other known greenhouse gases. In urbanized areas, these emissions have three main causes: transport, energy use in households and public buildings, and manufacturing and industry, with each sector contributing about one-third of the total. Such contribution to climate change intensifies the potential impact of EWE worldwide, including those that will be felt by cities (Independent, 2020).

Cities are at particular risk due to their high-density population, architectural design, and heightened level of air pollution. These characteristics can result in amplified EWEs in the form of hotter temperatures, stronger winds, larger hail, etc (Independent, 2020). Data from the Carbon Disclosure Project (CDP) demonstrates the elevated vulnerability of cities globally from EWEs (see Figure 4). Flash/surface flooding, heat waves, rainstorms, and droughts are said to be the most common EWEs

[1] See Section "2. Causes" for more information.

in cities. With 50% of the world population living in cities, these trends are worrying and elicit the need for change regarding how cities address and contribute to the production of EWEs (CDP, 2023).

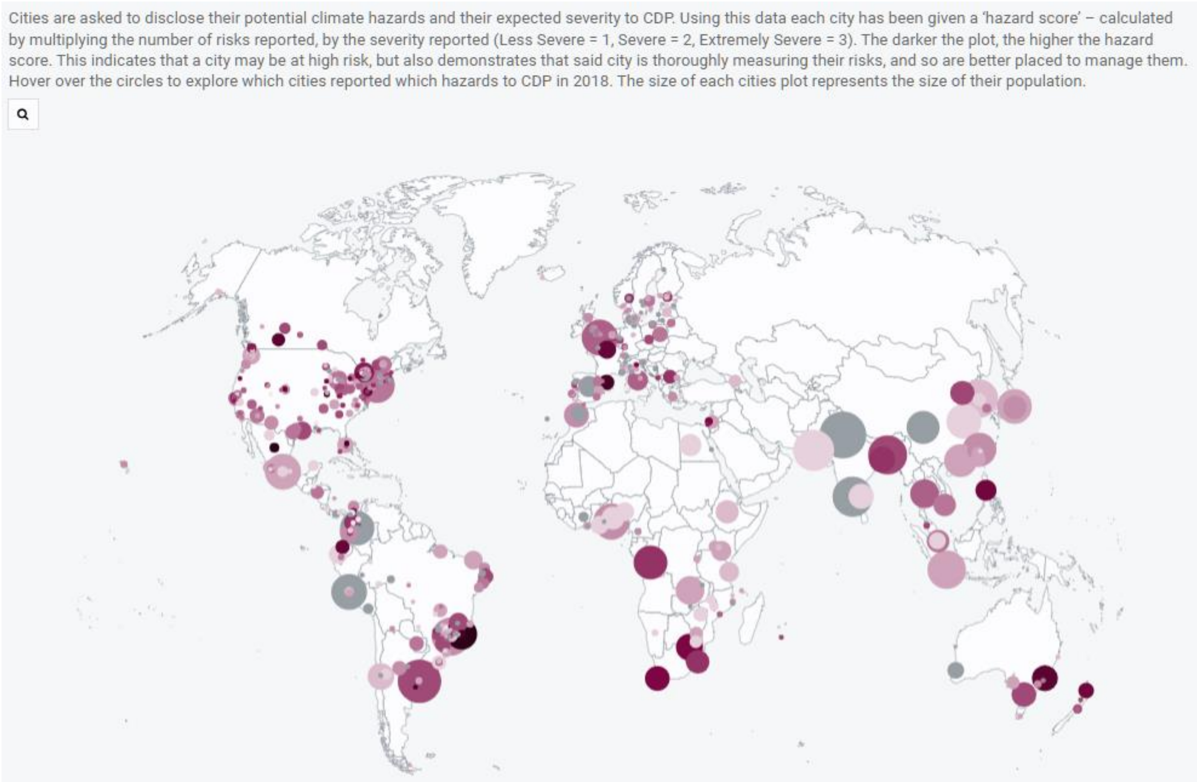


Figure 4: No city is safe, cities in all corners of the world are facing climate risks. Source: CDP, 2023.

Having faced hardships after EWE, many cities are starting to adapt to the challenge. In La Faute-sur-Mer in western France, residents must now build elevated refuge floors to mitigate fatalities from floods. This requirement was put in place after a flood in 2010 caused the deaths of 29 residents and the destruction of 600 houses (Euro News 2023). In Rotterdam, Netherlands a different approach has been adopted to counter floods. In this city, one neighbourhood upgraded their sewage and rainwater collection systems to help drain flood water, while another residential complex involved residents in the decision-making process, resolving to replace many of the impermeable materials in their courtyard, like stones, with flowers and compost bins. The investment in rain gardens and green infrastructure will lower risk of damage during floods and increase air quality (European Commission, 2022a).

At the same time that cities, their inhabitants, and infrastructure are exposed to the effects of climate change, they are also important agents in mitigating global climate change. Many of the proposed mitigation and adaptation methods to increase the environmental sustainability of cities and make them more resilient to climate change are related to the urban thermal environment.

KEY IDEAS

- EWEs are natural occurrences, but due to climate change and human actions, now effect more regions, last longer, are more intense, and occur more often.
- Cities account for 70% of total emissions worldwide, playing a large role in the proliferation of climate change and the intensification of EWE, but are also crucial agents in mitigating and adapting cities to these new realities.

2. Causes

EWEs are natural and have occurred for millennia. Since the industrial revolution, however, humans have played a role in influencing their occurrence and behaviour. **Today, EWEs are triggered by a combination of contributing factors, both natural and anthropogenic.** Natural causes include weather patterns and circumstances that have always been at play, whereas anthropogenic causes have only had an impact in the past few hundred years. It is the natural weather patterns that explain why typhoon and hurricane season occur every year at a certain time in a specific region and the anthropogenic causes that bring about the inconsistencies in their occurrences. While all EWEs have the potential to harm human society, the increase in their occurrences and intensity, which make them more dangerous and costly, is largely attributed to human influence. By recognizing the impact that humans have on EWEs, it becomes easier to identify where changes can be implemented to mitigate these influences on a local, national, and international level.

2.1 Natural causes

Currents, Wind Patterns, and Pressure Systems

Storms are naturally more likely to occur in regions where a cold front meets a hotter environment, when a high-pressure system meets and low-pressure system, and in other areas where conflicting environmental circumstances meet. These regions are found across the globe and have been present, though changing, since prehistoric times.

A storm generally develops when a high-pressure system meets a low-pressure system, producing extreme waves and winds at the ocean surface increase. These winds and waves become cyclones and hurricanes. Since the winds follow warmer currents, the storm is brought to the shore, as suggested by the Thermohaline Circulation (See Figure 5). In the tropics, where the wind blows from East to West, hurricanes are drawn to the hotter currents north of the equator. These wind patterns blow the storms directly through the Caribbean, to Florida, and up through the US. Every year, these hurricanes are predicted to hit in this region because of the consistent flow of warm water and the movement of storm wind above it. By tracking wind and ocean patterns, scientists can better understand the natural forces driving storms (Earth Reminder, 2021).

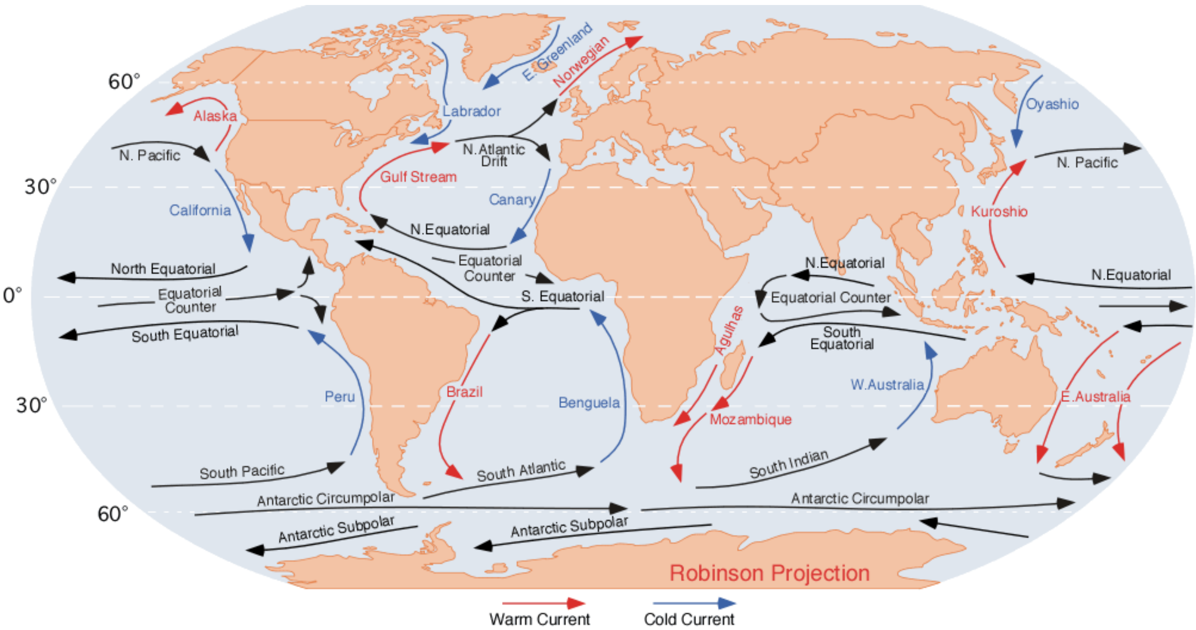


Figure 5: Depiction of Ocean Conveyor Belt, detailing the flow and temperature of ocean currents. Source: Ocean Motion.

The Four Seasons

Each season comes with its own set of meteorological challenges: the summer brings the heat; fall, the storms; spring, the rain; and winter, the cold. The impacts of these trends vary depending on the region.

Heat waves are most common during the summer months when high pressure at the ground´s surface causes the air to sink. The more it sinks, the more compressed it become, raising the pressure of the atmosphere and, in turn, the temperature. The temperature is said to increase by 1°C for every 100 meters of compression. During the summer, weather cycles slow down. With less cloud movement and wind circulation, the atmosphere can become humid. These factors create the ideal conditions for a heat wave to set and last for an extended period of time (Geographical, 2022). In the Atlantic, the warmer temperatures are also prone to inciting hurricanes from June into the fall since they depend on the presence of warm ocean water and wind. Monsoons in Asia also occur throughout the summer and fall because of the change in wind flow from cool to warm from the ocean into the shore (NOAA, 2023).

As the temperature drops and winter approaches, cold snaps and heavy precipitation in the form of hail or snow are more likely to occur. Storms and floods, however, are less likely due to the lack of warm currents and strong winds to drive them ashore. In some regions, spring weather is known for being unpredictable (Centers for Disease Control and Prevention, 2023). It is often associated with frequent storms, heavy rains, tornados, and floods. Because spring is a time of transition between the cold weather of the winter to the warmer weather of the summer, the weather becomes more volatile. These contrasting temperatures, as described above, often lead to EWEs.

Topography

Changes in altitude, proximity to the coasts, presence of lakes, and other geographical features can impact the type of EWEs experienced in a region. A city near the ocean, located by the equator, for example, is unlikely to experience snowstorms simply because it is the wrong environment to produce the conditions necessary for that type of event. That same city could, however, be prone to floods or heat waves because of the hotter temperatures and other environmental conditions (Earth Reminder, 2021).

Variations in Climate Patterns

Volcanic eruptions can cause oddities in climate patterns, which can in turn impact the development of EWEs. Eruptions often release large amounts of sulphur, such that the average temperature of the affected area may temporarily cool because the sulphur particles reflect the incoming rays of sun. This change in temperature can alter rainfall and atmospheric circulation patterns, leading to drought, cooler temperatures, or heavy precipitation. In the long term, however, eruptions will often contribute to global warming due to the release of many greenhouse gases into the environment (University Corporation for Atmospheric Research, 2023).

Volcanos can influence weather in other ways as well. In January of 2022, Hunga Tonga–Hunga Haʻapai volcano erupted on the island of Tonga, near Fiji, resulting in a sudden change in air pressure due to the release of at least 55 million tons of water vapour into the atmosphere. Since this event occurred under water and, due to the sudden change in air pressure, it caused a chain of tsunamis to badger the shores. This outcome is quite rare, as most eruptions do not usual emit such a large amount of water vapour (New York Times, 2022). In these ways, natural hazards that disturb climate patterns may incite EWEs.

Some variations in climate patterns are patterns themselves, meaning their occurrence is expected and they interrupt normal weather trends. The El Niño Southern Oscillation is one such example. It occurs every two to seven years, flipping the ocean currents and wind directions of the North Atlantic region and causing reversed weather conditions in the impacted regions. During its occurrence, EWEs (including changes in rainfall, temperature, and storm formation) are more likely to transpire because the weather is so drastically different than what is usually experienced in the impacted regions (National Geographic Society, 2022).

2.2 Anthropogenic causes

Climate Change

As outlined above, climate change is an ongoing natural phenomenon that has been exacerbated by human actions and is drastically changing our environment. **Climate change has been shown to have a particularly strong impact on temperature and moisture related EWEs.** The higher levels of moisture in the atmosphere in some regions, which is a result of increased global temperatures, augments the probability of heavy precipitation events and heat waves (National Academies of Sciences, Engineering, and Medicine, 2016). Hotter temperatures have also led to more extreme wildfires and a 19% increase in wildfire season length (WFF, 2020). Global warming has also led to an expansion of deserts, which causes more droughts and changes weather circulation patterns, leading to more precipitation in regions north of the equator. Furthermore, when atmospheric moisture levels are limited, another possible impact of climate change, evapotranspiration is reduced and vegetation in the region dries, increasing the likelihood of wildfires, and drought. Climate change continues to increase the intensity and frequency of all EWEs and is similarly amplified by the other anthropogenic causes of EWEs (National Academies of Sciences, Engineering, and Medicine, 2016).

