Ref. Ares(2024)1579446 - 29/02/2024

Urban Shift for green innovations

D2.1 Compilation of 2 Urban Challenges Background Papers

February 2024

Multicriteria

Work Package	WP2 – Defining Urban Challenges
Task	T2.2 Refining Urban Challenges
Due Date	Month 18 - February 2024
Responsible Beneficiary	Multicriteria
Version	1
Author(s)	Marite Guevara, Marta Carbonés, Isaac Farradellas, Camila Álvarez

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.

Executive Summary

This deliverable includes the formal definition of the challenges object of the Batch 1 & 2 living labs and all background information illustrating the definition of these challenges.

Throughout the UrbanShift project, two background papers have been meticulously crafted, one for each batch. These papers are designed in a highly communicative format, providing detailed insights into the urban contexts and associated challenges. They also outline the initiatives undertaken thus far and their alignment with European policy goals and strategies.

Batch 1 (October 2022-June 2023) focused on tackling the challenges of Food Waste & Urban Heat Island, while Batch 2 (October 2023-June 2024) explored Mobility & Extreme Weather.

The methodology employed to refine these urban challenges is guided by three key principles:

- **Relevance**: addressing common problems all across Europe and avoiding extremely particular topics requiring ad-hoc solutions.
- **Implementability**: refraining from fields that require high levels of technological specialization so that resources can be devoted to promoting creativity rather than training participants to achieve minimum experience knowledge.
- **High Transferability Potential**: challenges that are common enough across Europe so that solutions sought for can be later transferred across Europe in many different contexts, yet with similar characteristics, i.e. solutions.

To facilitate meaningful interaction among Urban Experts and learners, as well as engage a broader audience, the project conducted a Cities Network Engagement Roundtable (CNER). Another session is scheduled for April 24, 2024, comprising 2-3 hour online events divided into two parts:

- An open online debate where the selected challenges (changing from 1st to 2nd roundtable) are discussed with a broad audience (also including external audience) from state-of-the-art economic, technical, and cross-sectoral viewpoints.
- A 'private' feedback session between Urban Experts, trainers, and learners to help the startups and their startup solutions through their in-depth sector knowledge, giving real-life feedback on needs from industry (private sectors: enterprises and businesses), city planning.

These CNER events serve as crucial evaluation opportunities for startups, allowing them to gauge the extent to which their solutions meet stakeholder expectations in terms of innovation and feasibility. Additionally, startups have the chance to garner support from Urban Experts to guide their future endeavors as mentees.

To ensure timely incorporation of feedback and allow for agile adjustments, the roundtables are strategically positioned midway through the project batches.

The network established in WP2, linking Urban Experts with startups, is envisioned as a foundational platform for fostering enduring transdisciplinary partnerships beyond the project's scope, forming regional impact networks that endure beyond UrbanShift.

Urban Challenges for Batch 1:
Urban Heat Islands & Food Waste

Urban Heat Islands

1. What is an Urban Heat Island (UHI)?

1.1 Definition of the Challenge

In our world today, urban populations are increasing rapidly in size as more and more people continue to leave rural areas to migrate to cities. Because of this rapid urbanization, cities require large amounts of energy in order to function properly. Although cities occupy only about 2% of the earth's surface, city dwellers consume over 75% of the total energy resources available to carry out everyday activities in the urban environment (Madlener & Sunak, 2011).

As an urban area develops, changes occur in the natural landscape. **Buildings and roads begin to replace open space and vegetation**, causing surfaces that were once pervious and moist to become impervious and dry. These changes lead to the development of a phenomenon known as an urban heat island (UHI).

UHIs occur when a ***densely populated urban area experiences significantly higher temperatures than the surrounding rural or less populated area.*** When naturally vegetated surfaces such as grass and trees are replaced with **non-reflective, impervious surfaces**, those surfaces absorb a high percentage of incoming solar radiation, causing a warming effect (Taha, 1997).

The heat 'island' is the result of an unintended climate alteration due to a modification of land surfaces, caused mainly by an increase in **urbanization and anthropogenic activities.**

Urban heat islands are an important issue because **they can pose both health and environmental risks due to increased heat exposure and enhanced levels of air pollutants**, specifically ozone. It is imperative that city planners take the heat island effect into account when planning for a city to ensure the best actions are being taken to create a healthy environment for all inhabitants.

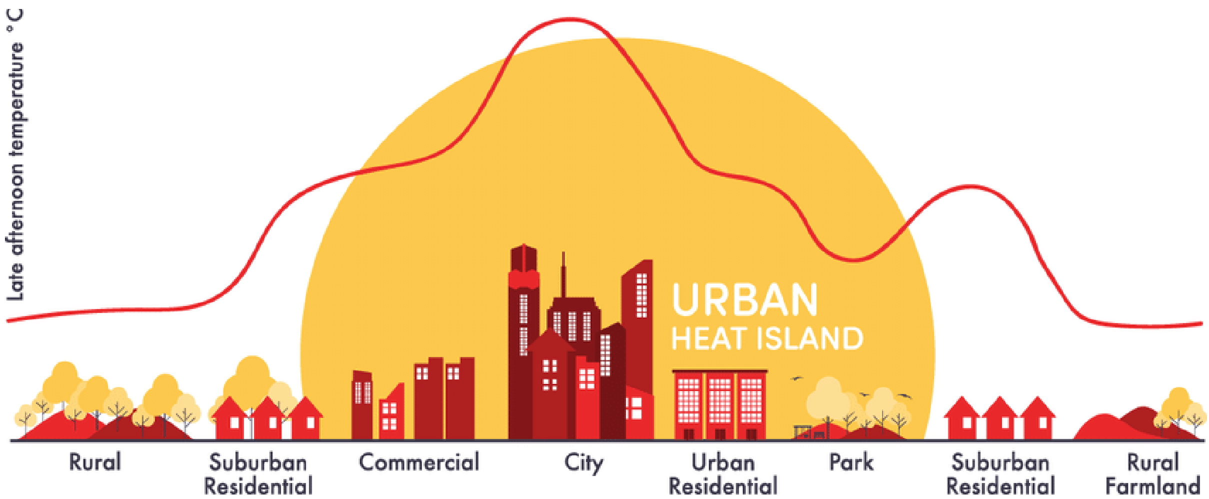


Fig. 1. Urban Heat Island effects upon different territorial environments. Source: Fuladlu et al., 2018.

KEY IDEAS

- Cities occupy only about 2% of the earth's surface but city dwellers consume over 75% of the total energy resources.
- UHIs occur when a densely populated urban area experiences significantly higher temperatures than the surrounding rural or less populated area.
- The heat island effect is related to the building materials of the city, and its ability to absorb and retain heat during the day, and emit it at night.
- Urban heat islands are an important issue because they can pose both health and environmental risks due to increased heat exposure and enhanced levels of air pollutants.

2. Background

2.1 History

Luke Howard, a British chemist and amateur meteorologist, was **the first to recognize the effect that urban areas have on local climate.** Between 1800-1830, Howard studied weather and climate in London and analysed temperature records through which he was able to detect and describe the urban heat island phenomenon many decades before any other researchers. His studies showed that temperatures in London, compared to those simultaneously measured in the surrounding countryside, were 3.7°F warmer at night, and cooler during the day (Mills, 2008). He attributed the concentration of smog (which he called 'city fog') to this phenomenon.

Since Howards first contributions towards studying urban heat islands, many researchers have been following his path. The makeup of urban areas differs across the world, causing the heat island effect to be magnified in certain locations rather than others due to geographic characteristics and variances. Researchers suggest the **annual mean air temperature of a city with one million or more people can be 1 to 3°C** (1.8 to 5.4°F) **warmer than its surroundings, and on a clear, calm night, this temperature difference can be as much as 12°C** (22°F) (U.S. EPA, 2008).

Sustained study of the urban climate effect did not begin until the late 1940's when researchers began to explore local variations in atmospheric properties, most notably air temperature. The table below presents a history of the field broken down by decade, with those contributions that represent critical developments in the field (Howard et al., 2009).

Period	Approach
1940-	Observation and description of urban effects using conventional meteor-ological equipment (e.g. thermometers).
1960-	Employment of statistical methods to test hypotheses; Move toward energy budget approach and explanation.
1970-	Application of computer modeling techniques; Observations of energy fluxes; More rigorous definition of urban 'surface', urban scales and observing urban effects.
1980-	Adoption of common urban forms for modeling and measurement; Use of scaled-physical models; Measurement of fluxes in different cities.
1990-	Establishing relationships between urban forms and their climate effect; Urban field projects examined by research teams.
2000-	Improved models of urban geometry; Increased links between modeling and measurement programs.

Fig. 2. Evolution of the UHI study in the 20th century. Source: Howard, 2007.

The work of Luke Howard has a special place in the history of the field because he is the first to recognize the UHI and because his analysis proves so prescient. The International Association for Urban Climate (IAUC) presents the Luke Howard Award to individuals that have made outstanding contributions to the field (Howard, 2007).

2.2 How are Urban Heat Islands and Climate Change related?

As it has already been explained, urban heat islands refer to the elevated temperatures in developed areas compared to more rural surroundings. The warming effect that results from urban heat islands is an example of **local climate change**. Local climate changes differ from global climate changes in that their effects are confined to the local scale and decrease with distance from their source. Global climate changes, such as those caused by excess greenhouse gas emissions, are not locally or regionally confined, though **the impacts from urban heat islands and global climate change are often similar**. For example, both urban heat islands and global climate change can increase energy demand, mainly through heating and cooling, and both can cause an increase in air pollution and greenhouse gas emissions.

Urban areas cover less than 3% of the global land area, and the area of extra heat is local and too small to have a direct impact on global climates. However, the UHI has relevance for the study of global climate change because **it makes it difficult to detect the influence of human activity on the global mean temperature**.

Many of the earliest established observation stations used to construct the globally averaged surface temperature record have initially been located near urban areas and their readings may have become contaminated by the UHI as settlements have grown over time. Some of the research on historical data indicates that global temperature trends are not significantly affected by the UHI and the effect on the global temperature trend is no more than 0.05°C through 1990 and not considered significant (e.g., Parker, 2006).

Others contend that attempts to adequately remove the urban effect, e.g., by using empirical relations between city size and UHI magnitude from urban-rural pairs together with population data or satellite measurements of night light used to classify urban and rural stations, may be inadequate and underestimate the urban effect (e.g., Kalnay and Cai, 2003).

Cities, however, **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, and, thanks to their intensive metabolism, they release 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, which are **transport, energy use in households and public buildings, and manufacturing and industry**, with each sector contributing about one-third of the total. Energy use is sensitive to temperature, and there is a **strong interdependence between the UHI and electricity demand** where fossil fuels are used to generate the electricity that is driving air conditioning. Electricity demand for cooling increases 3%–5% for every 1°C increase in air temperature above approximately 23°C ± 1°C (Sailor, 2002). This implies that a 5°C UHI can increase the rate of urban electric power consumption for cooling by 15%–25% above that used in surrounding rural areas during hot summer months and for cities located in (sub)tropical regions.

UHIs have impacts that range from local to global scales, which emphasize the importance of urbanization to environmental and climate change. Magnitude and rate of urban warming are comparable to that considered possible at the global scale, and any global warming will raise the base temperature on top of which the UHI effect is imposed. 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

- Sustained study of the urban climate effect did not begin until the late 1940's.
- Local climate changes differ from global climate changes in that their effects are confined to the local scale and decrease with distance from their source. UHI is an example of local climate change.
- UHI has relevance for the study of global climate change because it makes it difficult to detect the influence of human activity on the global mean temperature.
- Also, there is a strong interdependence between the UHI and energy demand. Cities have an indirect responsibility for the observed global warming as they are the major contributor of green-house gases.

2.3 The need for an urban focus on UHI and climate change adaptation in Europe

Climate change is upon us. With global temperature records being broken year after year and increasingly dire prospects for the magnitude of future climate change and its effects, in the 2020s the world and Europe have entered a new era. Unprecedented extreme weather and climate events — deadly heat waves, devastating droughts, sudden floods sweeping through city streets — are no longer tales from distant lands or far futures but a reality in the European context.