Land Use

Human land use, including agricultural development, deforestation, river channelling, and urbanization, further increase the likelihood of extreme weather occurrences. Modern industrialized agriculture is often categorized by monocultures, overtilling, inefficient water storage or watering methods leading to water loss to evaporation, and other unsustainable actions. These practices can result in the dehydration of the soil and the surrounding environment, increasing the likelihood of droughts and wildfires. The infamous Dust Bowl from 1930 to 1940 is a quintessential example of agriculture´s influence on drought occurrences. In this example, the overuse of farming lands in the United States led an accumulation of dust in the surrounding regions and a lack of water, causing drought and air pollution (NDMC, 2023). Now, similar effects transpire following deforestation efforts. In Brazil, this occurrence is of particular concern because the Amazon, one of the most biodiverse ecosystems in the world, is disappearing. Deforestation, which leads to a decrease in evapotranspiration and nutrient cycling, is causing the area to dry out and heat up. By destroying the natural environment, be it through deforestation or overcultivation, humans contribute to the depletion of resources and creation of EWEs.

Urbanization is another form of human land use that has influenced EWEs. With the presence of so many impermeable surfaces, such as cement, in cities, the soil beneath city streets is unable to absorb as much water, increasing flood risks. In Europe, flood volume has increased significantly over the past 30 years for this exact reason (Figure 6). Not only are floods more likely to occur, but they are often more severe due to their higher flow rates, made possible as a result of the perfect flow channels made up of modern city streets and avenues (USGS, 2003).

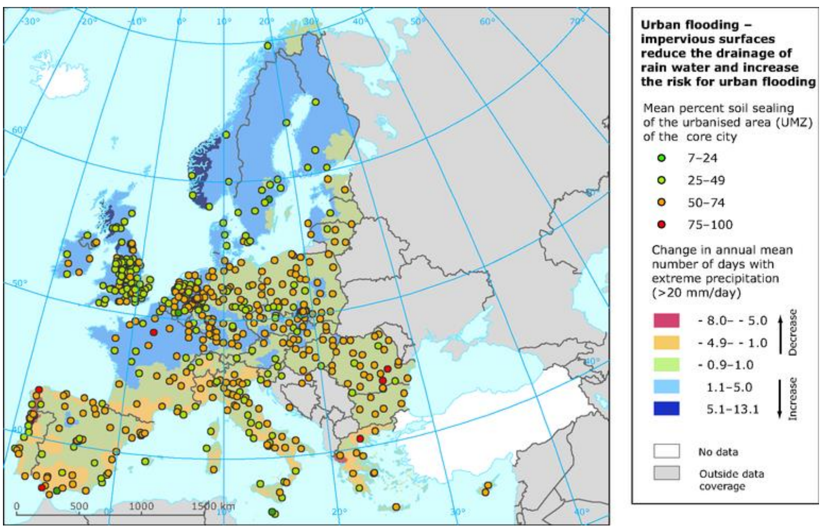


Figure 6: Increase in impervious surfaces and precipitation leads to higher chance of flooding. Source: EEA, 2012.

Another example of human influence on EWEs is the **urban heat island**, an occurrence in the urban environment “when a densely populated urban area experiences significantly higher temperatures than the surrounding rural or less populated area.” With the replacement of grass, forests, and other natural ecosystems with buildings and sidewalks, cities have increased their albedo, reflecting more of the sun´s rays and creating an even hotter environment. More than half of the world’s population currently lives in cities, releasing more than 70% of the total anthropogenic carbon dioxide (CO_2) emissions and a substantial proportion of other known greenhouse gases (Ersilia, 2023). The combination of an already warming globe and the intensified heat experienced in cities has created a volatile environment in which EWEs have a higher probability of occurring. In this way, cities are made particularly vulnerable to EWEs.

Land Management

Due to historical wildfire suppression practices, forests contain significantly more fuel from lack of natural fire occurrences. Between the surplus of dry wood and the other contributing factors such as higher temperatures, drier atmosphere, and water deficiencies, wildfires are bound to ignite. Having been supressed for so long, they are now more intense and severe, posing greater risk to the environment and poorly placed societies nearby. Now, some communities practice controlled burning where they purposely burn a region of the forest to help regenerate the area. This action enables the burning of a region without sacrificing the safety of the surrounding society (National Geographic, 2022).

City Placement

Poor urban planning that places cities in harm’s way of natural hazards, especially near wildfire prone areas or by the coast, is another issue that increases the severity of EWEs. Many coastal cities suffer from the intense impacts of storm surges and other sea-related EWEs due to the lack of natural barriers to act as a buffer between storms and city infrastructure. Consequently, storm damages are much more costly for coastal cities than those located inland, and local governments are required to invest not only in rehabilitation after each disaster, but must also construct manmade seawalls, damns, and other barriers. Of course, these challenges are made worse with the experienced climate-mediated rise in sea level.

Neighbourhoods situated near forests are also at higher risk. If a wildfire occurs, their proximity to the disaster can make it harder for them to avoid the potential impacts, making them more likely to suffer from the lower air quality, dangers of burn, and infrastructure damages.

Human Negligence

A study done by the World Wide Fund for Nature (WWF) and the Boston Consulting Group found that 75% of wildfires are human caused. In Europe, that means human negligence (e.g. burning rubbish and debris, industrial accidents, agricultural overspill etc), which causes 95% of wildfires in the region. In the US, negligence accounts for 84% and in Canada, only 40% of wildfires are caused by humans (WFF, 2020). Other causes include arson and lightning strikes. Studies have shown that lightning strikes are 40% more common and continue to increase in frequency due to an increase in global temperature and dry storms (i.e. when high surface temperatures cause rain to evaporate before hitting the surface). These conditions increase the likelihood of lightning to cause a fire due to the creation of a drier and more flammable surface environment (IAA-CSIC, 2023). Between 2019 and 2020, global wildfire counts increased by 13%. It is crucial that actions are taken to prevent wildfires, especially in Europe where just a little more care and awareness could reduce fire occurrences by 95% (WFF, 2020).

KEY IDEAS

- EWEs have both natural and anthropogenic causes.
- These factors work in harmony to create the conditions under which an EWE is more likely to occur. There is not one individual cause for each individual event.
- The intensification of EWEs in frequency and severity, though a result of both natural and anthropogenic causes, are primarily attributed to human influence.

3. Effects: Why does this matter to us?

EWEs impact human health, biodiversity, energy use, the economy, and culture. In regions commonly exposed to disaster, people often experience food and water insecurity and increased poverty, while the ecosystem suffers from biodiversity loss. Certain communities are at greater risk of impact than others. Indigenous people, small-scale food producers, children, pregnant woman, older adults, ethnic minorities people with outdoor jobs, low-income households, and persons with disabilities or with pre-existing health conditions may be disproportionately impacted (IPCC, 2023; EEA, 2022). Coastal regions are at even higher risk due to higher exposure to storms and floods, the two most commonly occurring EWEs.

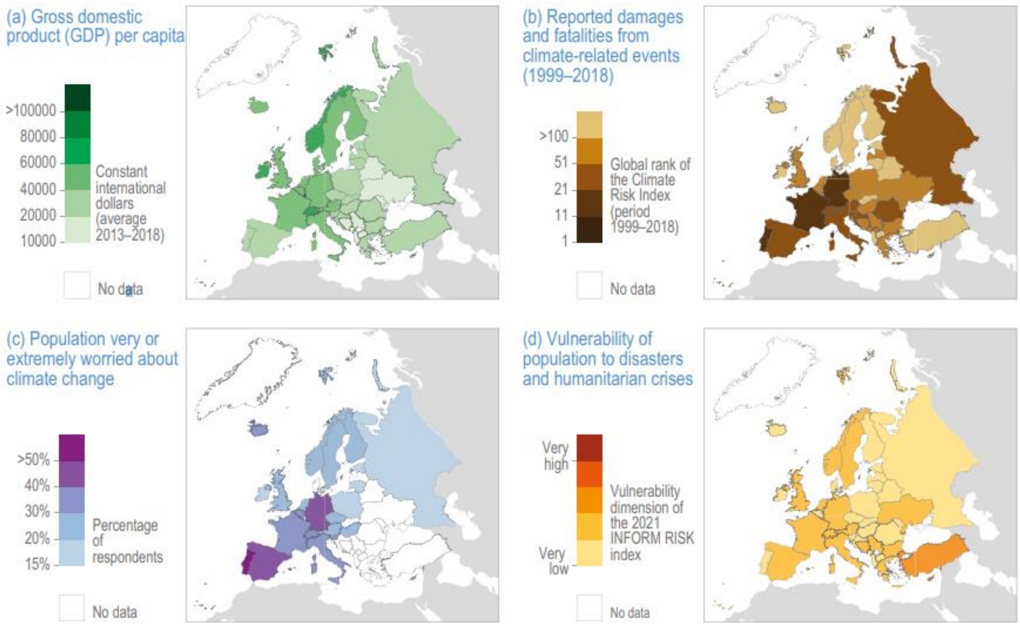


Figure 7: Damages to people and assets, vulnerability and adaptive capacity across Europe. Source: IPCC, 2021.

3.1 Human Health

Millions of people are impacted by the adverse effects of EWEs. EWEs can often lead to increase in disease and chronic illnesses due to reduced air quality, water quality, and sanitation. They can also cause injury, death, and mental health challenges.

Extreme heat events have caused an overwhelming majority of total fatalities out of all the EWEs. Often, these deaths are a result of heat stress, the phenomenon when the body can no longer control its internal temperature (HSE, 2023). The 2003 heat wave alone caused 45% of Europe's disaster related fatalities from 1970 to 1919 (World Meteorological Organization, 2021). Due to the increase in humidity, breathing can be made more difficult. People already at risk due to pre-existing conditions such as asthma, may suffer worse symptoms during times of extreme heat (IFRC, 2022).

Droughts, made more common by the rise in heat waves and global temperatures, have also been shown to lead to adverse health impacts. With reduced water availability, communities often suffer from decreases in agricultural production and dehydration, resulting in cases of food and water insecurity. This combination of malnutrition and dehydration can lead to more complex health problems or death. Droughts are often accompanied by wildfires or dust storms. Both phenomena lower the air quality. The increase in dust, smoke, and ash in the air can irritate the lungs, resulting in respiratory infections or chronic illness, such as asthma (CDC, 2022). From May to June 2023, smoke from fires in Canada made their way down to the United States, impacting people as far as New York City, Michigan, and Washington D.C. These far-reaching impacts demonstrate how everyone is impacted by EWEs and that these are issues that should be addressed on a global scale.

Extreme storms also have wide ranging impacts on human health. Economic and infrastructure damages due to storm surges, blown debris, and structural collapses can result in the destruction or closure of hospitals, farms, homes, sewage systems, electric poles, etc. These losses can mean a lack of healthcare, electricity, water, food, and housing for the communities impacted. During such a time of crisis, sanitation systems might be put on hold, increasing the spread of infections and diseases. At time of impact, people might suffer injuries or death due to floods and blunt-force trauma (DASH, 2022). After the storm, risk of carbon monoxide poisoning increases from misuse of generators or other gasoline and diesel-powered tools (PMC, 2013).

Flooding can result in similar health impacts as storms, including drowning, heart attacks, injuries, infections, and exposure to chemical hazards. Flooded communities often experience the same **disruption of services**, including health services, safe water, sanitation, and transportation ways, as those hit by storms (EEA, 2016). An estimated 10% of education systems and 11% of hospitals in Europe are located in potential flood-prone areas, making the risk of damage to such important locations all the more likely. Similarly, many low-income communities often live in more vulnerable areas due to the cheaper cost of land, resulting in a disproportionate impact of flood disaster on impoverished communities and ethnic minorities (EEA, 2023). In many regions, floods can result in the contamination of water ways, either by pollutants or salt water, making freshwater reservoirs unsafe to drink or use as bathwater. The World Health Organization estimates that from 2000 to 2014, more than 2,000 people were killed by floods and 8.7 million were affected (EEA, 2016).

The European population is becoming ever more vulnerable to climate change due to the average rise in age, as well as a move to urbanization and an increase in disease prevalence. In the north, vulnerability is propelled by high levels of urbanization and increased chronic respiratory illnesses; in the south, a rise in diabetes and kidney diseases is the biggest contributor; and, in central and eastern Europe, it is cardiovascular diseases. Such changes are making society ever more vulnerable to EWE.

In addition to the physical dangers that may result from EWEs, due to the stress, mental strain, and potential trauma experienced during and after such events, many people also suffer from depression or other mental illnesses. These stresses can be amplified in cases where communities are not only harmed by EWEs, but individuals are also forced to flee their homes, becoming refugees in other countries. Such migrations can also lead to additional economic burdens on the area being fled from and the regions hosting the refugees. Children are especially prone to experiencing mental health impacts because of climate change due to exposure to trauma during floods and other episodes. Climate anxiety is ever more prevalent, causing trepidation for the future (IPCC, 2023). Due to the commonly experienced lack of resources after an EWE, it is often difficult to address each health impact, and it is likely that mental illnesses are some of those that are most often neglected.

3.2 Biodiversity

Ecosystems suffer from many of the same impacts as society. Damages from storms and floods can result in the displacement of animals, the destruction or loss of habitats, disrupt migration patterns, increased disease, and a decrease in overall species fitness.

Many EWEs destroy the habitat and disrupt the lives of native organisms of the region impacted. Storms, for example, may disrupt migration, mating, and flight patterns of birds. In cases of strong winds, birds may be blown inland, of course of their original flight plan. Floods can also cause the inundation of breeding grounds, harming the reproductive capacity of organisms reliant on the area. Major flooding can also result in the destruction of forest, causing downed trees, stripped leaves, or broken branches. Such destruction does not only harm the trees, but the other species dependent living within and among them. Floods and storms can also increase the likelihood of wildfire, insect infestations, and establishment of invasive species. Heavy rains and fast flowing water can cause erosion of shorelines, further harming the ecosystem (The National Wildlife Federation, 2023). Species that are already at risk of extinction are even more vulnerable to the impacts of storms and floods. If their already limited habitat is destroyed, they may have no home to return to, lowering their chance of survival.