In November 2019, the European Parliament declared a global 'climate and environmental emergency' as it urged all EU Member States to commit to net zero greenhouse gas emissions by 2050 (EP, 2019). At the local level, the climate emergency was recognised by the mayors of 94 major global cities in September 2019 (C40 Cities, 2020). Despite the increasing awareness, the United Nations Environment Programme (UNEP) Emissions gap report 2019 found that, even if all countries' unconditional nationally determined contributions (NDCs) under the Paris Agreement are implemented, we are still on course for a 3.2 °C global temperature rise (UNEP, 2019). Therefore, as recognised by the proposed European climate law, which aims for climate neutrality by 2050 and enhanced climate resilience, **climate change is already creating and will continue to create significant stress in Europe, despite mitigation efforts**. Thus, increasing efforts to enhance adaptive capacity, strengthen resilience and reduce vulnerability are crucial (EC, 2020). The vulnerability of our society and the urgent need to increase its resilience to shocks have been brought home in 2020 by the coronavirus disease 2019 (COVID-19) crisis.

The sense of urgency in addressing climate change is felt by European citizens, too: 2019 will be remembered as the first year when school children initiated climate strikes out of concern for their future. The number of Europeans who consider climate change to be a very serious problem — currently 8 out of 10 — has grown over the past few years, and over two thirds of Europeans believe that adapting to the adverse impacts of climate change can have positive outcomes for EU citizens (EC, 2019).

Cities, towns and other human settlements are particularly important locations for urgent implementation of adaptive measures. As we have already seen, urbanisation is one of the main causes of increased local temperatures, and changes in temperature lead to an increase in energy demand, which, at the same time, raises anthropogenic emissions. What constitutes a challenge is that the proportion of Europeans living in urban areas is expected to increase from nearly 75 % in the present moment to over 80 % by 2050 (Eurostat, 2016). This evidence makes Urban Heat Islands a growing phenomenon.

Adaptation of cities is also necessary from an economic perspective. Urban areas host industry and services and are focal points of economic activity, generally characterised by high values of gross domestic product (GDP) per capita (Lavalle et al., 2017). Failure of climate change mitigation and adaptation was in 2019 seen as the number one risk to the economy in terms of its impact, and the second biggest risk in terms of likelihood of occurrence within the next 10 years, according to the World Economic Forum (WEF) multistakeholder survey. Since 2017, extreme weather has been assessed in the Global risks report as having the highest likelihood among the threats to the economy (WEF, 2020).

KEY IDEAS

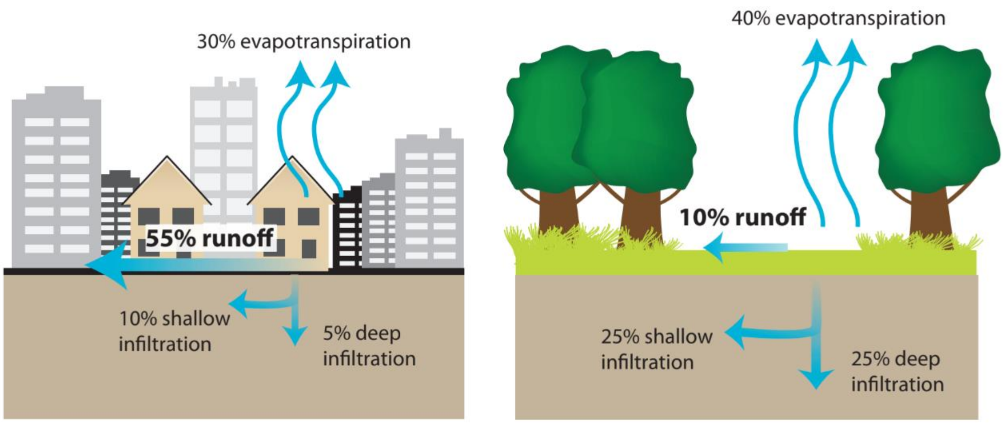
- Climate change is happening, projected to continue and posing serious challenges for cities.
- Urban areas are the places in Europe where most people are, and will be, vulnerable to the effects of climate change. UHI will be a growing phenomenon as urbanization is expected to increase.
- Europe's future depends on strong and resilient cities - towards a joint, multi-level approach to cope with climate change.

3. Causes: How do Urban Heat Islands form?

3.1 Reduced vegetation in urban areas

The UHI effect results from the interaction of different physical processes. One of the main causes of UHI is the reduced vegetation in urban areas.

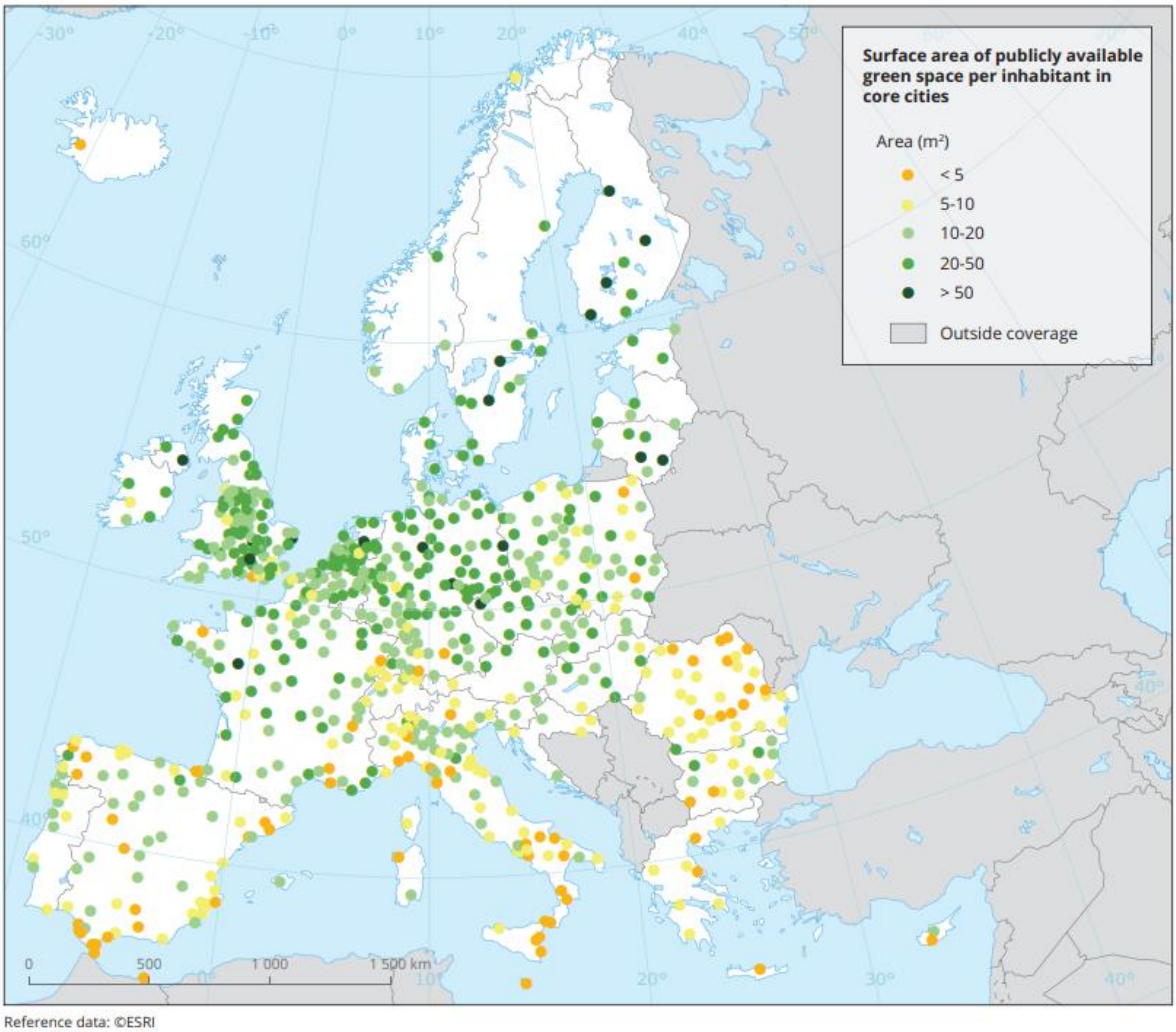
In rural areas, vegetation and open land typically dominate the landscape. Trees and vegetation provide shade, which helps lower surface temperatures. They also help reduce air temperatures through a process called evapotranspiration, in which plants release water to the surrounding air, dissipating ambient heat. In contrast, **urban areas are characterized by dry, impervious surfaces, such as conventional roofs, sidewalks, roads, and parking lots**. As cities develop, more vegetation is lost, and more surfaces are paved or covered with buildings. The change in ground cover results in less shade and moisture to keep urban areas cool. Built up areas evaporate less water (see Figure 3), which contributes to elevated surface and air temperatures.



Highly developed urban areas (right), which are characterized by 75%-100% impervious surfaces, have less surface moisture available for evapotranspiration than natural ground cover, which has less than 10% impervious cover (left). This characteristic contributes to higher surface and air temperatures in urban areas.

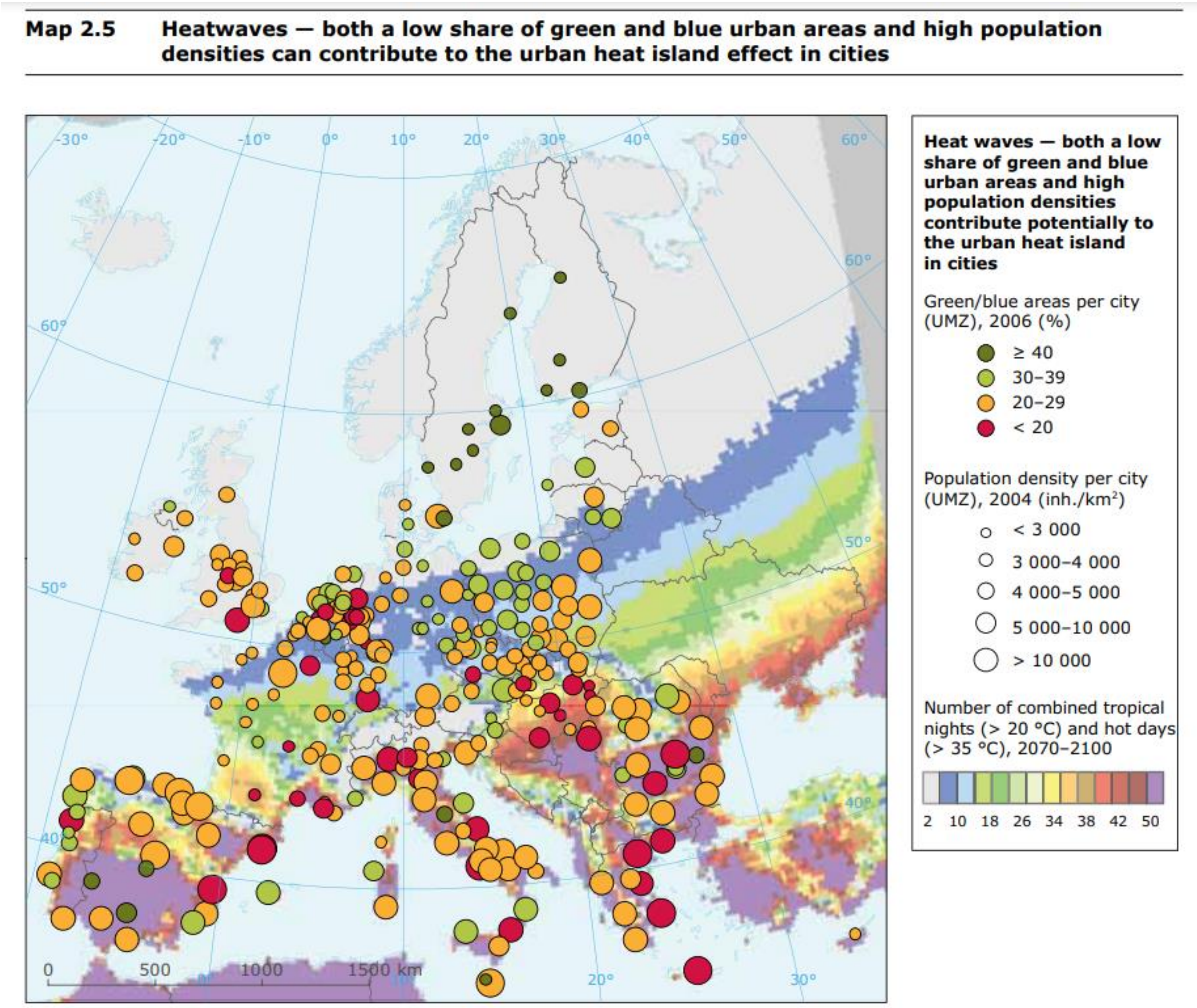
Fig. 3. Urban Heat Island effect upon different territorial spaces. Source: Filho et al., 2018.