Just as droughts can reduce food and water supply for humans, they can do the same for animals and plants. **With the increase in sea level rise and the rising risk of water contamination, organisms may have a harder time obtaining the resources needed for their growth**. An increase in wildfires can also result in the deterioration of forests. Already vulnerable due to the drier atmosphere and harmed by previous fires, trees are unable to defend themselves as well from infesting insects. Bark beetles and other similar critters can take advantage of the forest's weakness and eat away at the trees until there is little to nothing left (The National Wildlife Federation, 2023).

Marine heat waves can also have detrimental effects on marine biodiversity, causing the mortality of many marine species. They can lead to the regional mass extinction of kelp forests and seagrass, and the death of many marine invertebrates. They can even cause changes in species behaviour and like in the case of other EWEs, can help invasive species enter the impacted area (IUCN, 2022). Heat waves have also been shown to contribute to ocean acidification, a phenomenon that results in the increased carbonization of water and can lead to the expansion of inhospitable habitats within the ocean environment. Ocean acidification is also linked to coral reef bleaching, which means the loss of one of the most biodiverse types of habitats in the ocean (European Commission, 2023).

In urban environments, stormwater runoff can heat up the temperature of water in streams, rivers, ponds, and lakes due to its contact with hot surfaces within the city such as pavement and rooftops. When the runoff drains into sewers and is released into other bodies of water, it can raise the temperature of the water by over 4°C. **Such sudden temperature changes can cause stress on aquatic life, impacting their metabolism and reproduction. In some cases, such changes can even be fatal** (EPA, 2022).

The following figure depicts the percentage of suitable habitats that will remain in Europe under different levels of global warming. In all circumstances, insects are the most at risk, and being at the bottom of the food chain, their reduction in population size could cause a rippling effect of mortality to organisms higher up in the food chain (IPCC, 2021).

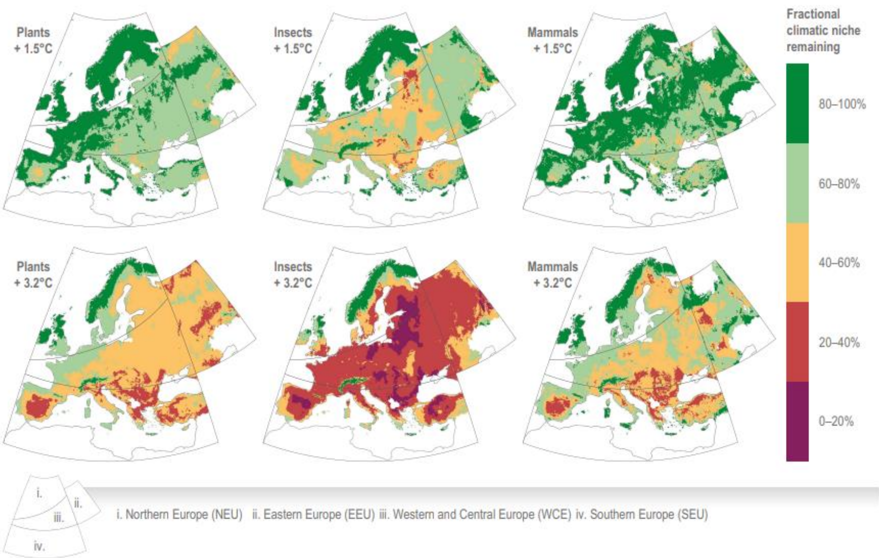


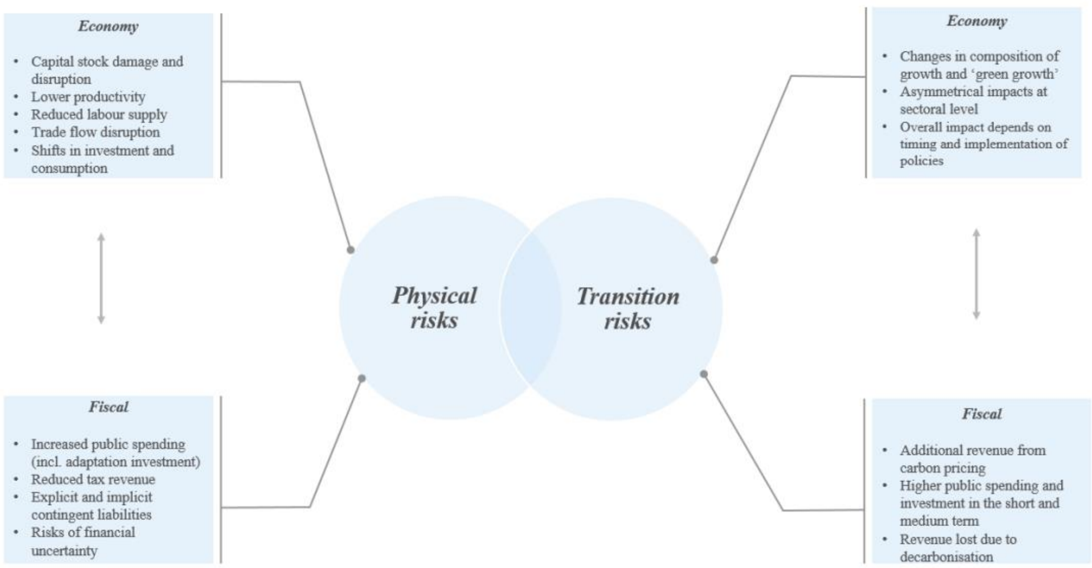
Figure 8: Species projected to remain in suitable climate conditions in Europe. Source: IPCC, 2021.

3.3 Energy Use

During times of extreme heat, the demand for air conditioning rises. One study shows that in several countries, the demand for electricity will increase by 1-9% for every 1.1°C increase in temperature. In the same vein, peak energy demand (when offices and homes are using the most energy to run air-conditioning systems, lights, and other appliances) could also rise to the point of overloading the system, requiring the implementation of controlled brownouts or blackouts to avoid power outages (EPA, 2022). Such high levels of energy use produce significant greenhouse gas emissions, amplifying the greenhouse gas effect and causing a greater demand for energy in the future. Due to the high price of electricity, low-income households are often unable to cool their homes to the same extent as wealthier families, causing them to live under uncomfortable conditions (EEA, 2022a).

3.4 Economic losses

Every EWE result in the loss of economy due to infrastructure damages, the cost of emergency aid services, and the drop in labour productivity. In many developed countries, these losses are insured, reducing the toll it has on the countries GDP and debt, but for developing countries, these disasters can be devastating for their economy. Like all other effects of EWEs, the **economic strains disproportionately impact already impoverished nations, communities, and individuals.**



Note: The list of vulnerabilities is non-exhaustive and only meant as an illustration. For instance, physical risks (in the form of a gradual transformation of the environment) could also have positive supply side effects in some regions, which are not presented here. Transition risks, related to mitigation policy efforts, refer to the the economic and fiscal consequences stemming from the transition to a low-carbon economy.

Figure 9: Economic and fiscal challenges from climate change. Source: European Commission; Batten (2018).

From 1980 to 2020, all members of the European Economic Area (EEA) experienced around €500 billion worth of total economic losses from EWEs. Germany, France, and Italy paid most of the total cost, while Switzerland, Slovenia, and France account for the highest losses per capita. Around 23% of total losses were insured, though this percentage varies per country, from 1% in Romania and Lithuania to 56% in Denmark. Economic losses are projected to increase by 200-300% by 2050 (EEA, 2022b).

Not only does each country's government pay the cost of economic damages from extreme weather, but so do the citizens. **Cost of living may increase as housing supply decreases and food and water become more expensive.** Worker displacement and damage to businesses may cause sudden closures and result in mass unemployment. These outcomes make the push towards green energy and a low-carbon economy more appealing, as such actions would provide built-in mitigation strategies to reduce economic damages after EWEs and create new jobs, lowering rates of unemployment (ILO, 2023).

Certain industries, such as tourism and agriculture, are particularly vulnerable to the impacts of EWEs. In Southern Europe, for example, tourism is expected to decline in the hotter summer months due to a predicted rise in heat waves. The losses economically from this decline may be compensated for a rise in tourism during other times of the year but estimates for these possibilities have yet to be made. With the shift in temperatures and an increase in drought during the summer months, generally the most agriculturally productive time of the year, a decrease in agricultural production seems likely. To adjust to these changes, farmers may have to shift their growing seasons and cultivate produce more acclimated to the given conditions (European Commission, 2022).

In addition to the more obvious economic damages from infrastructure destruction and hospital bills, **EWEs can also decrease work productivity, reducing the potential economic gain during work hours following and during such events.** This effect is of particular concern during times of extreme heat and humidity, when the human body must exert more energy to maintain internal body temperature. As thermal comfort decreases, completing physical and cognitive tasks can become more draining, resulting in a decline in productivity. Such declines often start at temperature above 25°C, so these same effects can also be felt during warm summer days (JRC Science for Policy Report, 2018). The trends for this impact on labour productivity in Europe can be seen in Figure 10.

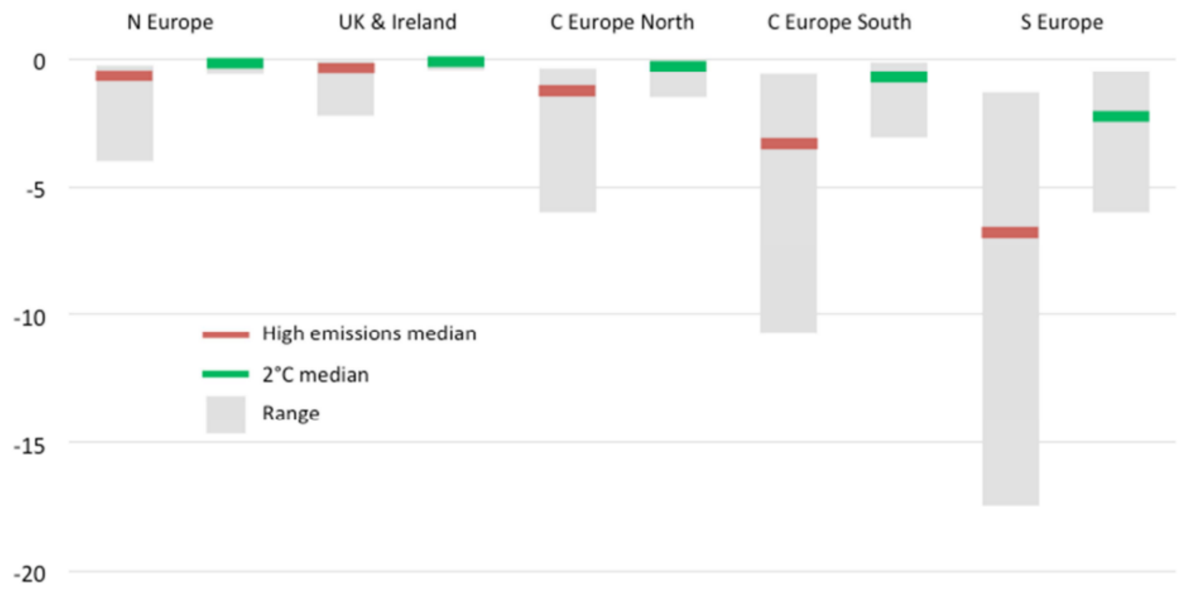


Figure 10: Regional differences from present (%) in daily average outdoor labour productivity due to climate change under a high warming scenario and a 2°C scenario respectively. Source: Climate impacts in Europe, JRC Science for Policy Report, 2018.

3.5 Cultural and Heritage Losses

Definition
Cultural and heritage losses refer to the loss of traditions, areas of cultural significance, or artifacts due to EWEs.

Table 4: Definition of cultural and heritage losses.

Loss of biodiversity or land may reduce a community's ability to practice their customs. For many coastal communities whose livelihoods depend on fishing or the environment in which they live, the destruction caused by EWEs may prevent them from continuing their cultural traditions. In regions where fish markets are suffering due to overfishing by commercial fishing boats, local communities have had to find other jobs, often turning to illegal incomes, or taking jobs that involve deforestation or the further destruction of their habitats. These practices often contradict the values of the indigenous people. Regardless, under the extreme circumstances, they must put their culture aside to ensure their survival (The Carbon Brief, 2023).

Some communities have roots in the land in which they find themselves. In this case, **the destruction of habitats by storms or floods may mean the loss of a sacred space, cemetery, or other area of cultural importance.** Such losses can be devastating to a community and cannot be replaced as easily as infrastructural damages that can be paid for (The Carbon Brief, 2023).

Additionally, **heritage can be lost in the form of destroyed historical artifacts**. Venice is a quintessential example of a city frequently hit with floods that is at risk of being submerged by rising sea levels and losing all its art. While some artifacts may be easily removed, the buildings and architecture are not. Though arguably not fundamental to society's survival, Venice's artifacts are an important collection of Europe's history and if lost, would devastate art historians as well as those connected to Venice's culture (The Carbon Brief, 2023).

Methods for measuring cultural losses have yet to be established. Such monitoring is made quite difficult, as something as small as a single tree holding sacred significance to a few people in a small community may not be reported despite its deep meaning to the related people. So far, the United Nations has neglected to consider such damages as valid, preferring to focus on the monetary losses experienced by EWEs; however cultural damages are still significant and should be taken into account when considering the potential impacts of EWEs (The Carbon Brief, 2023).

KEY IDEAS

- Extreme weather can harm the environment, subsequently lowering the mental and physical health of the organisms within it, including humans.
- With the destruction of infrastructure and the costs of rehabilitation, EWEs can take a toll on a country´s economy and in turn, raise the living expenses for individuals.
- Cultural and heritage history can be lost during EWEs, resulting in potential additional mental health burdens and sentimental suffering.

4. The Challenge in Europe

Europe is composed of forty-five countries and four main regions (see Figure 11), each of which contains a variety of different ecosystems (Shengen Visa, 2021). These varying environments coupled with the differing cultures, economies, and political structures in each region produces a range of conditions under which EWEs can form. Despite the many nuances between each country, they are all still subject to EWEs.

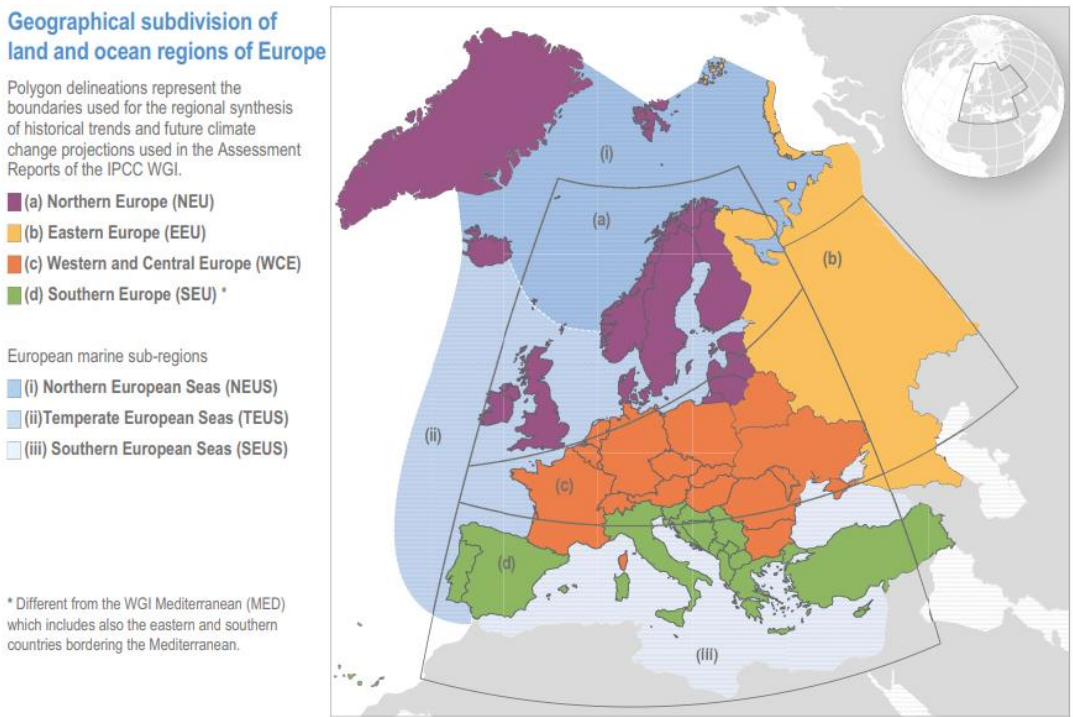


Figure 11: Map of Europe and its associated four subdivisions. Source: IPCC, 2021.

From 1970 to 2019, 1,672 disasters were reported in Europe, resulting in 159,438 deaths and €441.9 billion in economic damages. The most common disasters were floods (38%) and storms (32%), while **extreme temperatures accounted for the most deaths,** making up 93% of total fatalities. The 2003 and 2010 heat waves alone constitute 80% of deaths experienced over the 50-year period, with the 2003 event totalling 72,210 deaths (45% of all deaths) (World Meteorological Organization, 2021).

Within the European Union (EU) specifically, 1,117 natural hazards were reported between the years 1980 and 2020. The amount of meteorological, hydrological, and climatological disasters per year is shown in the following figure.

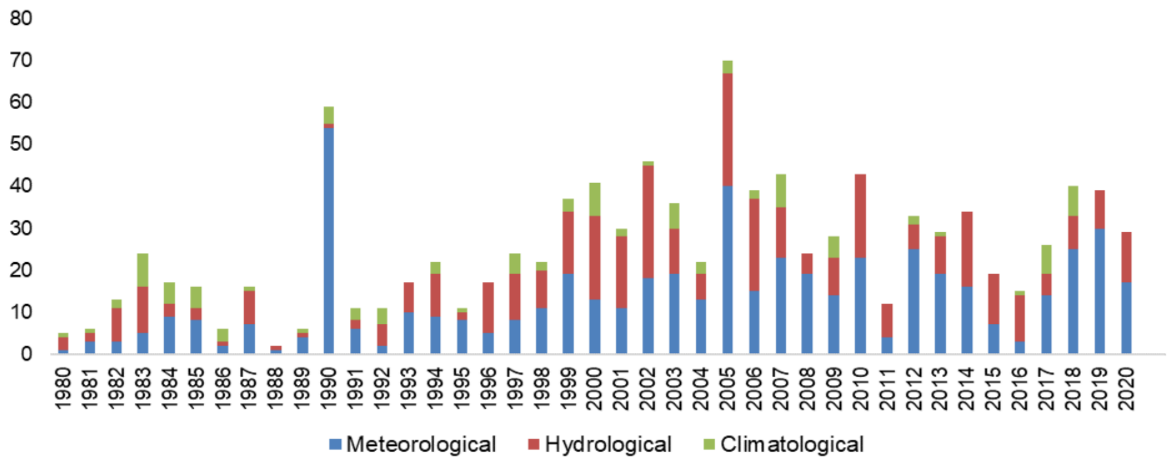
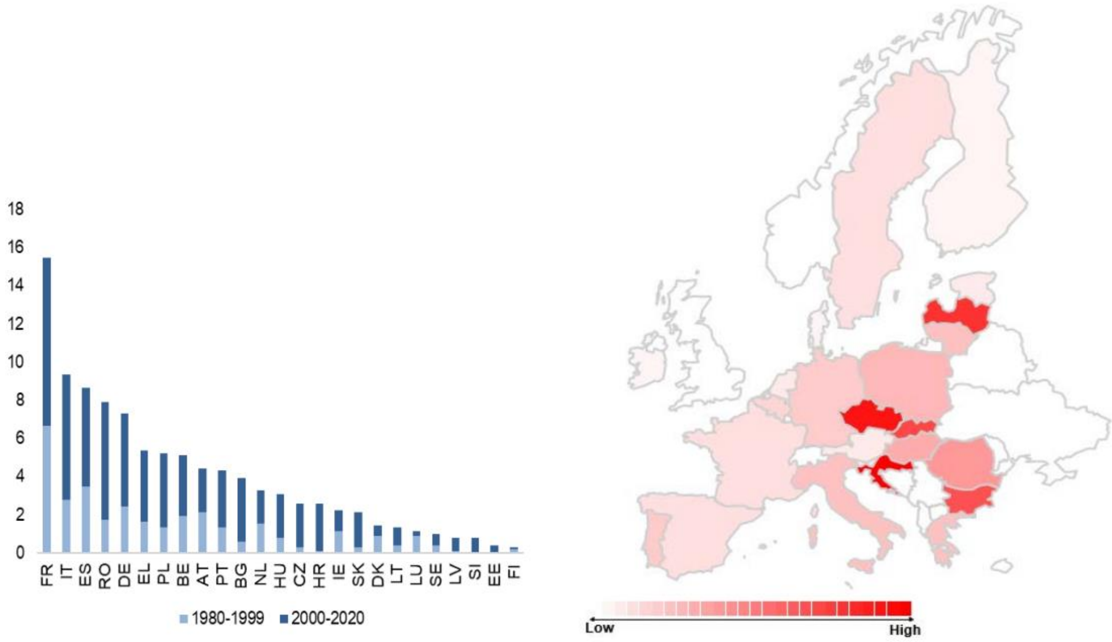


Figure 12: Number of weather- and climate-related events in the EU, by disaster subgroup. 1980-2020. Source: European Commission, based on The Emergency Events Database (EMDAT; CRED, UCLouvain), 2022.

The graph divides the events into three categories: meteorological (e.g., temperature extremes and storms), hydrological (e.g., floods), and climatological (e.g., droughts and wildfires). As depicted above, **meteorological events are the most common,** consisting of 543 total disasters over the forty-year period. Hydrological (389) and climatological (108) disasters follow in turn. Like the data found when considering the entire continent of Europe, **storms and floods account for almost 70%** (i.e., 35% each) of total reported disasters, followed by extreme temperature episodes (18%). Wildfires (8%), droughts (3%), and landslides (2%) all occur less frequently.

The distribution of these events between countries is quite uneven, with **France accounting for 15% of total reported events.** Italy (9.3%) is the next most impacted, followed by Spain (8.7%), Romania (7.8%), and Germany (7.3%). Greece, Poland, Belgium, Austria, and Poland have each averaged around 5% of total disasters. Sweden, Latvia, Slovenia, Estonia, and Finland have the least reported incidents (i.e., less than 1%), and the rest of the countries each account for around 3% of total reports (see Figure 13). **While all countries are experiencing an increase in number of disasters, many Central-Eastern European countries**, particularly Croatia, Czechia, Latvia, Slovakia, Bulgaria, Romania, and Hungary, **have had a particularly significant rise in EWEs over the past 20 years.** Some Southern European countries (i.e., Italy, Greece, and Portugal) have also noted the same trend (European Commission, 2022b).



Note: In the LHS graph, meteorological (e.g., extreme temperatures, storms), hydrological (e.g., floods), climatological (e.g., droughts, wildfires). In the RHS graph, information for Malta and Cyprus is missing.

Figure 13: Number of weather- and climate-related events in the EU. In the left, by country and decade (% EU total) and, in the right, by country, 2000-2020. Source: European Commission (2022), based on The Emergency Events Database (EMDAT; CRED, UCLouvain).

The following sections provide examples of each type of EWE and are listed in order of frequency in Europe.

4.1 Storms

Coastal regions in Europe are at high risk of storms due to milder winters. The coast of Britanny, France is noted to likely be impacted by an increase in storm surges, which are growing stronger with the rise in sea level (Experience ArcGIS, EEA, 2023). Since storms often come in from the ocean, the regions proximity makes it a perfect target for storms, as demonstrated by the 2022 February storms that blew through the region. Storms Eunice, Dudley, and Franklin, as they were called, were caused by a polar vortex and brought with them heavy rain, flooding, and winds equivalent to a Category 3 hurricane. Storm Eunice, the worst of the three, resulted in the deaths of sixteen people. In Poland, 1.2 million homes lost power on February 19. Many flights, trains, and ferries were cancelled and infrastructure damaged, including fatalities, power outages, and damage to trees, vehicles, buildings, and infrastructure (Euro News, 2022$_a$). Damages were concentrated in northern and north-western European countries, just outside of Britanny. Similar impacts resulted from storms Dudley and Franklin as well (see Figure 14). The total cost is estimated to be €4.8 billion (Milliman Report, 2022).

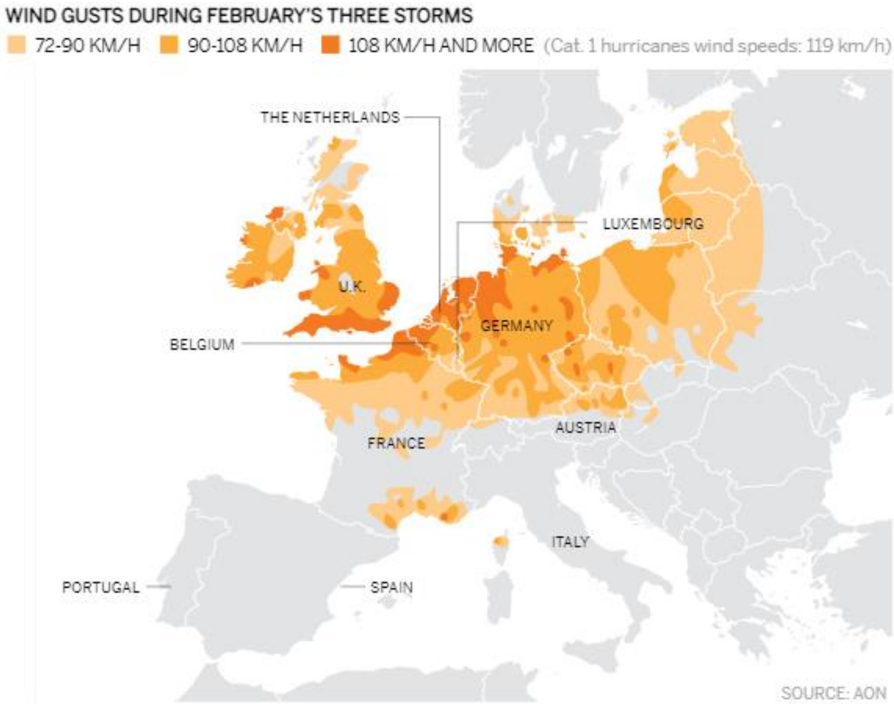


Figure 14: Wind gusts during February's three storms, 2022. Source: EU Copernicus Programme, 2022. Retrieved from https://www.milliman.com/en/extreme-weather-events-in-europe.

These storms also had an adverse effect on wildlife. Many marine creatures were washed ashore due to the strong winds and high tides (see Figure 15). Of these animals, many did not make it back to their habitat, having died after their displacement (ITV News, 2022). In the United Kingdom, the habitats of species including the silver-studded blue butterfly, sand lizards and smooth snakes were destroyed. Bats were found discombobulated, lower numbers of flying insects led to a drop in birth rates for birds in the region, toads suffered from lack of rain, which they rely on to facilitate their migration, and drought combine with a shorter flowering season resulted in the decline in butterfly populations. While some animals may be able to evolve to the increase in storms and other environmental changes, others will not be able to keep up with the fast-changing world, likely resulting in another mass extinction event if efforts are not taken to mitigate these impacts (Euro News, 2022$_b$).

Figure 15: Octopi found walking along the Welsch shoreline after Eunice storm. Source: ITV News, 2022.

Storms often occur alongside other storms, as was the case in the February storms. This phenomenon is called storm clustering. Storm clustering can result in more volatile and dangerous storms, which could be one explanation for the many damages experienced in February 2022 (Moody's, 2022). Storms like these are expected to occur more often and with greater intensity in the future.

4.2 Floods

As previously demonstrated, EWEs are not caused by solely climate change, but the average increase in global temperatures has most definitely increased the potential for floods and other events. For every 1°C increase in temperature, there is a 7% increase in moisture in the air. The wetter environment created by this change makes heavy precipitation events and, in turn, flooding, more likely. **Pluvial, river, and ocean floods are all expected to increase in frequency in Europe**. Northern and Eastern Europe is expected to experience a 35% increase in heavy precipitation causing flash floods, while low lying cities throughout Europe are projected to have a rise in coastal and river floods (Experience ArcGIS, EEA, 2023).