At present, around 40 % of the surface area of European cities consists of green space, with an average of 18.2 m2 of publicly accessible green space per inhabitant. Only 44 % of Europe's urban population currently lives within a walkable distance (300 m) of a public park (Maes et al., 2019).



Map 1. Surface area of publicly available green space per inhabitant in core cities. Source: EEA, 2020, adapted from Maes et al., 2019.

Notwithstanding, the presence and accessibility of green areas (both public and private) varies greatly between countries and between individual cities. According to the 2016 European Quality of Life Survey, **the highest numbers of people with difficult access to recreational or green areas were in Albania, Turkey, Romania, and the lowest numbers were in Denmark, Sweden and Finland** (Eurofound, 2016). The access to publicly available green space shows a North-South disparity in Europe (see Map 1). Therefore, in some of the cities where the highest increase in frequency of heatwaves is projected (Map 1), poor access to green space may deprive the urban population of an effective cooling mechanism.



Map 2. Green areas and blue areas (with water bodies) per city. Source: EEA, 2006.

3.2 Materials

Properties of urban materials, in **particular solar reflectance, thermal emissivity, and heat capacity**, also influence urban heat island development, as they determine how the sun's energy is reflected, emitted, and absorbed.

The following figure shows the typical solar energy that reaches the Earth's surface on a clear summer day. Solar energy is composed of ultraviolet (UV) rays), visible light, and infrared energy, each reaching the Earth in different percentages:

- 5 percent of solar energy is in the UV spectrum, including the type of rays responsible for sunburn.
- 43 percent of solar energy is visible light, in colours ranging from violet to red.
- 52 percent of solar energy is infrared, felt as heat.

Energy in all these wavelengths contributes to urban heat island formation.

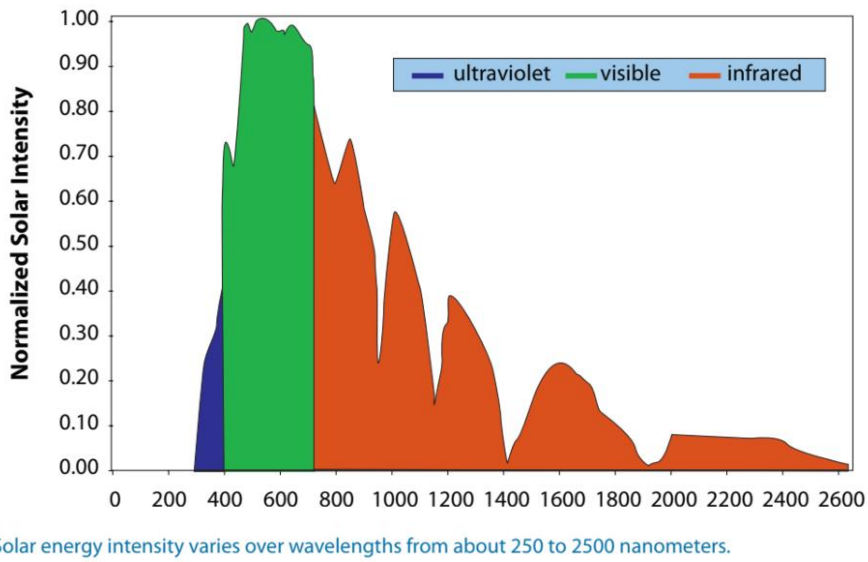


Fig. 4. Solar Energy versus Wavelength Reaching Earth's Surface. Source: EPA, 2017.

Solar reflectance, or albedo, is the percentage of solar energy reflected by a surface. Much of the sun's energy is found in the visible wavelengths; thus, solar reflectance is correlated with a material's colour. **Darker surfaces tend to have lower solar reflectance values than lighter surfaces**. Researchers are studying and developing cool coloured materials, though, that use specially engineered pigments that reflect well in the infrared wavelengths. These products can be dark in colour but have a solar reflectance close to that of a white or light-coloured material.

Urban areas typically have surface materials, such as roofing and paving, which have a lower albedo than those in rural settings. As a result, **built up communities generally reflect less and absorb more of the sun's energy**. This absorbed heat **increases surface temperatures** and contributes to the formation of surface and atmospheric urban heat islands (EPA, 2017).

Although solar reflectance is the main determinant of a material's surface temperature, **thermal emittance**, or emissivity, also plays a role. Thermal emittance is a measure of a surface's ability to shed heat or emit long-wave (infrared) radiation. All things equal, surfaces with high emittance values will stay cooler, because they will release heat more readily. Most construction materials, except for metal, have high thermal emittance values. Thus, this property is mainly of interest to those installing cool roofs, which can be metallic.

Another important property that influences heat island development is a **material's heat capacity**, which refers to its ability to store heat. Many building materials, such as steel and stone, have higher heat capacities than rural materials, such as dry soil and sand.

As a result, cities are typically more effective at storing the sun's energy as heat within their infrastructure. Downtown metropolitan areas can absorb and store twice the amount of heat compared to their rural surroundings during the daytime.

3.3 Heating and cooling energy needs

The formation of UHIs is not only due to a city's fabric. **Heat emitted by human activities - such as cooling or heating of buildings, industrial processes, and transportation - also plays a key role**. These anthropogenic heat emissions can increase air temperatures by approximately 1-3°C (Ma et al., 2017). Although anthropogenic heat emission is generally larger in winter, **the negative impact is strongest in summer during heat waves,** when already high temperatures are being increased even further.

One of the summer sources of anthropogenic heat emissions is **air conditioning systems**. Although they improve indoor conditions through cooling, air conditioning systems can negatively influence the outdoor urban microclimate due to their emission of waste heat in the urban canyon. Modelling studies have shown that during prolonged heat periods, air conditioning usage can increase urban air temperatures up to 3°C locally (de Munck et al. 2013).

Air conditioning usage in cities increases	Energy demand increases	Increase of climate change and UHI effect
Due to rising temperatures and prolonged heat wave events, high demand for cooling of indoor spaces has arisen	The growing use of air conditioners in homes and offices around the world is expected to be one of the top drivers of global electricity demand over the next three decades	Air conditioning systems further add to the UHI effect as the waste heat generated by these systems increases local temperatures in built-up areas

Table 1. Anthropogenic heat feedback cycle, based on ZAMG & Hollósi and de Wit, 2020.

3.4 Additional factors

Weather and location strongly influence urban heat island formation. While residents have little control over these factors, communities can benefit from understanding the role they play.

Weather	Geographic location
Two primary weather characteristics affect UHI: wind and cloud cover. In general, urban heat islands form during periods of calm winds and clear skies, because these conditions maximize the amount of solar energy reaching urban surfaces and minimize the amount of heat that can be convected away. Conversely, strong winds and cloud cover suppress UHI.	Climate and topography, which are in part determined by a city's geographic location, influence UHI formation. For example, large bodies of water moderate temperatures and can generate winds that convect heat away from cities. Nearby mountain ranges can either block wind from reaching a city, or create wind patterns that pass through a city. Local terrain has a greater significance for heat island formation when larger-scale effects, such as prevailing wind patterns, are relatively weak.

Table 2. Additional factors contributing to UHI.

4. Urban Heat Islands in Europe

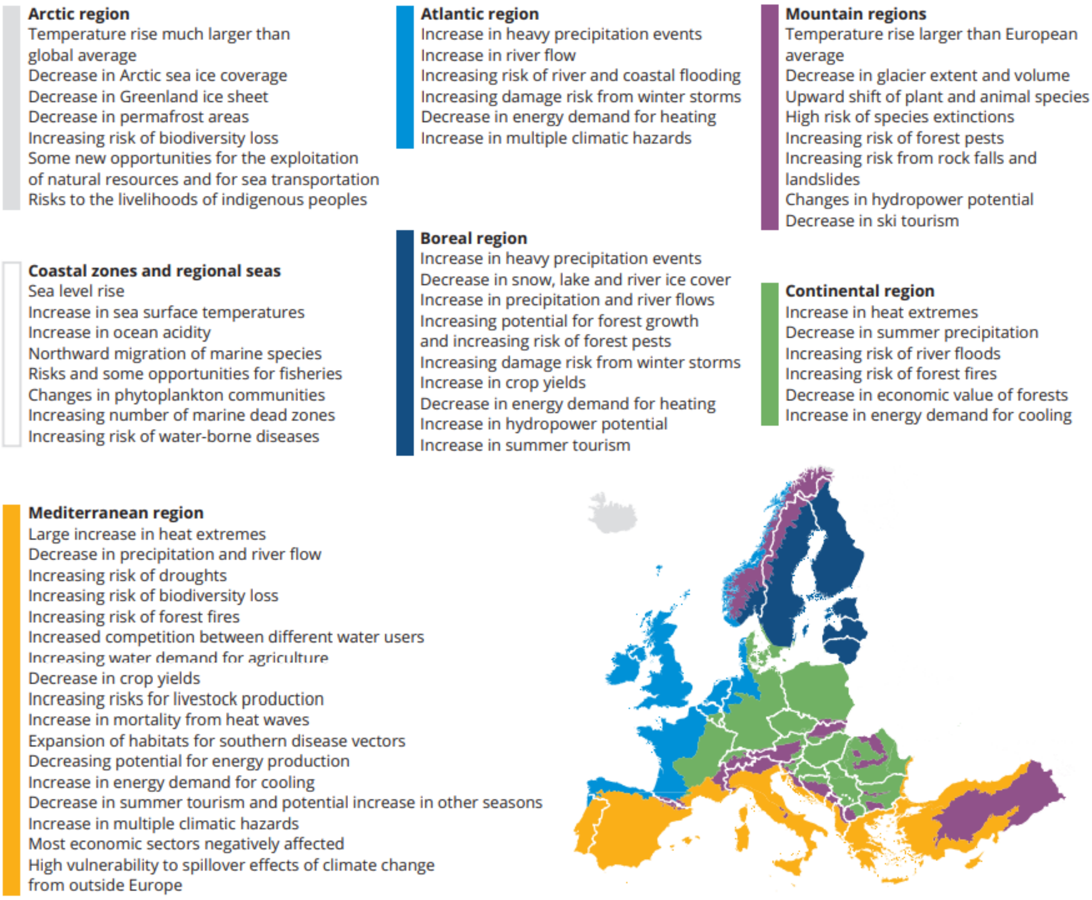
4.1 Overview of climate-related risks to European cities

The key climate change hazards and impacts in Europe, both present and projected, vary among regions (EEA, 2017b).

Boreal region	Atlantic region	Mediterranean region	Continental region
Projections suggest a larger than average temperature increase, in particular in winter, an increase in annual precipitation and river flows, less snow and greater damage from winter storms. More frequent and intense extreme weather events are projected to have an adverse impact on the region.	The low-lying coastal areas have been affected by coastal flooding in the past and these risks are expected to increase as a result of sea level rise and potentially storm surges. Stronger extreme precipitation events, in particular in winter, are projected to increase the frequency and intensity of winter and spring river flooding, urban floods and associated impacts.	It is facing decreasing precipitation and increasing temperatures, in particular in summer. The competition between different water users over decreasing water resources is expected to increase. Forest fires and adverse impacts of heat on human health and well-being are expected to increase, alongside propensity for vector-borne diseases.	Increasing heat extremes are a key hazard. Together with reduced summer precipitation, they can increase drought risk, health risks and energy demand in summer.

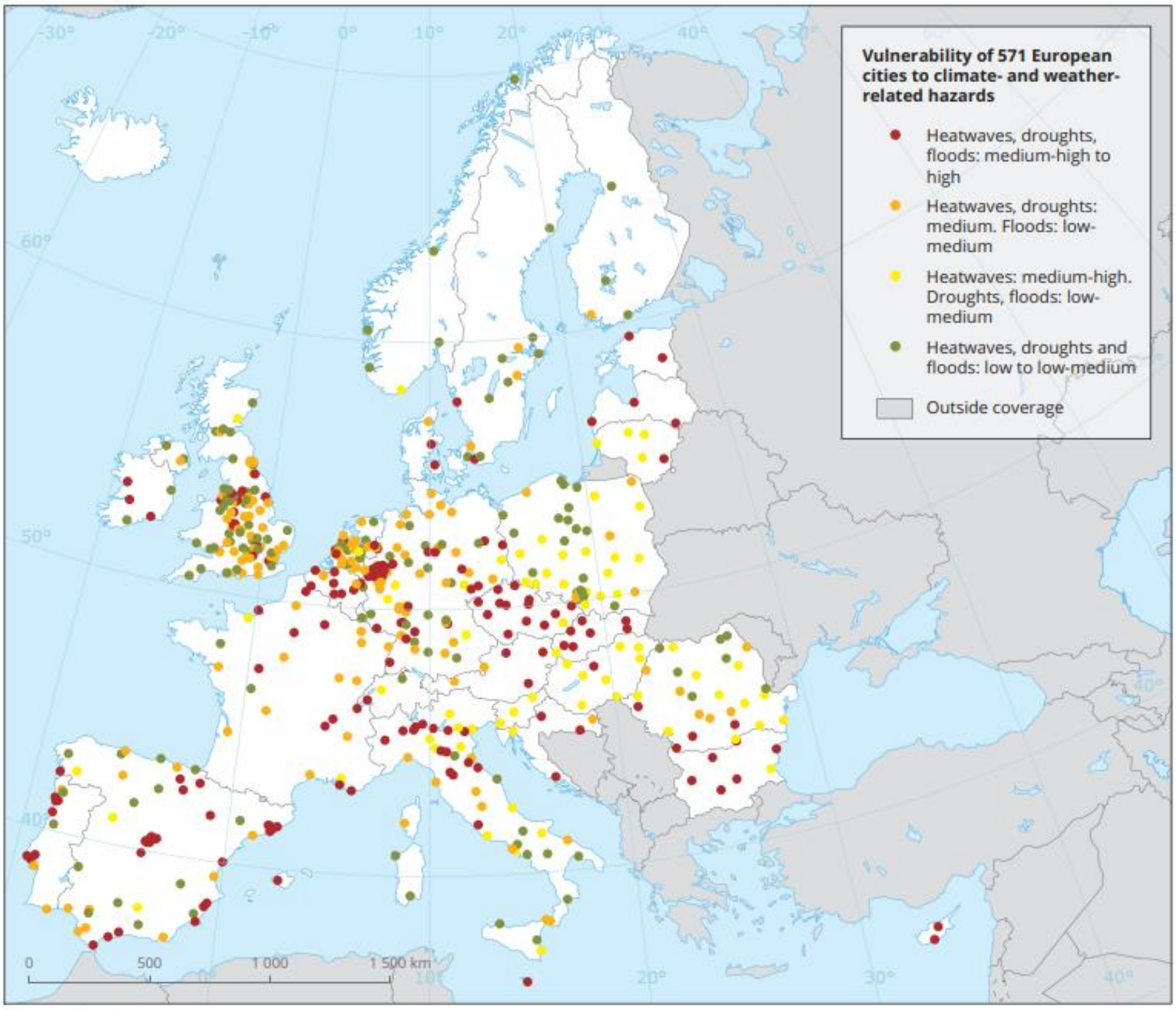
Table 3. Climate change hazards and impacts in Europe among regions, based on EEA 2017.

A more detailed description of the different climate-related risks is provided in the following map:



Map 3. Key observed and projected climate change and impacts for the main biogeographical regions in Europe. Source: EEA, 2020.

Within the framework of the Horizon 2020 research project Reconciling adaptation, mitigation and sustainable development for cities (Ramses), Tapia et al. (2017) assessed the vulnerability of 571 European cities using a range of indicators from thematic domains. The cities were clustered according to their vulnerability to heatwaves, flooding and droughts. According to this analysis, it is difficult to identify clear spatial patterns of vulnerability among European cities. **The cities with high levels of vulnerability to all hazards are more numerous in central Europe, Estonia, parts of Germany, Latvia and Romania but also scattered throughout Europe.**



Map 4. Vulnerability of 571 European cities to climate- and weather-related hazards. Source: EEA, 2020, based on Tapia et al., 2017.

4.2 High temperatures

Climate projections for Europe show a temperature increase across the continent, the strongest seasonal warming occurring during summer in southern Europe and during winter in northern Europe (IPCC, 2014). In particular, the projections show a marked increase in temperature extremes, leading to an increase in the number, frequency, and intensity of heatwaves.

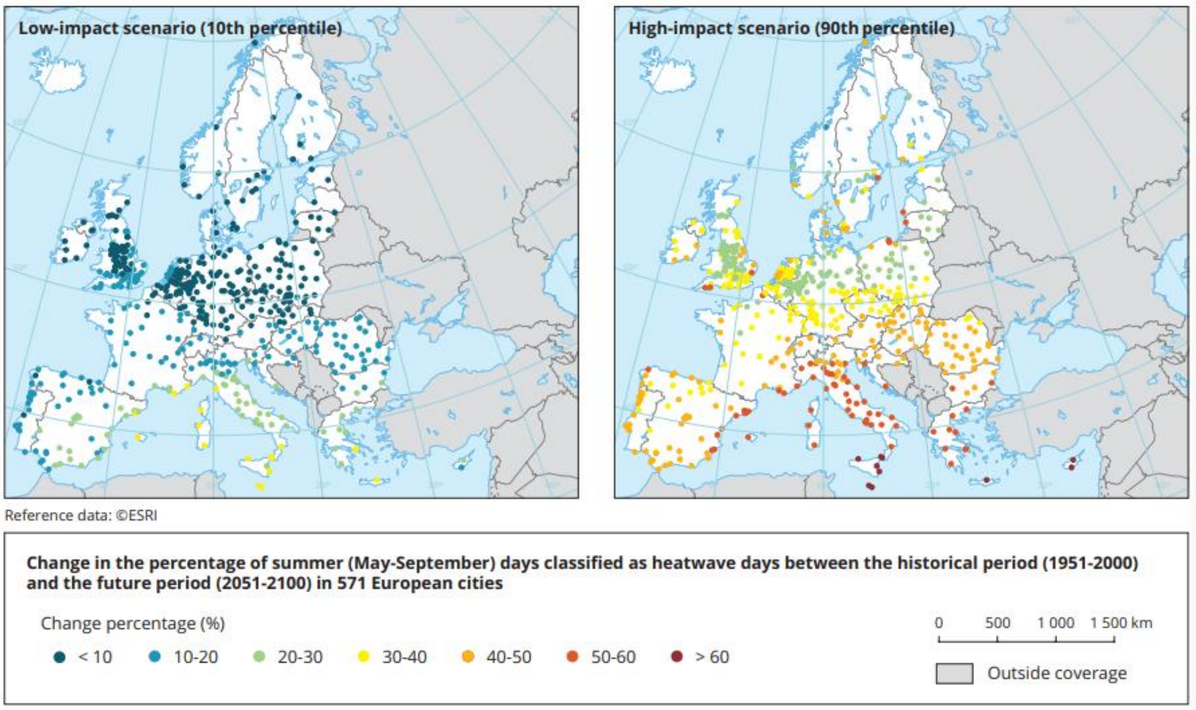
With the need to develop a good study of urban heat islands and how they impact society, it's necessary to clarify exactly what a heat wave is and what defines it. According to the World Health Organization (WHO) and World Meteorological Organization (WMO), there is no consensus on the definition of a heat wave, however, as an operational definition it is understood as an unusually **hot, dry or humid period, day or night, that begins and ends abruptly, lasting for at least two to three days, with discernible impact on humans and natural systems.**

Under a high-emissions scenario, by the end of the century 90 % of the summers in southern, central and north-western Europe will be warmer than any summer from 1920 to 2014, with the most severe health risks for southern Europe and the Mediterranean coasts, where many densely populated urban centres are located (Lehner et al., 2016). In the second half of the 21st century, under the RCP 8.5 scenario, very extreme heatwaves are projected to occur as often as every 2 years (Russo et al., 2014).

For some cities, the projected temperature increases are much higher than the computed global averages. Under the RCP 8.5 scenario, by the end of the century, many cities (e.g. Bucharest, Madrid and Zagreb) are likely to experience average temperatures of up to 7 °C in the hottest months compared with current conditions (Milner et al., 2017); for some cities, the number of heatwave days is expected to increase by a factor of 10 (Lauwaet et al., 2015; Wouters et al., 2017).

4.3 Heatwaves

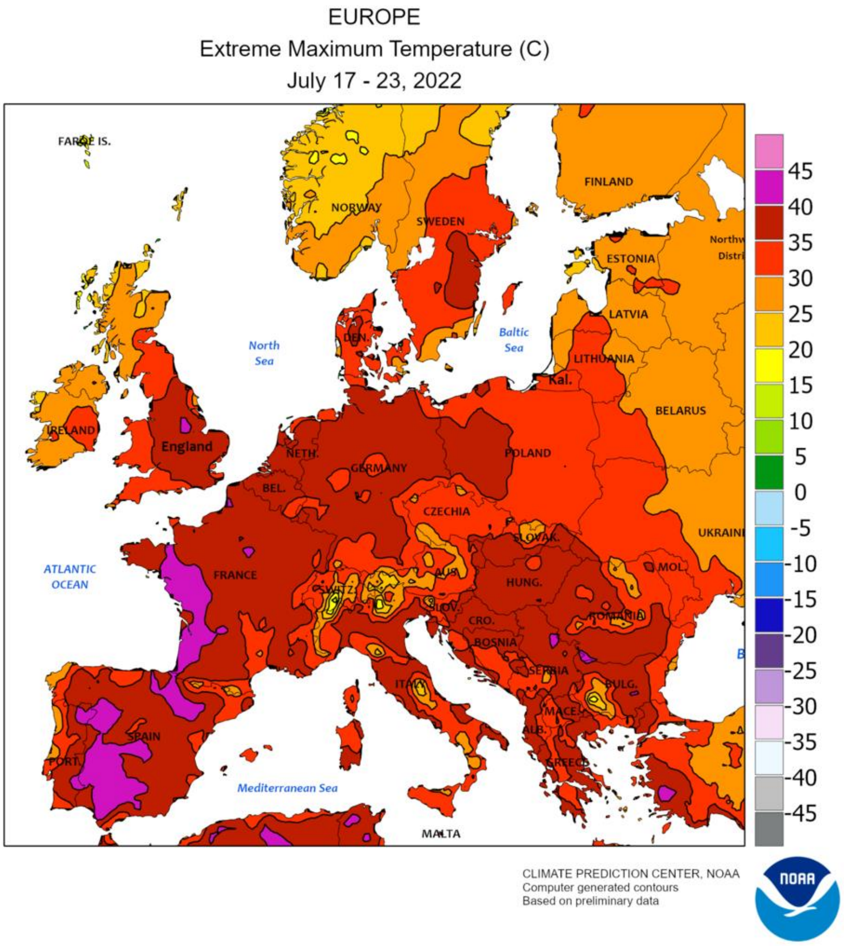
European countries are strongly affected by heat waves; this natural hazard causes more deaths in Europe than any other. However, according to Guerreiro et al. (2018), **cities in southern Europe will see a larger increase in the number of heatwave days** (Map 5). The projected increase in the number of heatwave days ranges from 4 % in Trondheim (Norway) for the low-impact (10th percentile) scenario to 69 % in Lefkosia (Cyprus) for the high-impact (90th percentile) scenario. However, **increases in maximum temperature during heatwaves are expected to be larger in cities located in central Europe** (Guerreiro et al., 2018).