Germany and the surrounding regions felt the brunt of this shift with a fatal flood in July 2021. Heavy rainfall led to overflowing rivers, stressed draining and sewer systems, and the loss of over 200 lives (ESOTC, 2021). Germany alone had to pay €30 billion to cover the damages (Climeworks).

Figure 16: The Ahr River in Insul, Germany, on July 15, 2021 after heavy rainfall. Source: CNN, 2021.

Just in May of 2023, three different countries reported flood events: Italy, Croatia, and Bosnia and Herzegovina. Due to this year's longer winters in these countries and the subsequent drier soil conditions, the high density of rainfall could not be absorbed and has resulted in extreme flood conditions. Such heavy rainfall makes the soil less fertile and can lead to **flash droughts**, a new term used to describe droughts that start more rapidly and often are accompanied with high temperatures, which lead to high levels of soil evaporation and a less fertile environment (Euro News, 2023). In Italy alone, 15 people died and 36,000 were evacuated. Another 10,000 people were affected by the floods in Bosnia and Herzegovina, and even more in Croatia (Flood List, 2023[a, b, & c]). The estimated cost of these floods has not yet been assessed; however, it is clear that much infrastructure and economic opportunities were lost.

Figure 17: People rescued in Faenza, Italy, Thursday, May 18, 2023 - AP/Luca Bruno. Source: Euro News, 2023.

Floods like these are expected to become more frequent and will likely result in a lack of fertile soil for agriculture, driving prices higher and limiting food supply. They will continue to damage infrastructure, interrupt the flow of day-to-day life, and further risk the death and health of citizens.

4.3 Heat Waves

Europe is becoming ever more vulnerable to heat waves a result of having drier springs and consequently drier soil. Instead of evaporating water from the ground, the sun's energy is directed to increasing air temperature. The little water that is evaporated saturates the air near the ground surface, ultimately making dehydrating the air and decreasing the chance of precipitation. These conditions make Europe more susceptible to heat waves so that when a weather anomaly passes over the region, a heat wave is all the more likely to occur and last for an extended period of time. Long lasting heat waves can also lead to **heat domes.** If the high-pressure system that originally created the heat wave remains over a given region for an extended period of time, it can start to trap the heat in the area, cycling the warm air up and down the dome and raising the temperature within the dome. **Since drier land conditions can lead to higher atmospheric water content, heavy rainfall is likely to follow periods of heat waves and drought, causing floods,** like those experienced in Germany in 2021 (MIT News, 2022).

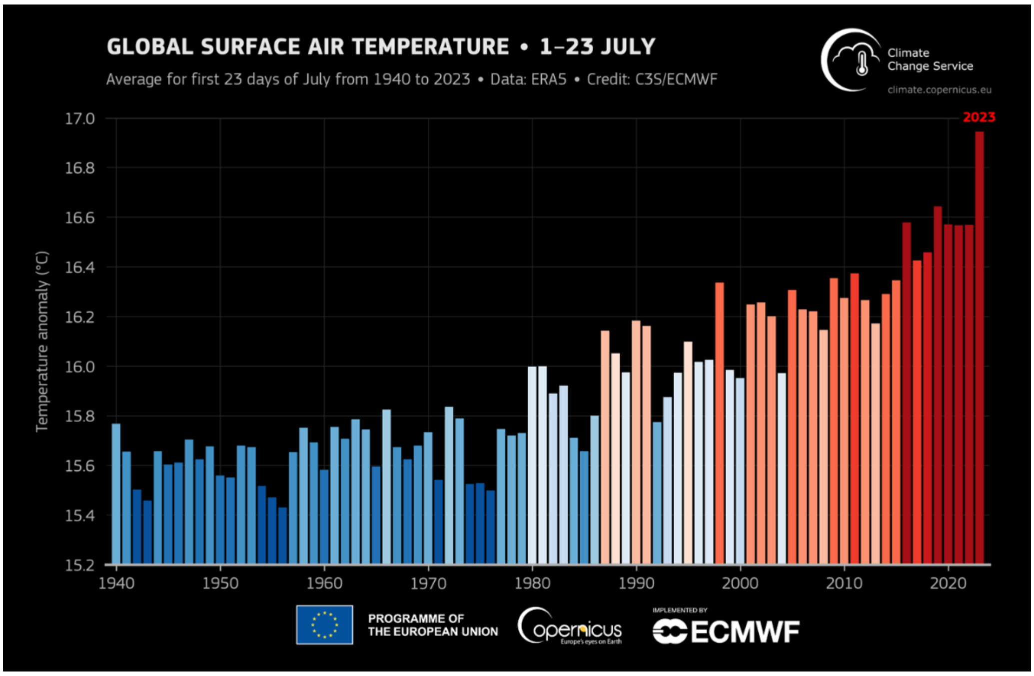


Figure 18: Globally averaged surface air temperature for the first 23 days of July for all months of July from 1940 to 2023. Data: ERA5. Credit: C3S/ECMWF. *Source: World Meteorological Organization*

The summer of 2023 was Europe's hottest in history. According to ERA5 data from the EU-funded Copernicus Climate Change Service (C3S), the first three weeks of July have been the warmest three-week period on record and the month is on track to be the hottest July and the hottest month on record. These temperatures have been related to heatwaves in large parts of North America, Asia and Europe, which along with wildfires in countries including Canada and Greece, have had major impacts on people's health, the environment and economies.

Figure 19: Tourists cool off by a fountain at the Plaza de Espana (Spain square) during the second heat wave of the year, in Seville, Spain, July 2022. Credit: Jon Nazca/REUTERS/Alamy Stock Photo. Retreived from https://www.scientificamerican.com/article/zoe-becomes-the-worlds-first-named-heat-wave/.

4.4 Wildfires

With the increase in drought and extreme heat, Europe has become more susceptible to wildfires. In 2022, wildfires raged Europe, impacting 26 out of the 27 EU countries. Spain, Portugal, France, Italy, and Greece were hit the worst, making 2022 Europe's second worst fire season since 2000. Though only 10% of wildfires are forest fires, they account a quarter of total wildfire emissions because of the high levels of carbon stored in the biome (WFF, 2020). During 2022, many of Europe's fires transpired in forests, resulting in a high level of carbon emissions. In all of Europe, including but not limited to the EU, 45 countries were impacted, 1,624,381 hectares were burned, almost the size of Montenegro, and around 6.4 megatons of carbon were emitted. In Greece, 40 firefighting aircrafts were deployed to manage the fires, many of which are on loan from other NATO countries. Gironde, France had to temporarily evacuate 40,000 people from their homes in July 2023 to mitigate the potential fatalities from the fire. While the fires were devastating, economically they were not as harmful as they could have been due to investment in prevention and mitigation. **A World Bank study explained that with every €1 invested in wildfire prevention, another €10 are saved in damages**. Overall, the fires resulted in an estimated €2 billion in damages (Euronews, 2023).

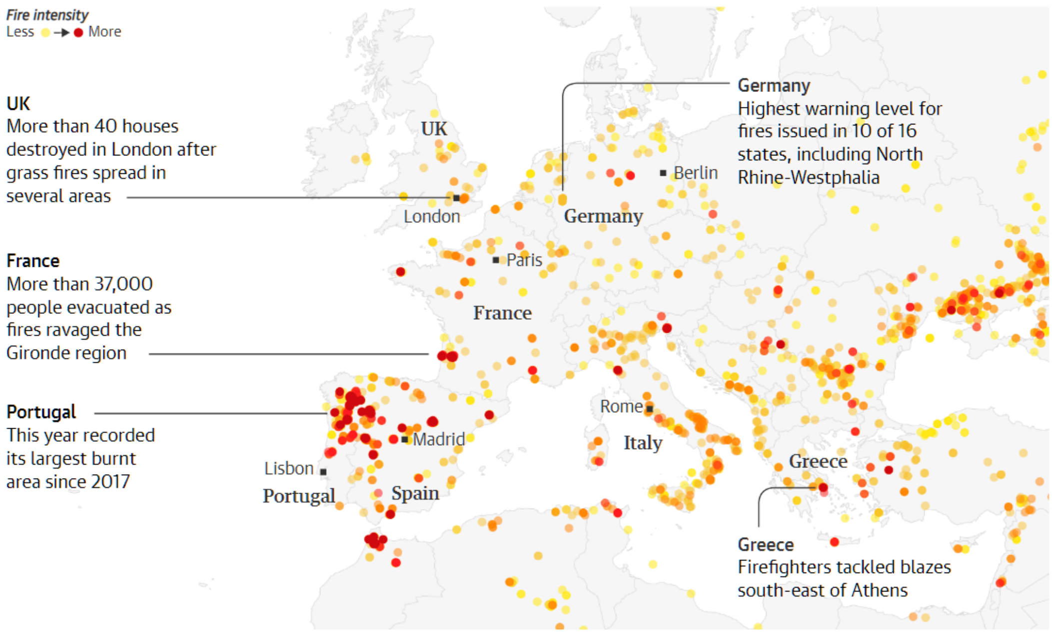


Figure 20: Map of European fires in 2022, categorized by intensity. Source: The Guardian, 2022.

4.5 Drought

In the summer of 2022, Europe experienced its worst drought in 500 years and its most expensive 2022 weather event, with EUR 19 billion in insured losses. In August, two-thirds of Europe was under a drought warning. Without climate change, such extreme conditions might occur every 400 years; now, World Weather Attribution estimates they could happen every 20.

Droughts pose as a particular threat in Southern and Central Europe due to the expected drier and warmer winters, which would reduce snow accumulation. These trends would result in a reduction in long-term water storage (e.g., snow, ice, and glacial ice), which would normally maintain soil moisture through the slow release of water through snowmelt (EEA, 2021).

The impacts of drought can be devastating and costly, affecting society, agriculture, infrastructure, the economy, and ecosystems. According to the European Drought Observatory, in May 2023, **21.3% of EU territory was at risk of drought**, with 5.6% being in "alert" condition, meaning they were actively experiencing drought and suffering from its impacts, including vegetation stress and soil moisture deficits (see Figure 21) (Joint Research Center, 2023). Between 2000 and 2021, 62,000 km of cropland were affected by drought, **reducing agricultural productivity, and resulting in decreased food accessibility**. 52,000 km of woodlands were similarly hampered, hindering the EU from accomplishing their climate action plan due to a decrease in carbon sequestration and storage within those areas. Of course, the biodiversity of those forests also suffered from the droughts. Wetlands have the most carbon storage capacity and have experienced the largest increase in impacted area in the EU, causing worry for the long-term storage and sequestration capacity of the ecosystem. Drought frequency and intensity is expected to increase over the next decade, likely to spread beyond Southern and Central Europe into the Northern regions (EEA, 2023).

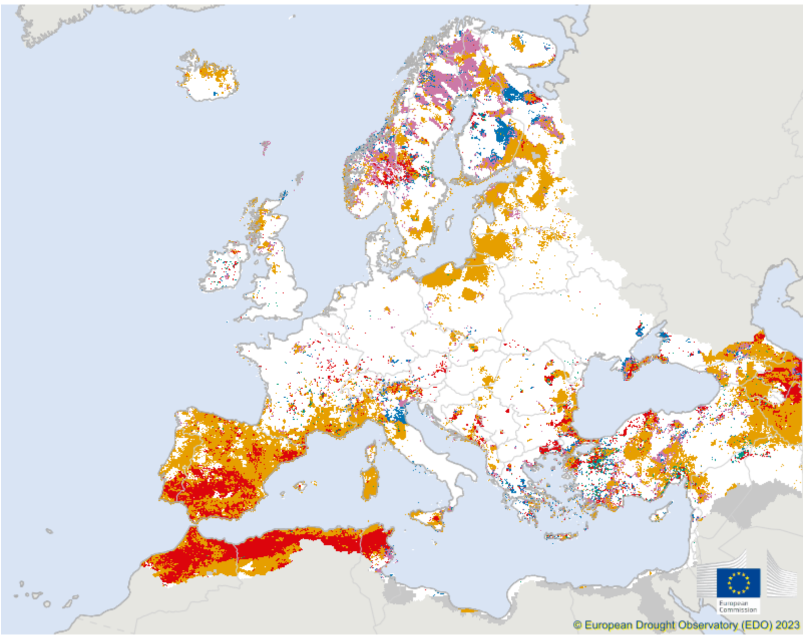


Figure 21: Situation of Combined Drought Indicator in Europe - 3rd ten-day period of May 2023. Source: JRC, 2023.

KEY IDEAS

- The majority of EWEs experienced in Europe are storms and floods.
- Heat waves account for more than 90% of total deaths caused by disasters.
- EWEs of all types are expected to increase in frequency throughout Europe, some being more common in certain regions.

5. Future Trends

Countless studies have demonstrated that increases in EWEs are highly likely to occur across Europe regardless of the level of global warming reached in the coming years. Heat waves, heavy precipitations, floods, droughts, and wildfires are the most likely to increase in severity and duration (European Commission, 2022). Despite this general expectation, trends for each type of extreme weather vary depending on the region and season. See Figure 22 for a summary of the overall trends expected across Europe.