Map 5. Change in the percentage of summer (May-September) days classified as heatwave days between the historical period (1951-2000) and the future period (2051-2100) in 571 European cities. Source: EEA (2020), adapted from Guerreiro et al. (2018).

Recent examples of heat waves include the record-breaking heat wave in Europe in 2003 and the Russia heat wave in 2010, which caused unprecedented heat-related death tolls (Schär & Jendritzky, 2004; Russo et al., 2015). The August 2003 heat wave caused more than 14,800 deaths in France, while Belgium, the Czech Republic, Germany, Italy, the Netherlands, Portugal, Spain, Switzerland, and the United Kingdom all reported high excess mortality rates (Confalonieri et al., 2007). **European countries were also affected by heat waves during the summer of 2015, 2019** (NOAA, 2015; WMO, 2019), **and 2022**, when record maximum temperatures were recorded. Southern and southeastern Europe was greatly affected by the heat wave of 2017 (Kew et al., 2018). The 2022 heat waves affected certain parts of Europe, causing evacuations and heat-related deaths. The highest temperature recorded until now in the continent was 47.0 °C (116.6 °F) in Pinhão, Portugal, on 14 July. In September 2022 it was reported that the European Union saw 53,000 excess deaths in July, although no causal link was attributed. Oficial losses include 26,304 deaths: France 11,000; Germany 8,138; United Kingdom 3,200; Spain 2,894; Portugal 1,063; Ireland 6; Poland 3 (EU, 2022).

Below, the map shows the July 2022 heatwave that heavily affected Europe, and broke all records of previous highest temperatures.



Map 6. Extreme Maximum Temperature of the Heat Wave in July 17 to 23, 2022. Source: Climate Prediction Center, NOAA (2022).

Analysis of the impact of extreme thermal conditions on mortality in Croatia showed that mortality during warm events is more pronounced than during cold events. The prolonged effect of high temperatures can significantly **increase mortality**, which was the highest during the first three to five days of extreme heat (Zaninovic & Matzarakis, 2013). A proportion of the deaths during heat waves can be attributed to very ill people, who might have lived longer without the heat stress situation (Confaloniere et al., 2007).

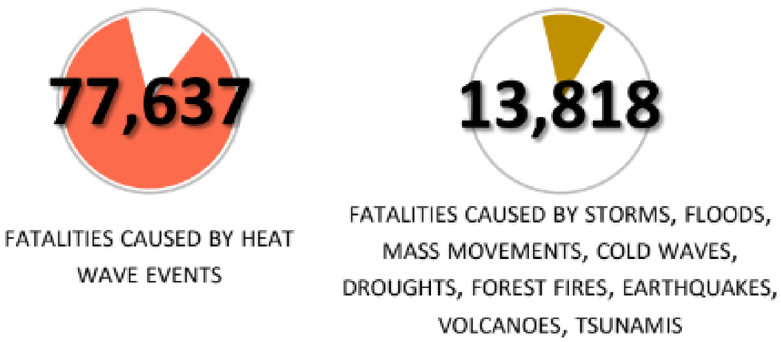


Fig. 4. Of all the natural hazards affecting the EEA member states in the period 1980-2017, heat waves account for some 68 percent of the fatalities and about five percent of total economic losses. Source: EEA, 2019.

A study of three heat wave events affecting the city of Cluj-Napoca in Romania in 2015 also shows **economic losses related to heat waves.** The estimated potential loss reached more than €2.5 million for each heat wave day, totaling more than €38 million for the three cases considered (Herbel et al., 2018).

KEY IDEAS

- Europe is strongly affected by heat waves, and the UHI effect enhances the excessive heat in cities during heat waves.
- Heat waves cause more deaths in Europe than any other natural hazard.
- Economic losses related to heat waves are huge and need to be considered.

4.4 The UHI effect

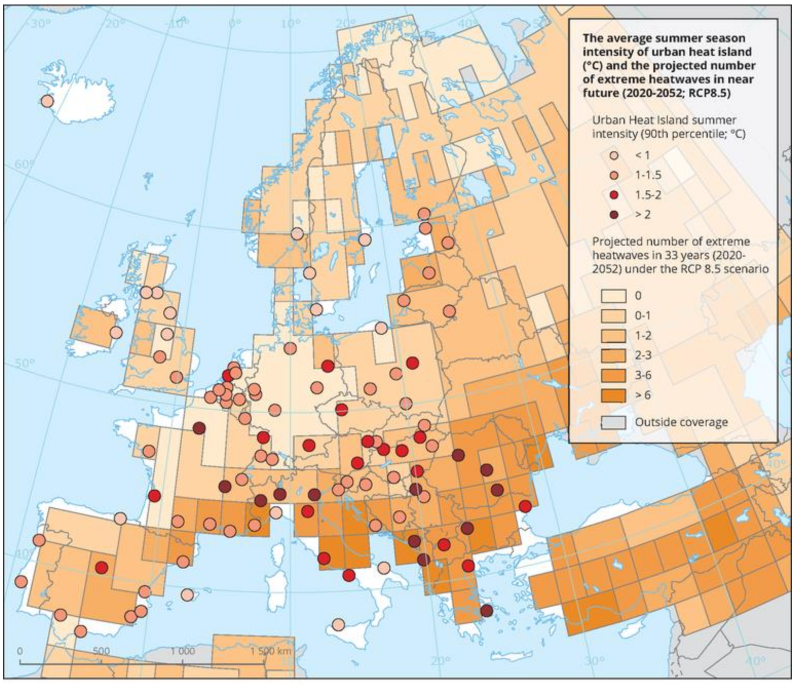
The UHI effect is strongly linked to climate conditions (the average wind speed and the number of sunny days), so a strong north-south gradient is present among the European cities. **The UHI effect is particularly strong in some of the locations that are projected to experience a dramatic increase in the number of extreme heatwaves** (see Map 7). These include cities in **south-eastern Europe,** such as Tirana (Albania), Sofia (Bulgaria) or Podgorica (Montenegro), **central EU and the Baltic republics**. However, predicted future heat waves will hit specially the coast of the Mediterranean.

Studies in Central Europe show that **maximum UHI values can develop during night** (Santamouris, 2007). Maximum UHI intensity varies between 1-12°C and the highest values correspond to anticyclonic periods of weather, while much larger variations (more than 10-15°C) are rarely observed due to local wind circulation reinforcement that mixes air and limits the extent of UHI.

The UHI effect is a typical feature associated with urban climate that enhances the excessive heat in cities during heat waves, and has negative impacts on people's health and city functions. The presence of cities more vulnerable to heatwaves mainly in the southern and central EU and the Baltic republics is linked to a combination of elderly populations, high air pollution levels and small average dwelling sizes.

Heat waves and extreme temperatures are an increasing concern for many cities across Europe and globally. Extreme temperatures are among the deadliest hazards in Europe. Between 1980 and 2017, heatwaves accounted for 68 percent of natural hazard-related fatalities among the European Economic Area countries and five percent of economic losses. The increase in the intensity and frequency of heat events is linked to global climate change, which poses a serious challenge for urban areas in Europe.

The following map presents the projected number of extreme heat waves in the near future across Europe and the summer intensity of the urban heat island effect in 100 European cities.



Reference data: ©ESRI

Map 7. The summer season intensity of urban heat islands (°C) and the projected number of extreme heatwaves in the near future (2020-2052; RCP 8.5). Source: EEA (2019); VITO (2019).

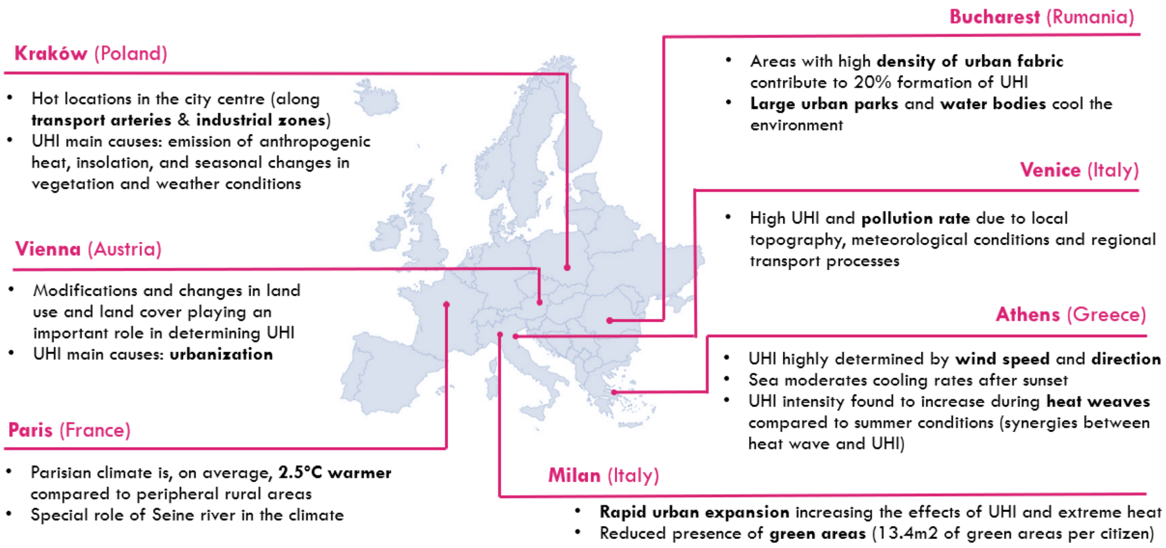
KEY IDEAS

- Heatwaves claim more human lives than any other weather-related disasters, and UHI exacerbates the risks to vulnerable populations.
- While temperatures are projected to rise across Europe, cities in south-eastern Europe face the highest projected increase in the frequency of heatwaves combined with the lowest provision of green space and the most pronounced urban heat island (UHI) effect.
- Climate change is conducive to the incidence of vector-borne diseases in Europe, in particular in the south. Higher urban temperatures improve the climatic suitability for vectors such as the tiger mosquito, contributing to the risk of disease spread.

5. UHI case-by-case: some European examples

In this section, general descriptions on how UHI is caused and its effects on different European cities is presented, with the main objective of understanding the multiple elements that affect this climate-related phenomenon as well as its consequences.

First, a map with the summarised information is provided:



Map 8. UHI in different European cities. Source: own elaboration.

Kraków

- Hot locations are mainly in the city centre, along the main transport arteries and industrial zones.
- The thermal structure is influenced by emission of anthropogenic heat, insolation of the surfaces, and seasonal changes in vegetation and weather conditions.
- Despite relatively small height differences in the city's buildings (about 100 m), relief is an important factor, as it forces the formation of a cold air lake in the valley floor (outside densely urbanised areas) and air temperature inversion.

Vienna

- Modification and changes in land use and land cover play an important role in determining local climate
- Building construction and increasing soil sealing lead to intensification of the UHI effect.
- City growth induces higher heat load, which in the future is expected to superimpose on regional climate warming, and can lead to long-term consequences.

Venice

- The climate of Venice has a seasonal pattern: temperature rises in summer and contributes to increasing levels of temperature, demands on cooling systems, and health problems related to both mixing and dispersion of pollutants.
- Several studies have shown that the local topography and meteorological conditions, natural and anthropogenic emissions and regional transport processes, make this area one of the most polluted in Europe.

Paris

- The nocturnal UHI is concentrated over the city centre and the densely built-up suburbs but rapidly decreases and becomes insignificant (i.e. less than 0.5 C) beyond 5 km from the city core.
- At night there is a heat release from urban infrastructures that is mostly observed in dense urban areas. Inversely during the day, the city centre is less affected by UHI, because it is partially protected from incident radiation due to shading effects related to the high building density.
- The residential districts undergo cumulative effects of urban warming and soil drying under heat

wave conditions.
- At night, the maximum UHI reaches 2.84 C for the city centre compared to the surrounding countryside.
- Great proportion of inhabitants are affected by UHI (PUHI = 42% in this case).

Milan
- Increase of mean air temperature for Milan from 1900 to 2000
- Rapid urban expansion which enhances the effects of extreme heat
- Reduced presence of green areas: on average only 13.4 m2 of green areas for ever citizen, approximately the 9% of the total size of the city terrain

Bucharest
- Highly urbanised areas change the characteristics of the active surface and, in such a way, alter the natural climate of the area, deviating daily, monthly and yearly means of temperature and humidity, changing wind speed and direction.
- Points with high density of urban fabric have certain locations within a city that contribute with a proportion of 20% to the formation of urban heat islands.
- Some elements of spatial context such as large urban parks or water bodies can alter the relationship between density of urban fabric and temperature.