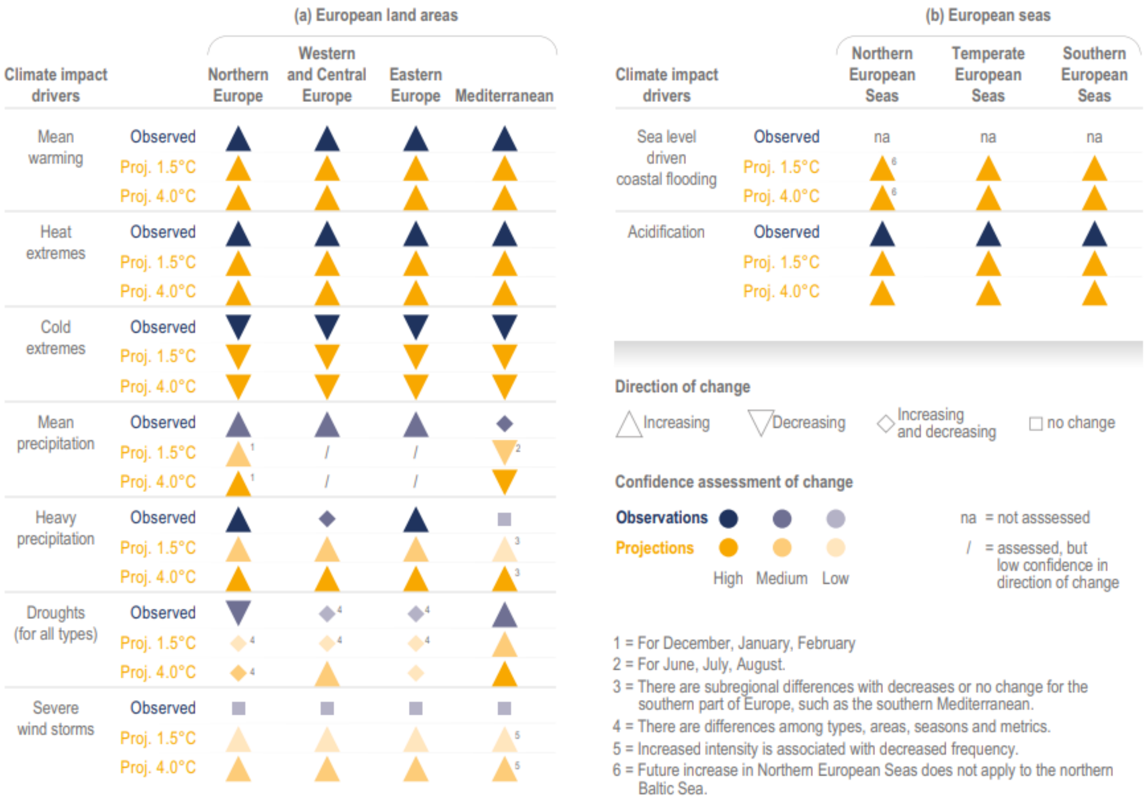


Figure 22: Observed and projected climate impact drivers for Europe – Observations from 1970-2019, Projected changes based on warming levels. Source: IPCC, 2021.

5.1 Meteorological Trends

According to the Sixth Assessment IPCC report, **temperatures will continue to rise in all of Europe at rates exceeding global mean temperature changes, regardless of future global warming conditions.** Heat waves expected to increase in frequency and critical thresholds for humans and ecosystems are projected to be surpassed no matter the level of greenhouse gas emissions or global warming. Cold periods and frost waves are predicted to decrease in frequency. Figure 23 demonstrates the predicted frequencies in heat waves under different emission scenarios. As seen in the graphs, Southern Europe is likely to experience the most heat waves, as concurs with data showing that areas of warmer climates generally experience more heat waves (EEA, 2022).

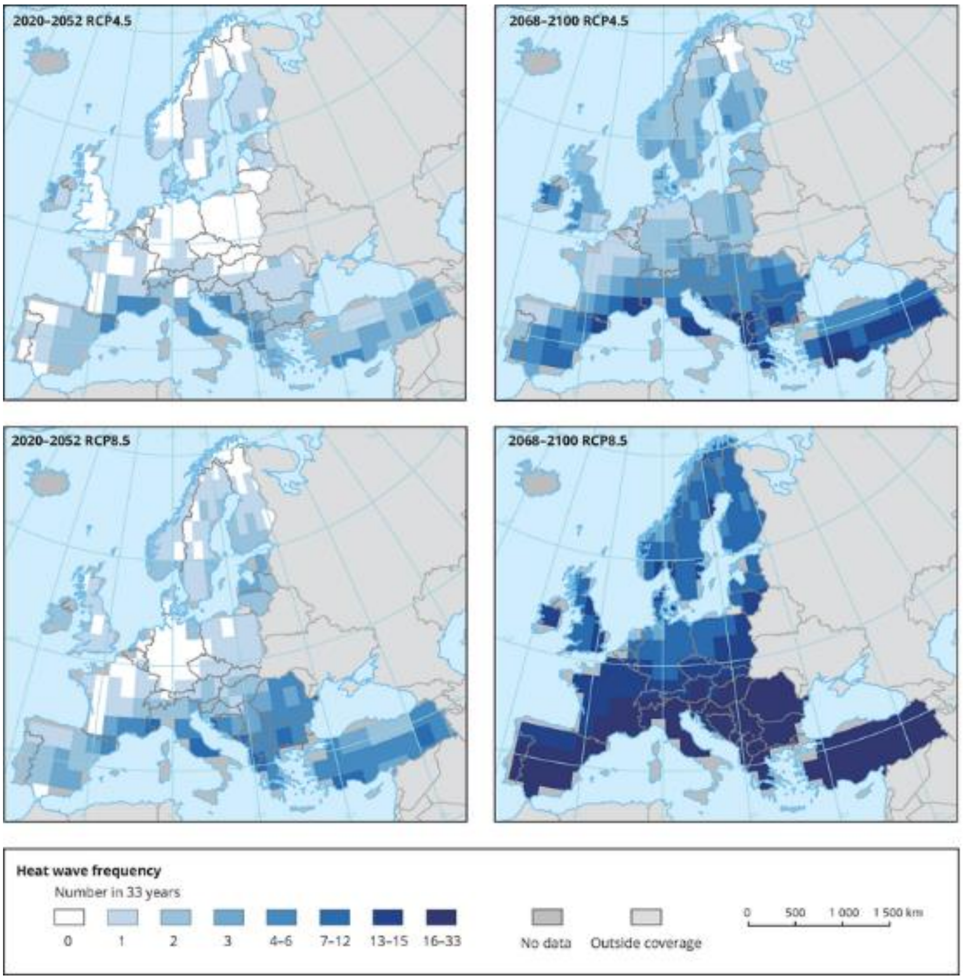


Figure 23: Number of extreme heat waves in future climates under two different climate forcing scenarios. EEA, 2022.

At global warming of 2°C above preindustrial temperatures, Northern Europe is likely to experience an increase in strong windstorms (IPCC, 2021).

5.2 Hydrological Trends

Due to the increase in temperature across Europe and the subsequent rise in humidity, **precipitation events are overall likely to increase over the course of the 21st Century** (European Commission, 2022). These predictions, however, still vary depending on the region and season. In Northern Europe, precipitation patterns are projected to increase drastically in the winter, while they are said to decrease at similar rates during the summer from the Mediterranean to Northern Europe (IPCC, 2021). This expected rise in precipitation events is likely to result in an equivalent increase in landslides (European Commission, 2022).

In all areas except for the Mediterranean, extreme precipitation and pluvial floods are expected to increase if global warming increases 1.5°C from pre-industrial levels. If levels reach 2°C, river floods in Northern Europe and Eastern Europe are expected to decrease, while in Western and Central Europe they have been observed to and are expected to continue to increase in frequency.

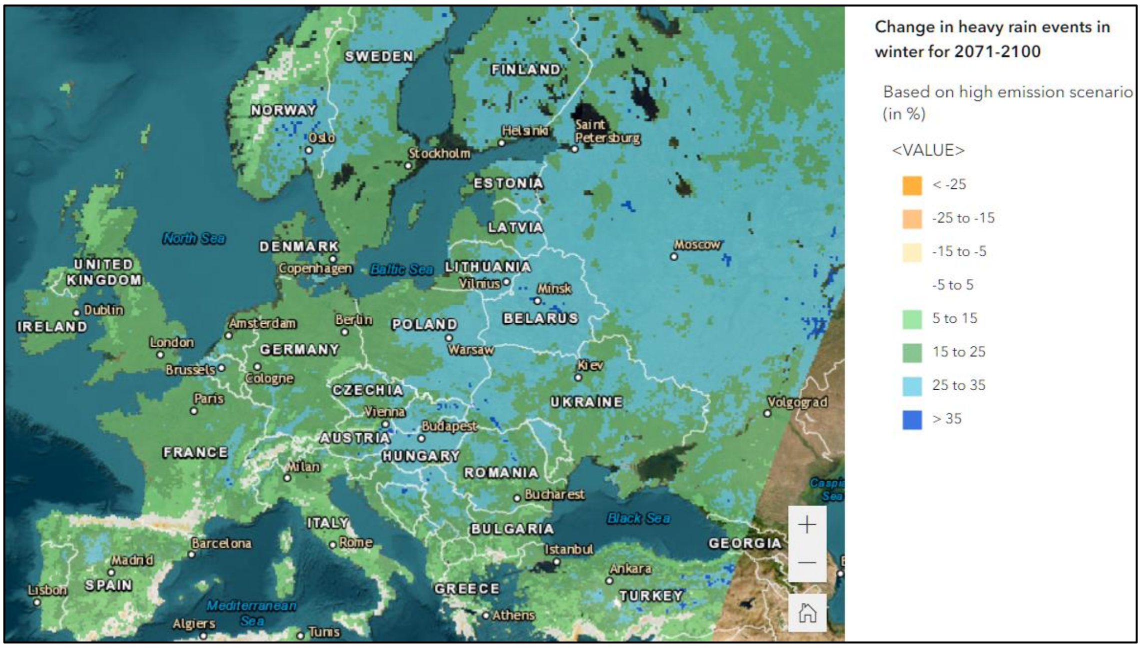


Figure 24: Projected change (%) in heavy rain in winters for a high emissions scenario (period 2071-2100, compared with 1971-2000). Source: Experience ArcGIS, EEA, 2023.

Regardless of global warming trends, **sea level in all of Europe except for the Baltic Sea is expected to rise at rates above the global mean**. These rising levels will lead to more extreme and more frequent coastal floods and other sea related disasters. Such a rise in episodes will result in more coastal damage and the submergence of many shorelines. These changes are projected to continue throughout the 21st century and into 2100 (IPCC, 2023). According to WHO, "Coastal flooding in the EU could potentially cause five million additional cases of mild depression annually by the end of the 21st century under a high sea level rise scenario in the absence of adaptation." (EEA, 2021b). That translates to a 1% increase of cases of mild depression per year if the population were to remain at 2022 levels of 447.7 million people (European Union, 2023). Additionally, snow coverage, glaciers, permafrost, and snowfall are expected to experience a strong decrease in frequency and duration (IPCC, 2023).

5.3 Climatological Trends

Most analyses state **that agricultural, hydrological, and ecological droughts are also likely to increase in frequency in Southern Europe** (IPCC, 2023). In most of Northern Europe, the opposite is expected. **Southern Europe is expected to experience more wildfires** due to the increase in warming, droughts, heat waves, and dry spells. In the Mediterranean, Eastern Europe, and Western and Central Europe, an increase in aridity and wildfire conditions is projected to occur at global warming of 2°C. The wildfires that raged much of Europe in 2022 are an excellent example of how increasing temperatures are leading to drier environmental conditions (European Commission, 2022).

5.4 Urban-related Trends

Cities, as previously shown, will continue to be targeted by EWEs. By 2050, it is expected that two-thirds of the world population will live in cities and eight times as many city dwellers will experience high temperatures. In just twenty-five years, 800 million more people could be at risk of rising sea levels and increased storm surges. The IPCC report claims that under the 1.5°C warming scenario, cities will experience "exacerbated urban heat islands, amplification of heat waves, extreme weather volatility, floods, droughts, coastal inundation, and an increase in vector-borne diseases like malaria and dengue fever." (CDP, 2023). These predictions clearly demonstrate the need for adaptation by cities to better prevent these risks.

KEY IDEAS

- Frequency, duration, and intensity of EWEs are expected to increase in the coming years.
- These changes will vary depending on the region and season.
- Increased temperatures worldwide are predicted to result in a rise in heat waves throughout Europe, leading to more rain in the winters and more droughts and fires in the summers.

6. Strategies for EWEs Adaptation and Mitigation

6.1 Ensuring Climate Justice in Mitigation Strategies

Recognizing and understanding EWEs is the first step towards addressing their potential adverse effects; however, more needs to be done to properly reduce their impact. **Individuals, companies, and governing organizations need to work together to address the dangers of EWEs.** One fundamental element that must be incorporated into such problem solving is the inclusion of all individuals impacted. Seeing that the communities that are most impacted by the EWEs are often those that do not have a voice at the table, it is crucial to ensure that they are involved in the process of addressing EWEs.

Climate justice links human rights to climate action with the aim of protecting the environment without sacrificing the needs of society (CDP, 2023). Three principles must be considered when striving for climate justice: distributive justice, procedural justice, and recognition (see Table_ for definitions). **To achieve climate justice, existing inequalities must be addressed to ensure that the same opportunities and outcomes are realized by all.** Actions that invest in vulnerable communities will result in a more equitable solution, bringing everyone to the same level, rather than providing everyone with the same resources from which some will benefit more than others (EEA, 2022) (see Figure 25).

Term	Definition
Distributive Justice	The allocation of burdens and benefits among individuals, nations, and generations.
Procedural Justice	The participation of all concerned bodies in the decision-making process.
Recognition	The respect for, engagement with, and fair consideration of diverse cultures and perspectives.

Table 5: Definitions of the three principles of Climate Justice. Based on EEA, 2022.

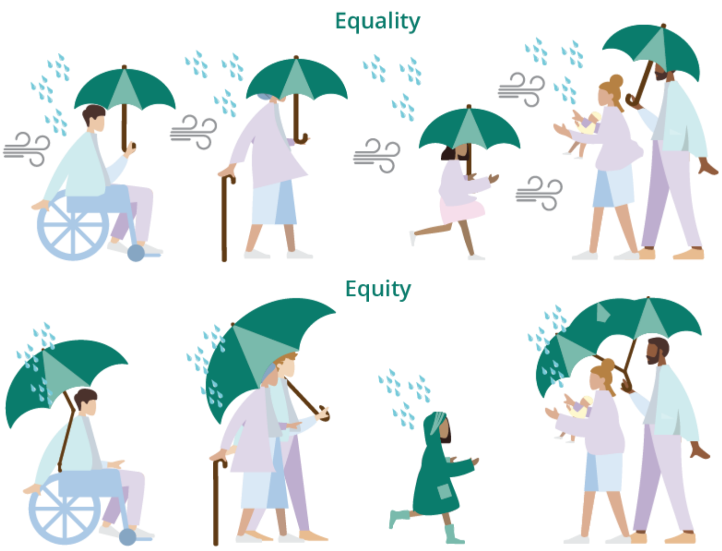


Figure 25: Juxtaposition of equality and equity. Source: EEA, 2022.