Athens
- UHI amplitude is highly determined from the wind speed and direction but also the daily maximum ambient temperature.
- The daily maximum UHII and the daily maximum ambient temperature are not necessarily synchronized, although they usually occur around afternoon hours.
- The synoptic wind largely determined the development or not of sea breeze at the coastal sites, influencing the amplitude of UHI.
- The higher heat capacity of water at coastal sites establishes more stable conditions, moderating cooling rates after sunset.
- The UHI intensity was found to increase during heatwaves, contributing to synergies between HWs and UHI.

6. Effects: Why do we care about Urban Heat Islands?

Urban populations are expected to increase by 2–3 billion by 2050, but we have limited understanding of how future global urban expansion will affect urban heat island (UHI) and hence change the geographic distributions of extreme heat risks. This is why shedding light on the multiple effects of this phenomenon is not only interesting but also necessary.

Elevated temperatures from heat islands can affect a community’s environment and quality of life in multiple ways.

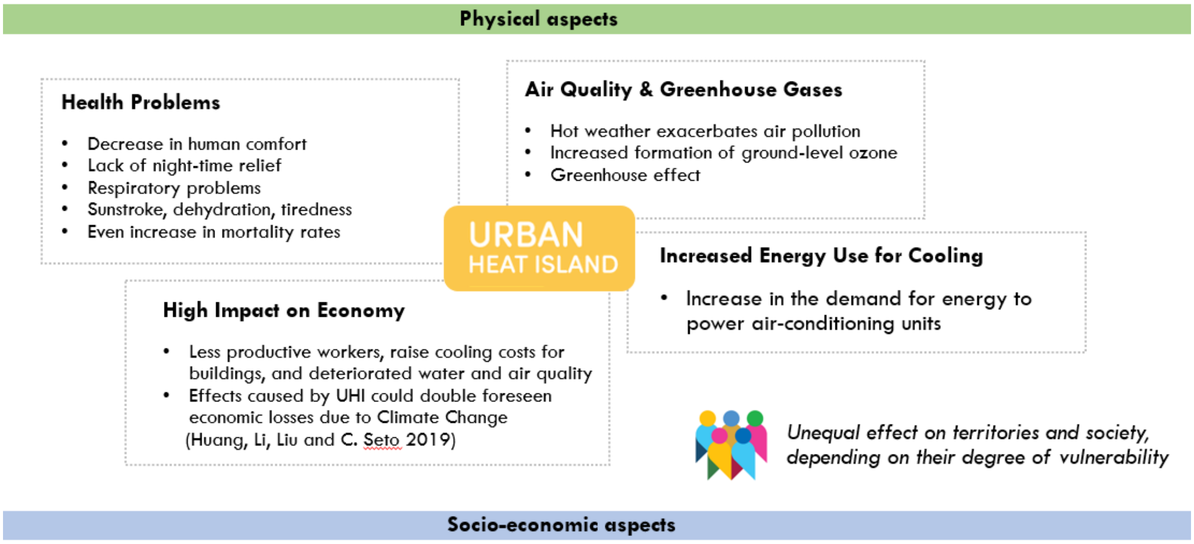


Fig. 5. Effects of UHI, from physical to socio-economic aspects. Source: own elaboration.

6.1 Human Health

Urban residents are exposed to high heat-related risks in a changing climate. Besides experiencing the effects of global temperature rise, they experience local temperature increase due to the UHI effect.

Increasing temperatures decrease human comfort in hot climates and raise mortality rates at temperatures outside an optimum range. People living in urban areas exposed to the UHI are at greater risk than those in nonurban regions. In many parts of the world, heat already has a devastating impact on human health, and excessive heat events (heat waves) have led to many deaths in many large, midlatitude cities (e.g., Athens, Chicago, New York, Paris, Philadelphia, Rome, Shanghai, and Seoul), making it the most important weather-related killer. Higher minimum temperatures due to the UHI and subsequent lack of night-time relief exacerbate the heat wave process and likely increase heat stress and mortality. Air conditioning seems to have a positive effect in reducing heat-related deaths, but waste heat emitted by air conditioning is also contributing to the UHI (Cooling Singapore, 2017).

The impacts that these heat situations generate in cities have an impact on both the **physical and mental health of people**. Also, there are indirect impacts, like increase in accidents, loss in labour productivity, increased risk of forest fires, impacts on water resources, transport restrictions, agricultural losses… Regarding the health effect of the maintained heat waves of the UHI, it affects particularly **vulnerable groups**.

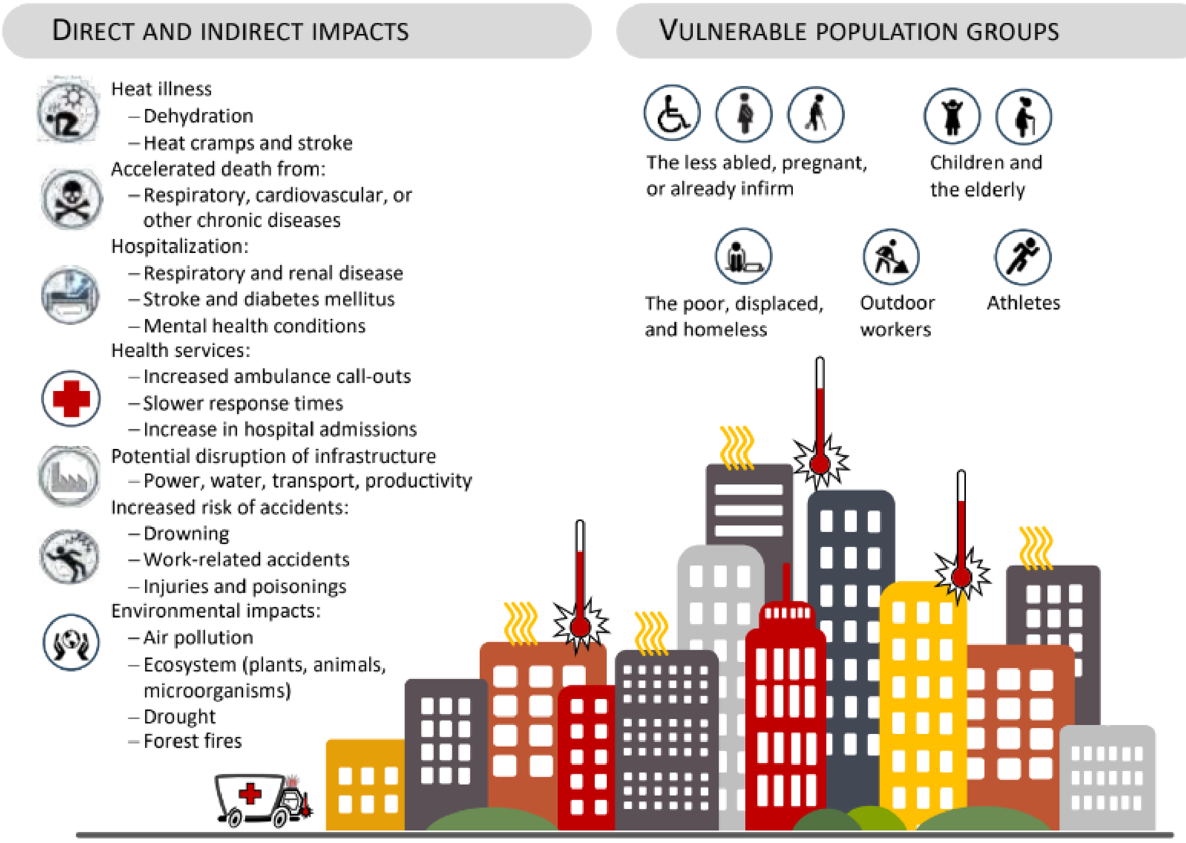
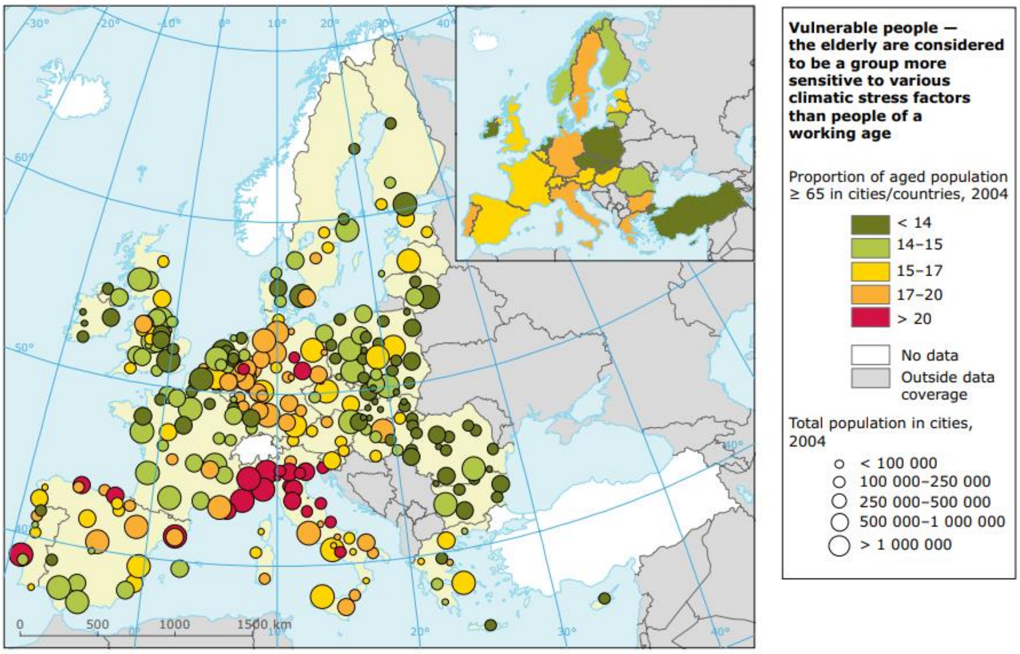


Fig. 6. Direct and Indirect impacts of heat waves and UHI effects on people. Source: Analysis of Heat Waves and Urban Heat Island Effects in Central European Cities and implications of Urban Planning.

Vulnerable groups include the **elderly, due to changes in their thermoregulatory system, as well as infants, whose thermoregulation is still immature and whose dependency level is high**. In addition, **workers** who might be exposed to extreme heat all day, as well as pregnant women, people with chronic diseases, and sick and poor people, are at high risk during heat waves. Housing conditions and social isolation are additional risk factors. Living in a poorly insulated building or on the top floor can aggravate the situation and pose additional risk factors, since the living space cannot be kept cool. Social isolation may lead to a delay when help or medical care is needed.

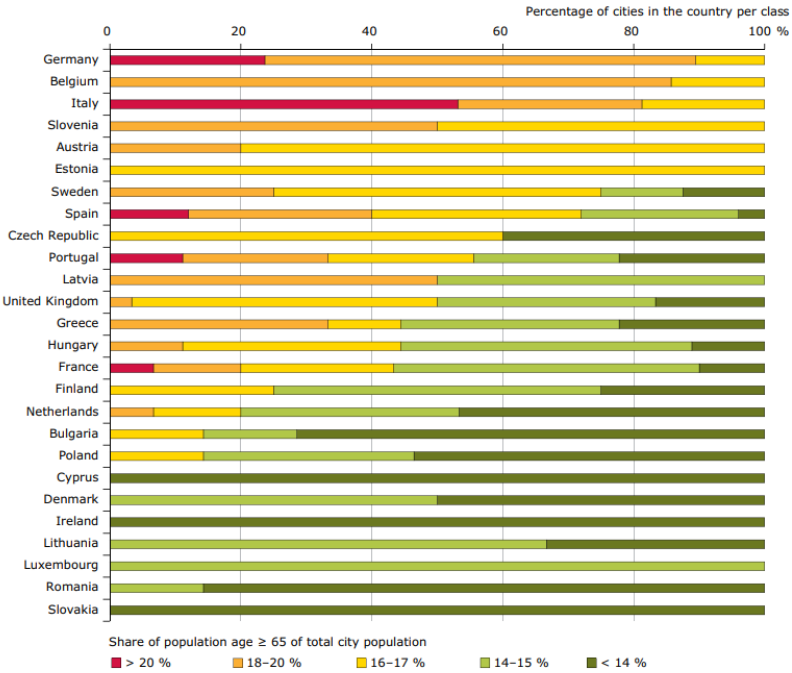


Note: Total population in cities; proportion of population aged ≥ 65.
Data for Bulgaria, Cyprus, Czech Republic, Finland, France, Ireland and Latvia are from 2001.