Groups that may be considered more vulnerable include children, pregnant woman, older adults, ethnic minorities people with outdoor jobs, low-income households, and persons with disabilities or with pre-existing health conditions. Social isolation can increase the likelihood of death during an EWE, as well as inability to understand a country´s official language, which can prevent adherence to warnings and safety protocols. This misunderstanding is of particular importance for new immigrants (EEA, 2022).

IPCC report demonstrated that from 2010 to 2020, human mortality from EWEs was fifteen times higher in regions with higher vulnerability than those with very low vulnerability (IPCC, 2023).

Insurance affordability is one limitation that has increased the adverse impacts felt by disadvantaged communities after EWEs. Wealthier people generally live in less flood risk areas, so their insurance is cheaper, while poorer communities who cannot afford the high costs of insurance live in high-risk areas with more expensive insurance. Few countries in Europe – only Spain, France, Romania, and Belgium – cover flood insurance, requiring it as mandatory and supporting citizens when costs are overwhelming. In countries like Poland and Portugal, however, where insurance costs are the highest, no federal financial aid is provided. Changes in government services to help support those most vulnerable are crucial to reducing the economic burden of EWEs (EEA, 2022).

Flood protection through flood proofing homes has been shown to be the most economical solution to mitigating the potential property damage incurred by floods. Again, this solution is expensive and can only be leveraged by property owners; renters and those living in social housing communities cannot implement these defences into their building without building approval. **Between the high costs and implementation limitations, flood proofing is made inaccessible to many.** Federal zoning policies to enforce the implementation of such structures into at risk areas paired with financial assistance could help reduce the inequality experienced and reduce flood damages. Similar government action could be taken to address equivalent challenges posed by other EWEs (EEA, 2022). The following figure demonstrates a few of the strategies taken by cities around the world to address EWEs.

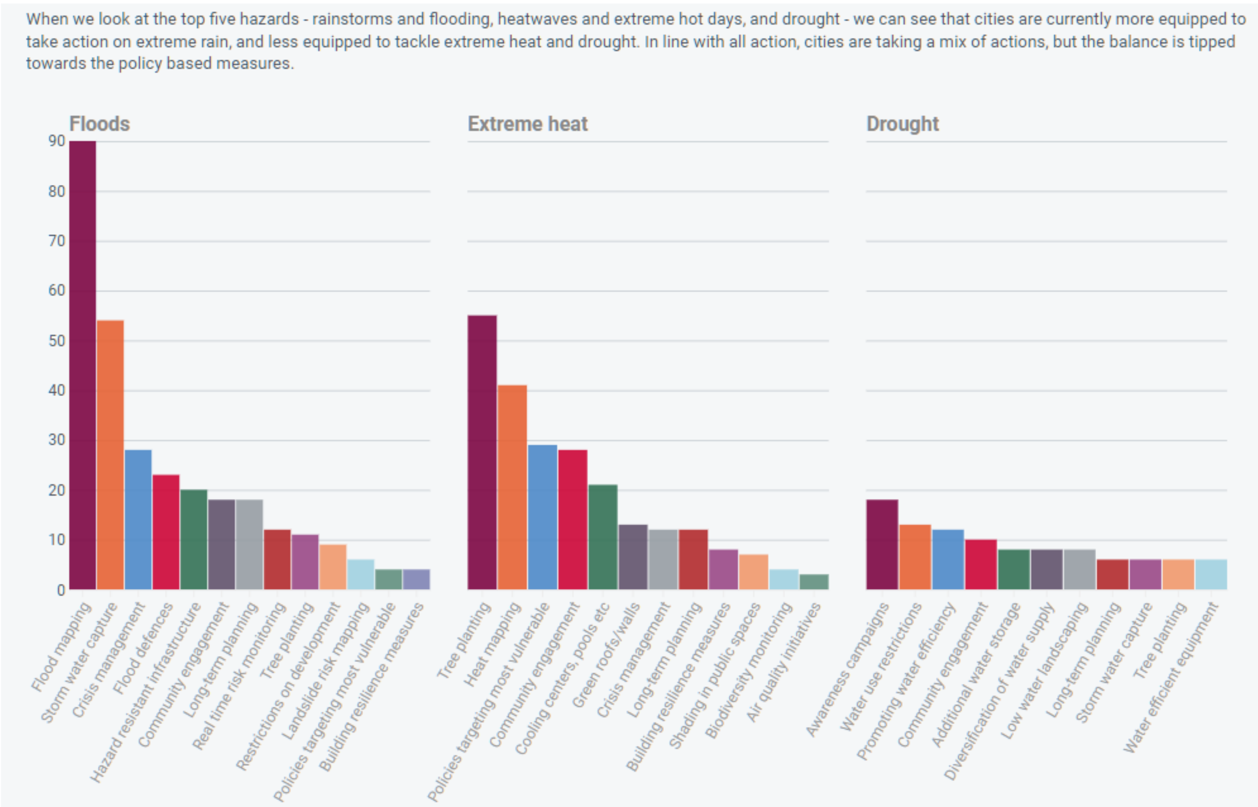


Figure 26: Policy based solutions are the current focus for cities, with infrastructure change taking a back seat. Source: CDP, 2023.

Identifying communities that are discriminated against and suffer from climate inequality is crucial to properly implementing such solutions and preventing further injustice. The environmental justice index in Berlin can be used as a guide for how to identify these communities and distribute aid equitably among them. **Climate justice is not only important on the national level, but on the subnational and local levels as well.** The more localized planning and adaption measures are, the more impactful they can be. Local officials and citizens are those most closely related to the issue, so localizing solutions can make them more applicable to and successful in each community.

6.2 Federal Commitments to EWEs Adaptation and Mitigation

Many countries in Europe have realized the importance of acting against EWEs and have developed plans and strategies to properly address these challenges, focusing on aiding the most impacted communities. The European Green Deal has committed to integrating climate justice goals into their policies and uses the European Pillar of Social Rights as a guide to do so properly. Out of the 38 countries in the EEA, a third have explicitly included strategies to identify vulnerable communities in their mitigation strategies. Of the 16 European countries analysed in a WHO report in 2021, 11 reported that their National Heat Health Action plan fully addressed vulnerable groups while the remaining five had only partially addressed them. Such consistent commitment to vulnerable groups could significantly reduce the impact of EWEs on the economy, human health, energy use, and the environment.

Investment in EWEs resistant infrastructure

Many countries are constructing and installing infrastructure that prevents damage from EWE as a means of mitigating damages. Portugal, which suffers from many coastal floods, is putting up seawalls and gryones to physically impede flood waters from damaging the city (Norwegian Meteorological Institute, 2013). The ‘MOSE system’ takes similar steps to reduce flooding in Venice, Italy. During high tides, the system activates, creating a flood barrier in the highest risk areas to reduce flood risk (Figure 27). In Riba-Roja de Túria, a municipality in Valencia, Spain, the city is constructing green firebreaks (i.e., strips of low-flammable vegetation) to halter fire spread. They are also investing in a waste-water recycling system to increase fire resistance (Climate Adapt, 2023).

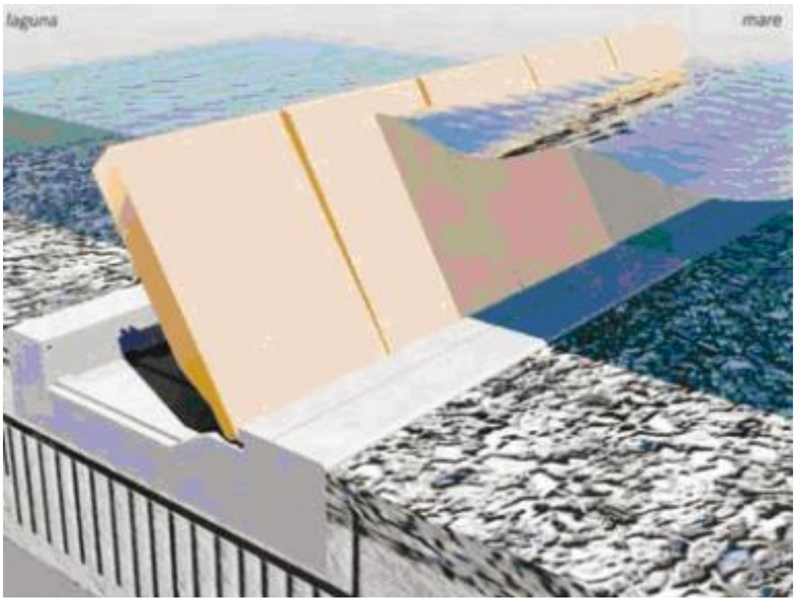


Figure 27: Smart barriers to shield La Serenissima from freak tide. Source: Agenzia Giornalistica Italia.

Improved ecosystem management

Strengthening the ecosystem of a region is another way to reduce damages from EWEs. France is strengthening their forests by installing and regenerating, practicing wider spacing and strong and early thinning, and using wood-based heating for energy. These actions can increase biodiversity and reduce vulnerability to strong winds, storms, and droughts.

Greenifying neighbourhoods: tree planting and construction of water features

Some actions taken by these countries include the implementation of **tree planting** and **construction and restoration of water features** in areas designated as vulnerable to mitigate the impacts of heat waves in a residential area of Trnava and Košice, Slovakia.

The **Vienna environmental department - MA 22**, had been dealing with the topic "heat in the city" for more than 15 years. This included a climate assessment and map based on thermal images and the implementation of measures, such as green space networking, roof greening, façade greening and rainwater management. This led to the creation of an ecosystem-based adaptation solution; the greening of the building 'façade' or front wall.

In Paris, Flemish Brabant, Belgium, Germany, and Sweden, programs were developed to **green disadvantaged schools and neighbourhoods**, while projects in Amsterdam and Malmö focus on mitigating flood impacts by installing **green roofs** that can store excess stormwater or constructing sustainable drainage systems (EEA, 2022).

Hands-on warnings, rescues, and post-disaster care

Some regions have focused on providing aid to disadvantaged communities during and after EWEs. In Bologna, Italy volunteers can assist vulnerable citizens make their way to safety during an EWE. Another program in Kassel, Germany provides free calls to warn people of coming heat waves. In Lisbon, the municipality care department aids homeless people during times of crisis and in Finland, three NGOs provide mental healthcare to youth suffering from climate anxiety and other similar stressors (EEA, 2022).

Relocation of cities

Very few areas are willing to sacrifice their homes and way of life in order to reduce impacts from EWEs, but many people consider the idea of evacuating certain regions to prevent damages. Venice and other coastal regions could relocate their populations for safety reasons. The economic, social, and cultural costs of such a change are so large that such a move seems unlikely.

Better forecasting

Many countries are investing in **increasing their ability to predict EWEs** so that they can better respond when disaster strikes. In Hungary, efforts to improve drought forecast are of particular importance. While they are working to better predict droughts, they have yet to develop a strategy for once drought hits. ENSEMBLES is a European project that aims to accurately predict EWEs and other climate change related occurrences. 66 partners from across the EU, Switzerland, Australia, and the USA are participating in this project.

Raising awareness

In order to ensure that new climate policies are followed and to increase public understanding of climate change and EWEs, countries are also working on improving public awareness of EWEs. Alliance in the Alps is an Austrian organization that aims to do just that. In the United Kingdom, a campaign run in 2003 led to 72% of the flood-risk population knowing that they were at risk of impact. 96% of those people were also aware of at least one action that they could take to reduce flood risk. Not only are individuals learning about how to address these issues, but also businesses, tourist companies, construction industries, and insurers. With a more informed population, the public becomes able to play a role in their safety and overall risks are likely to decrease.

Involving the local community in problem-solving

The European Climate Pact and **the European Mission on Adaptation** have emphasized the importance of **citizen engagement**, including vulnerable groups, **in developing adaptation strategies**. In France, the most vulnerable communities helped establish the second national adaptation plan and regional climate policies, while in Slovenia municipalities worked with disadvantaged populations to achieve the same result. In Dresden, Germany, the same method of consulting with residents in vulnerable communities was used. This process led to the improvement of thermal comfort in homes and the neighbourhood as well as the development of tree planting and window shutter installation plans. In Prague, citizen engagement led to the installation of green roofs in bus shelters to increase comfort and ventilation. Finally, in Finland children, youth, the elderly, and the Sami indigenous people were consulted to develop strategies to address climate change (EEA, 2022).