Source: Eurostat, Urban Audit database, 2004.

Map 9. Proportion of aged population (65 years or more) in cities/countries, 2004. Source: EEA, 2017, extracted from Eurostat, Urban Audit database, 2004.

Figure 2.3 Percentage of population aged ≥ 65 — share of cities per class per country (based on Map 2.7)



Note: Generally, only cities with more than 100 000 inhabitants are considered.

Fig. 7. Proportion of aged population (65 years or more) in cities/countries, 2004. Source: EEA, 2017, extracted from Eurostat, Urban Audit database, 2004.

6.2 Air Quality and Greenhouse Gases

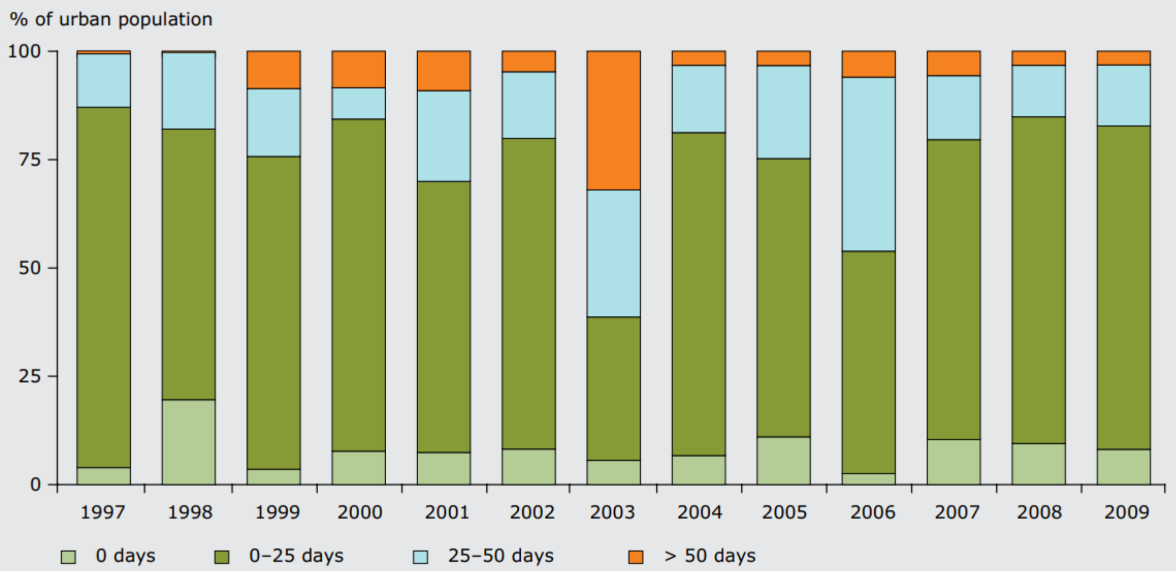
Air pollution in urban areas places additional stress on humans, and some pollutants have synergies with heat (Nawrot et al., 2007). Hot weather exacerbates air pollution through increased formation of ground-level ozone and, because periods with high temperatures usually coincide with dry periods, more particulate matter remains in the air (EEA, 2010). Evidence for a synergistic effect on the mortality rate due to high temperatures and ozone-levels is increasing (Bell et al., 2005; Medina-Ramón et al., 2006; Stedman et al., 1997). Hence, part of the health effects and increased mortality during heatwaves – which are exacerbated by UHI - may therefore be caused by decreased air quality (Filleul et al., 2006).

The EEA ‘Air quality in Europe 2021’ report updates and expands on an earlier assessment of the status of air quality by comparing pollutant concentrations in ambient air across Europe against the new WHO air quality guidelines published in September 2021. It finds that **the majority of Europeans are exposed to levels of air pollutants known to damage health**.

- In the 27 Member States of the European Union (EU), 97% of the urban population is exposed to levels of fine particulate matter above the WHO guideline. Levels of particulate matter are driven by emissions from energy use, road transport, industry and agriculture.
- Regarding nitrogen dioxide, 94% of the urban population is exposed to levels above the WHO guideline, due predominantly to emissions from road transport.
- 99% of the urban population is exposed to levels of ozone above the WHO guideline, linked to emissions of nitrogen oxides and volatile organic compounds, including methane, and high temperatures associated with climate change.

Increasing temperatures and heatwaves in the future are expected to exacerbate the existing ozone problem. Forsberg et al., 2011 projects an **increase of ozone-related deaths over the next 60 years in Europe**, with 10 to 14 % increase being marked for Belgium, France, Portugal, and Spain.

Figure 2.4 Percentage of the EU and EEA-32 urban population potentially exposed to ozone concentrations over the target value threshold set for protection of human health, 1997–2009



Source: EEA, 2011c (CSI 004).

Fig. 8. Percentage of the EU and EEA-32 urban population potentially exposed to ozone concentrations over the target value threshold set for protection of human health, 1997-2009. Source: EEA, 2011.

Human activities are the key driver behind the dangerous levels of particulate matter, nitrogen dioxide and ozone in urban air. Overall emissions of all key air pollutants across the EU declined in 2019, maintaining the trend seen since 2005. Nevertheless, delivering clean and safe air for Europe will require ongoing and additional reductions in emissions. Looking ahead, the report says more action is required by all Member States if they are to meet future emission reduction commitments under the **EU's National Emissions reduction Commitments Directive (NEC Directive)**.

The EU has also set standards for key air pollutants in the EU's Ambient Air Quality Directives. Under the European Green Deal's Zero Pollution Action Plan, the European Commission set the 2030 goal of reducing the number of premature deaths caused by PM2.5 by at least 55% compared with 2005 levels.

To this end, the European Commission initiated a revision of the Ambient Air Quality Directives, which includes a revision of EU air quality standards to align them more closely with WHO recommendations. Citizens and stakeholders are invited to express their views through a public consultation run by the European Commission until 16 December 2021.

In 2019, air pollution continued to drive a significant burden of premature death and disease in Europe. In the EU, 307,000 premature deaths were linked to exposure to fine particulate matter in 2019, a decrease of 33% on 2005.

Top 10 European cities with the cleanest air

City name	Country	Fine particulate matter in ug/m3	Population in the city
Umeå	Sweden	3,1	125080
Faro	Portugal	3,6	61015
Funchal	Portugal	3,9	104024
Tampere	Finland	4,1	238140
Narva	Estonia	4,2	53424
Stockholm	Sweden	4,2	1745766
Uppsala	Sweden	4,2	219914
Tallinn	Estonia	4,5	438341
Bergen	Norway	4,7	267950
Reykjavik	Iceland	4,9	132252
Norrkoping	Sweden	4,9	140927

Table 4. Top 10 European cities with the cleanest air. Source: EEA, 2021.

Top 10 European cities with the least clean air

City name	Country	Fine particulate matter in ug/m3	Population in the city
Nowy Sącz	Poland	26,8	83896
Cremona	Italy	25,7	72399

Padova	Italy	25,3	210077
Venezia	Italy	24,6	258685
Vicenza	Italy	24,2	109855
Slavonski Brod	Croatia	23,7	52836
Brescia	Italy	23	196340
Zgierz	Poland	22,5	56529
Lomza	Poland	22,4	63000
Zory	Poland	22,1	62456
Gliwice	Poland	22,1	179806

Table 5. Top 10 European cities with the least clean air. Source: EEA, 2021.

6.3 Water Quality

High temperatures of pavement and rooftop surfaces can heat up stormwater runoff, which drains into storm sewers and raises water temperatures as it is released into streams, rivers, ponds, and lakes. Water temperature affects all aspects of aquatic life, especially the metabolism and reproduction of many aquatic species. Rapid temperature changes in aquatic ecosystems resulting from warm stormwater runoff can be particularly stressful, and even fatal, to aquatic life.

One study found that urban streams are hotter on average than streams in forested areas, and that temperatures in urban streams rose over 7°F during small storms due to heated runoff from urban materials (Somers, K. et al, 2020).

6.4 Biodiversity

The urban heat island effect has been linked to species distributions and abundances in cities. However, effects of urban heat on biotic communities are nearly impossible to disentangle from effects of land cover in most cases because hotter urban sites also have less vegetation and more impervious surfaces than cooler sites within cities.

Despite the short history of research on the biotic effects of urban heat, researchers have found important patterns across diverse taxa. For example, remnant native plant communities in urban environments may be altered under warming conditions, favouring more xerophilic species.

6.5 Energy Use

Heat islands increase demand for air conditioning to cool buildings. In an assessment of case studies spanning locations in several countries, electricity demand for air conditioning increased approximately 1–9% for each 2°F increase in temperature (Santamouris, M., 2020). Countries where most buildings have air conditioning, such as the United States, had the highest increase in electricity demand. This increased demand contributes to higher electricity expenses.

Heat islands increase both overall electricity demand, as well as peak energy demand. Peak demand generally occurs on hot summer weekday afternoons, when offices and homes are running air-conditioning systems, lights, and appliances. During extreme heat events, which are exacerbated by heat islands, the increased demand for air conditioning can overload systems and require a utility to institute controlled, rolling brownouts or blackouts to avoid power outages.

6.6 Economy

A recent study published by IOP Publishing indicates that the effects associated with the warming caused by urban heat islands could double foreseen economic losses due to climate change (Huang et al., 2019). As already mentioned, higher temperatures cause workers to be less productive, raise cooling costs for buildings, and deteriorate water and air quality.

On average, the global gross domestic product (GDP) is expected to drop by 5.6 percent by 2100 due to climate change. In contrast, the most-impacted cities are expected to lose 10.9 percent of their GDP (University of Sussex, 2017).

A report published by the University of Sussex in 2017 pointed out that overheated cities face climate change costs at least twice as big as the rest of the world because of the urban heat island effect. The study by an international team of economists of all the world's major cities was the first to quantify the potentially devastating combined impact of global and local climate change on urban economies.

The researchers provided cost-benefit analyses of several cooling measures in the report, including cooling pavements, green roofs and the reintroduction of vegetation in urban areas. For example, transforming 20 percent of a city's pavement and rooftops to cooling surfaces could save a city up to 12 times what the structures cost to maintain and install, providing a bump to the local GDP.

The authors explained that their new research is significant because so much emphasis is placed on tackling global climate change, while they show that local interventions are as, if not more, important.

Thus, city-level adaptation strategies to limit local warming have important economic net benefits for almost all cities around the world. Measures that could limit the high economic and health costs of rising urban temperatures are therefore a major priority for policy makers.

KEY IDEAS

- Urban heat islands can affect a community's environment and quality of life in multiple ways.
- The impacts of elevated temperatures are not equally distributed among the population. Effects on territories and society depend on their degree of vulnerability.
- Increasing temperatures have an impact on both the physical and mental health of people.

7. Mitigation Measures: Strategies to reduce Urban Heat Islands

7.1 Strategic Planning

Modification and changes in land use and land cover play an important role in determining local climate characteristics. City growth—both in terms of densification and urban sprawl—induces higher heat load, which in the future is expected to superimpose on regional climate warming.

Strategic planning is the best way to go. Having considered climate change projections, urbanisation and anthropogenic heat, the data can help cities better analyse UHI effects. Extensive meteorological observational networks and different data sources from remote sensing and citizen weather stations can be used for urban climate analysis. Examples of cities that use various data sources include Cluj-Napoca and Vienna. These tools include monitoring networks, with the establishment of an appropriate operational monitoring system (cost-intensive); alternative networks like citizen weather stations (supplemental information); measurement campaigns (evaluate specific aspects of urban climate); or remote sensing data.