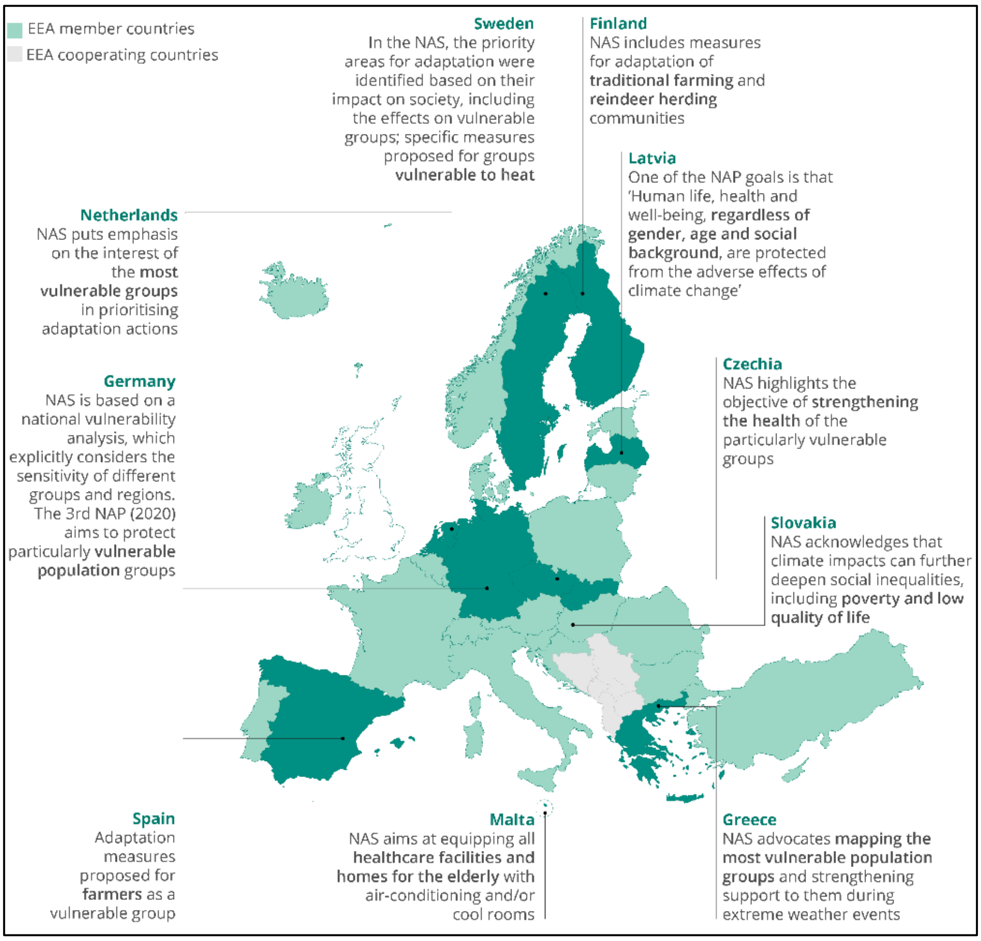


Figure 28: Examples of equity considerations in national adaptation policies.
Source: EEA, 2023. https://www.eea.europa.eu/publications/just-resilience-

Get to know more: *The Role of Healthier Soils*

Healthier soils are more resilient and can play a crucial role in **regulation of floods, sand and dust storms, landslides, and droughts, by contributing to the improvement of water-holding capacity, reduction of erosion risks and construction of resilient landscapes.**

Indeed, soils rich in organic matter have a greater ability to absorb and retain water. Organic matter acts like a sponge, absorbing water and releasing it gradually over time, reducing surface water runoff. Moreover, biodiversity, in its abundance and diversity, is another essential factor. For instance, earthworms create depressions in landscapes that slow down the flow of rainwater, facilitating landscape rehydration (Reporter, 2022).

These factors are part of soil characteristics along with structure, depth, permeability, and texture. Those affect the soil ability to store and transfer water to aquifers through subsurface lateral flow and seepage. This natural buffering effect helps to regulate the severity and frequency of **floods** (Saco, et al., 2021).

Figure 29: Hochwasser am Rhein in Köln (left); US megadrought (right). Source: Global Citizen, 2021.

Soils with improved drainage capacity and higher organic matter content can increase the resilience of ecosystems to the effects of local or regional **drought**. Practices such as cover cropping and mulching can act on these factors as well as on soil strength and cohesion through the root system and thereby minimize evaporation and runoff. Using mulch, for example, has been shown to increase soil water retention by 10%. Generally, integrated water management, soil compaction reduction, agricultural diversification and biodiversity conservation have proven to be effective in reducing erosion and mitigating natural hazards, including **drought and landslides** (Saco, et al., 2021).

Figure 30: Dust squalls from convection over west Africa. Source: EUMETSAT, 2006.

Sand and dust storms occur when strong winds lift a large amount of sand and dust from bare, dry soils into atmosphere (World Meteorological Organization, 2022). Their control can be achieved through the stabilization of soil using an integrated multi-scale and multi-functional approach. Practices that promote long-term soil cover, retention of plant residue, and improved soil health enhance soil structure, microbial communities, and fertility, thereby stabilizing the soil. Effective rangeland management practices, such as controlling animal density, implementing rotational grazing, and introducing drought-tolerant improved pastures, can prevent and reverse land degradation, thus avoiding desertification (Saco, et al., 2021).

Soil management strategies have already been adapted to combat the effects of EWE.

In agriculture, **giving structure to the soil by reducing tillage, or practicing crop rotation will allow it to better absorb water,** retain moisture longer and consequently minimize the damages caused by heavy rains. Cultivating adapted crop varieties that are more resistant to drought and use water efficiently, as well as choosing shorter-season crops, can also help to mitigate the impacts of EWE (National Association of Conservation Districts, 2019).

In urban areas, the phenomenon of soil sealing can be observed. This occurs with the layering of impermeable materials during construction. This phenomenon implies the removal of the upper layer and disturbances in depth resulting from building foundations, which lead to long-lasting soil degradation. Therefore, it makes the infiltration of water into the soil almost impossible, also preventing its retention. Consequently, urban soils experience a decline in their ability to regulate floods. The occurrence of floods is also heightened due to alterations in precipitation patterns linked to the urban heat island effect, which is another consequence of soil sealing in urban areas (Saco, et al., 2021).

Thereby, it is crucial today to act for a **global management to maintain the health of both agricultural and urban soils.** These healthy soils have the capacity to protect both nature and human from the increasing risks associated with EWE.

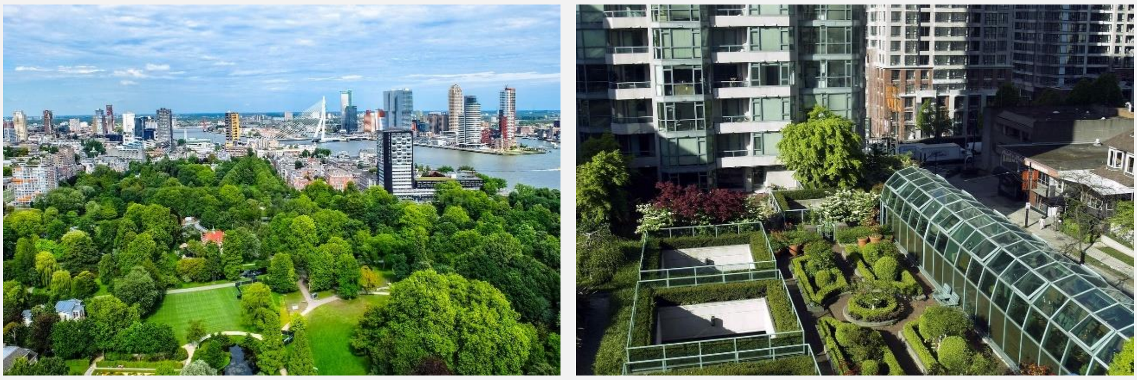


Figure 31: Rotterdam Park (left); Greening of roofs in Moscow (right). Source: IESE, 2019.

6.3 Start-ups and Urban Projects

In addition to the actions taken by governments to mitigate the impacts of EWEs, **many smaller companies and start-ups have taken it into their own hands to develop technology and systems that help address EWEs**. The following table details just some of the many startups that have taken the initiative to develop their own solutions to the problem. These companies utilize different strategies to monitor EWEs and mitigate their effects. The implementation and development of projects like these is crucial to addressing EWEs and will likely play a large role in Europe's climate action strategy.

DRONEHOPPER FIREFIGHTING DRONE	Climate Alpha
A company founded in Madrid, Spain produces heavy-duty drones that are designed to put out wildfires in urban and agricultural areas. Their drones can carry 600 litres of water and are built to fly under strong winds in 24/7 operations. They create firewalls and defence systems to protect communities and properties during fires.	Developed in Singapore, Climate Alpha works to provide predictions on the best locations to invest in real estate. They use artificial intelligence to measure socioeconomic, demographic and market indicators and combine that data with information on EWE risks to determine future property values. Using this platform, investors can better understand the financial and climate risks of purchasing in certain areas.
iREACT	AQUIPOR
I-React, a company based in Turin, Italy that takes a different approach in monitoring EWEs by combining data from European monitoring systems, earth observations, historical information, weather forecasts, and civic reports collected on a mobile app and social media tool. This aggregation of information ensures a wider collection of information that can then be cross-	A startup from Washington, United States, Aquipor, has developed porous cement that allows for stormwater to be absorbed into the ground. It is produced in a low emissions manner that makes it not only better climate adapted than concrete, but also less negatively impactful on the environment. FloodMap (Australia), BufferBlock (Holland),

checked. Individuals are also empowered by the ability to provide first-hand information to policymakers and first responders.	StormHarvester (UK), and Flood-Con (USA) are all startups working on mitigating the impacts of floods on the environment through better drainage systems and other initiatives.
sensible weather	TENEVIA A new vision of environmental monitoring
Based in California, United States, Sensible Weather provides weather insurance for travellers. They monitor the weather conditions for the trip and if rain or another disaster is predicted, they will reimburse the client for their experience. For example, when booking a trip to an amusement park, one can purchase insurance through sensible weather and if the trip is cancelled due to poor weather conditions, the costumer will receive a reimbursement for the cost of the trip. Other similar companies include MeteoTech (France), Wetterheld (Germany), and New Paradigm Underwriters (USA).	Founded in Grenoble, France and used across France and in two places in Germany, they use surveillance cameras along rivers to monitor flood risk and water movement during active floods. Since the cameras are not submerged in the water nor located on satellites in space, their lenses are less likely to experience interference from murky waters or clouds, making the system even more sound. Many other companies have developed technology to be able to monitor floods, wildfires, and other natural hazards, including Tesello (Portugal), Serinus (Germany), Vandersat (Netherlands).
CHOMP	ONO EXPONENTIAL FARMING
Founded in Hong Kong, Chomp aims to reduce food waste by collecting unsold goods from bakeries and restaurants and selling them as mystery boxes. During times of higher food insecurity due to transport or cultivation problems during and following EWEs, the reduction of food waste is crucial to ensuring that everyone has access to a healthy diet. Similar companies like Peko Produce (Canada), Too Good to Go (UK), Treatsure (Singapore), and Tabete (Japan) follow similar models to reduce food waste globally.	Ono Exponential Farming is a vertical, indoor farming startup that grows herbs, fruits, and vegetables in Milan, Italy. Their products are local and pesticide free. By growing food indoors and under highly monitored conditions, they can regulate the impacts of EWEs on their crops without experiencing the uncertainty and risks often felt in farms that can suffer from over sun-exposure and droughts during heat waves or fertilizer and pesticide runoff and overwatering during heavy precipitation and flooding events. Interius Farms (Canada), Harvest London (UK), and Madar Farms (UAE) are a few of many other startups that also mitigate impacts of EWE on food accessibility.

Table 6: Collection of eight startups that aim to prevent, monitor, and mitigate EWEs and their impacts.

7. Barriers to Climate Adaptation and Mitigation Strategies

While there are many solutions to address EWEs, there are also many limitations that makes such solutions difficult to implement. The main barriers to implementation are detailed below.

Lack of knowledge on EWEs causes hesitation to address them

Some people are unconvinced that there is enough information on EWEs to warrant such drastic adaptation to them. Without a clear understanding of their impacts, causes, and occurrence patterns, some politicians, like those in Ireland and Sweden, believe that that climate change and extreme weather events are problems of the future that are too elusive to address now. Over the years, many efforts have been made to better understand EWEs, but due to their unpredictable nature, it is difficult to learn much about them. Just as business decisions are made without a complete understanding of what their outcomes will be, so must climate decisions be made. A lack of information should not prevent action to protect and mitigate impacts of EWEs.

Imprecise plans result in no accountability of stakeholders
Another challenge that may be faced when attempting to implement climate policy is a lack of detail. Due to the uncertainty of the issue, general plans are often made that outline possible measures that can be taken to address EWEs, but details on the relationships between and responsibilities of individuals, communities, organizations, and governments is often left unclear. Without explicit instructions, each actor may expect for others to complete the desired tasks, leading to no one taking responsibility for the work that needs to be done. In order to ensure that these plans are followed through, all steps and responsibilities for each actor and problem must be provided to the involved parties.

No standards available to guide policy
Since EWEs are a relatively new problem that have rarely been addressed before, there is little historical knowledge to guide problem solving and implementation processes. Furthermore, each region deals with a vast variety of disasters and each individual event is unique. With so much variation, no one plan can be applied across the board. And without the support of previously successful strategies, policy makers are hesitant to invest in potentially helpful projects that may not be successful. By reviewing climate policy standards often and carefully monitoring projects, politicians may be comforted by the increased standardization of disaster mitigation solutions and therefore become more willing to support the cause.

A need for increased collaboration
While specializing solutions to the specific region and event being addressed enables more effective mitigation, this strategy also prevents cross-project collaboration. Projects to reduce the impacts of EWEs on society could be made more efficient if supported by coordinated efforts and information sharing. Efforts to integrate monitoring systems and research data should be made to ensure that disaster mitigation solutions can benefit everyone involved.

8. Suggested Sources

To learn more about EWEs, please see the links below (all of which have been referenced in this document). In addition to these sources, consider reviewing those found in the reference page of this document.

The Intergovernmental Panel on Climate Change (IPCC) is an international organization that collects and analyses data on climate change and its impacts on the human and natural environment. Their 2023 Sixth Assessment report has one section devoted solely to EWEs that provides information on what they are and their potential impacts, focusing on projections in the future depending on different emission scenarios. See the link below for more information:
https://www.ipcc.ch/report/ar6/wg1/chapter/chapter-11/

The Carbon Disclosure Project published a document outlining the impacts of EWEs on cities across the world. It is a short report that contains information on the risks of EWEs in urban areas and explains a few measures that can be taken to mitigate said risks. See the link below for more information:
https://www.cdp.net/en/research/global-reports/cities-at-risk

In 2013, the **Norwegian Meteorological Institute** released a report on extreme weather in Europe, covering information from what are extreme weather events to how they are present in Europe to what actions are being or can be taken to confront them. See the link below for more information:

Co-funded by
the European Union

http://real.mtak.hu/8366/1/EASAC_EWWG_Extreme_weather_report.pdf

For a thorough summary on the impacts of climate change and EWEs in Europe, see the following link from the **European Environment Agency (EEA)**. The EEA has published many relevant reports on this topic and is a highly recommended source when looking for information within Europe on EWEs.
https://experience.arcgis.com/experience/5f6596de6c4445a58aec956532b9813d/page/The-European-overview/

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