The highest surface temperatures are found in urban areas and are related to local land use characteristics. Satellite data on land use and land cover, can provide complimentary information to guide sustainable urban planning (World Bank, 2020).

There are many steps that cities can take to make them more resilient to extreme heat events and the negative impacts of the UHI effect. Cities need to gain a better understanding of what drives the heat waves and UHI effects they are subject to. Strategic planning for increased resilience to UHI effects should identify specific public investments and actions to promote green, blue, or white adaptation measures (the first ones related to increasing vegetation, the second to water bodies, and the third to cool materials).

Fig. 9: Different climate adaptation measures. Source: World Bank, 2020.

There are analytics and models available to inform urban planning and infrastructure development resilient to future climate change. In parallel to improved urban planning, cities also need to also plan for improved preparedness and response to UHI effects.

7.2 Strategies and Processes to reduce UHI

Over the last decades, an increase of UHIs could be observed as a manifestation of micro-climatic changes in urban environments seen in cities worldwide. If cities seek to become more resilient to both long-term impacts of climate change and short-term UHI effects, it is essential to **improve adaptation efforts by sustainably modifying the city structure, the building design, and the urban planning of living space**.

A robust integrated approach involving urban planners, architects, meteorologists, climatologists, geographers, economists and social scientists appears to be useful when developing UHI adaptation strategies. Some of the tools that result from this approach go through the change of how we build and arrange our cities, and include different strategies and processes, from the implantation of green roofs and high albedo roofing materials to the adaptation and change of urban planning.

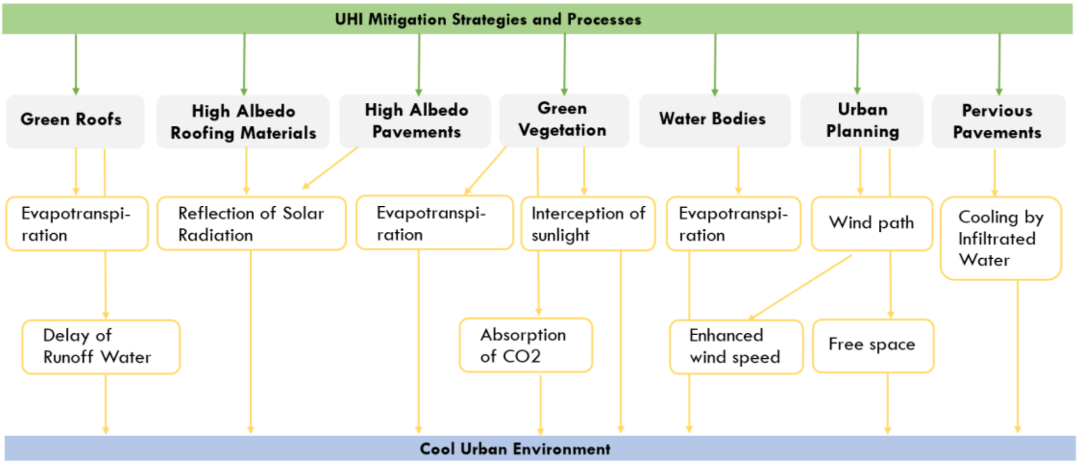


Fig. 10: UHI Mitigation Strategies and Processes. Source: own elaboration, extracted from Nuruzzaman, 2015.

In general, we can differentiate five types of measures when dealing with the mitigation of UHI in urban settings:

- Vegetation
- Urban Geometry
- Materials & surfaces
- Water bodies & features
- Shading

The following sections present a general description of these measures, and a more detailed approach to them is presented in *Annex. Strategies and Processes to reduce UHI: some examples.*

A. Vegetation

Vegetation has been used extensively as a UHI mitigation strategy worldwide and expert studies argue that more actions should be taken to increase the share of green areas in cities for mitigative and adaptive purposes.

Properties of vegetation include high albedo and low heat admittance that have the effect of reducing accumulation of incoming solar energy in the urban area. Additionally, certain types of vegetation such as trees can provide shade and minimise the heat gain from solar radiation, which then improves thermal comfort significantly. Also, the ambient air temperature reduction and building shading by vegetation can lower building energy demand for indoor cooling purposes.

Green infrastructures can perform multiple roles in urban areas, such as providing recreation, biodiversity, cultural identity, environmental quality and biological solutions to technical problems. It is this multifunctionality of green resources that differentiate it from its 'grey' counterparts, which tend to be designed to perform one function, such as transport and drainage, without contributing to the broader environmental, social and economic context.

Green resources do not only support adaptation, but also mitigation efforts. Human-related activities (building, power and heat production, transportation) in cities are responsible for about 70% of the CO_2 emissions; therefore, climate change mitigation requires rapid modification of a city's metabolism (IEA, 2017). Although the achievements of emission reduction goals are mainly related to a modification of production and consumption patterns and increases in efficiency (IEA, 2017), the cooling effect of urban green resources may indirectly translate into lower CO_2 emissions by decreasing the power demand for indoor cooling and heating (Song et al., 2018). At the same time, it can increase carbon storage and sequestration rates. Green approaches may also contribute to reducing transport-related emissions by linking strategies to reduce or avoid private car usage with cycling and pedestrian facilities (i.e., green corridors, parks). This may reduce pollutants as well.

However, perhaps the most crucial contribution of urban green resources from a climate change perspective is that they **foster the resilience building of urban dwellers**. Due to the UHI effect, urban dwellers are particularly vulnerable to thermal stress and their impacts that are being intensified due to climate change (Filho et al., 2018). For urban areas to be sustainably livable both now and in the future, as well as ensuring the filtration of pollution, noise reduction and thermal comfort, there appears to be a solid case for the implementation of urban greening policies and strategies, especially in the developing countries of the global south.

Fig. 11: Integrating nature into cities can provide citizens with urban cooling, cleaner air, regulated water supplies and flood protection. Image credit - Max Pixel, licensed under CCO.

B. Urban geometry

Urban geometry can provide numerous opportunities in promoting liveable environments and can be effective in getting the most out of natural effects/elements to counter UHI. T**he building layout, the location of urban elements, the building height and geometry** are variables that condition the thermal performance of the urban area. The arrangement of these elements affects the spatial coverage of the shadowed areas as well as the wind environment.

The implementation of **effective shading during the day** in combination with **increased night ventilation** proves to be a viable strategy to avoid summertime overheating. Enhancing air movement in between buildings through suitable urban design of street canyons and building geometry can be an efficient measure. Also, passive cooling strategies and design measures, such as orientation of the building, glazing, shading, and thermal mass, as well as nighttime ventilation, should be exploited in order to reduce or ideally avoid air conditioning systems in residential buildings. These passive design measures have the benefit of being both cost-effective, when considered at an early planning stage, as well as highly effective in terms of energy efficiency.

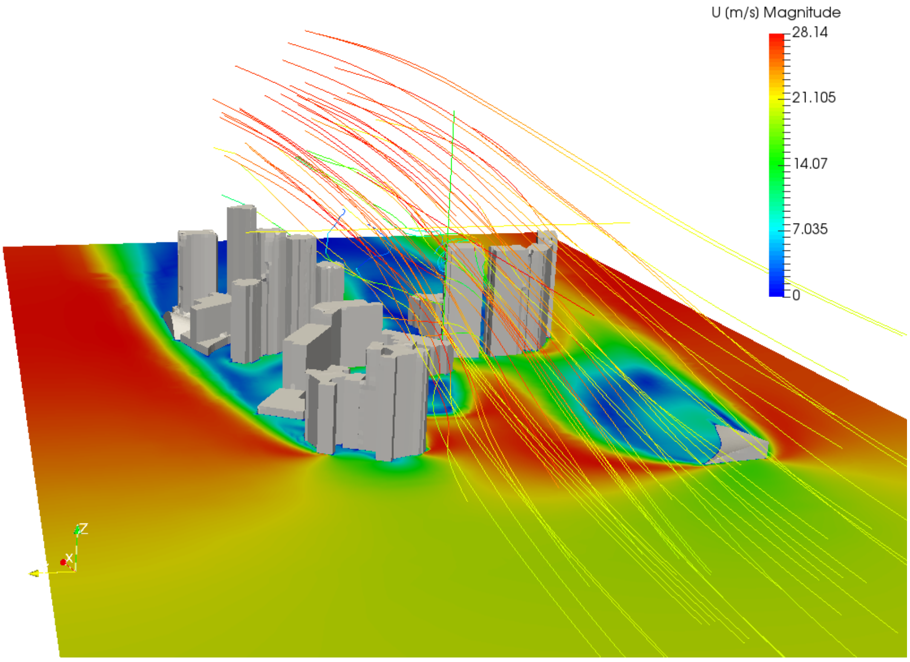


Fig. 12: Urban ventilation and airflow. Image credit - Climate Resilient Cities.

C. Materials & surfaces

Traditional pavements such as concrete and asphalt can reach temperatures of up to 48-67°C (120-150 °F) in the summertime (EPA, 2008). As we have already explained, these surfaces contribute to urban heat islands, especially at night time, by trapping and storing heat during the day and releasing it at night. Hot pavements can also heat stormwater as it washes over the pavement and into local waterways, causing the water to warm and impairing water quality.

The use of reflective pavements is one of the most well studied and most cost effective mitigation measures for combating the UHI effect by **reducing the surface temperature of the pavement**. It is easier to vary the albedo of a pavement than its thermal inertia.

Essentially, to make a pavement more reflective, two parameters can be changed: the colour of the pavement, and its surface roughness (Santamouris, 2013). One of the most practical means for mitigation of the UHI effect is to make pavement surfaces whiter, or as light-coloured as possible (Pomerantz et al., 2003). Making a pavement surface a lighter colour decreases the amount of solar radiation that it absorbs, and increases the amount of light and heat radiation that it reflects back into the atmosphere. A reflective pavement with an increased albedo can be developed by applying reflective paint or a sealant of thin bitumen with exposed light coloured aggregates to the surface of the pavement (Mohajerani et al., 2017).

Ideally, cool materials would be used on every road construction site; however, their application is often limited for economic or aesthetic reasons, and, instead, warm or hot pavements are used. The global implementation of reflective roofing, pavements and other structures would **reduce the air and pavement temperature, offset billions of tons of carbon dioxide emissions, reduce smog and aid the ailing environment** (Yang, Wang and Kaloush 2015). Hence, making cool pavements more available, durable and affordable may be an effective area of future study.

Fig. 13: A stretch of Coronado St. in Los Angeles is one of 15 blocks that is piloting a cool pavement. Image credit - Jed Kim/Marketplace.

D. Water bodies & features

Water bodies' ability to regulate the microclimate arguably has the potential to mitigate the UHI effect. Water bodies commonly found in urban areas are usually described as a permanent or temporary collection of water in the form of small stationary water or ponds. These **water bodies contribute to altering the surrounding thermal environment due to its cooling effect**, either by evaporation or transfer of heat between air and the water. In real urban conditions, however, the heterogeneity makes it difficult to assess the cooling benefits and to isolate the effects of individual parameters (such as shape, surface area, wind condition or solar radiation) under the complex physics process involved in urban meteorology (Nedyomukti et al., 2016).

Water bodies and features can act as **countermeasures to improve overheated building environments to some degree.** The effect of water is related to its surface temperature, which does not increase as much as the rest of the urban area. Thus, it can be considered as a cool sink. Also, water evaporates and increases the humidity of the air. Depending on the regional context, this can have a positive impact on the local thermal comfort. Additionally, depending on the size of the water body, specific wind circulation patterns can be developed with its corresponding consequences in the nearby environment.

Huanchun Huang, et. al., in "*Scale and attenuation of water bodies on Urban Heat Islands*", proposed the concept of core water surface ratio and a related method for measuring the scale sensitivity, with a view to investigating the variation patterns of water bodies and heat islands in daytime data. The study showed that the effect of the water body in reducing the temperature of its surroundings gradually decreases with increasing distance. Specifically, temperature rises by 0.78 °C for every 100 m away from the water surface.

During summer daytime, water surfaces reduce UHI, and **the reduction is low in the morning and maximum in the afternoon.** This illustrates that the cooling effect of water bodies has clear temporal variation (Huanchun Huang, et. al., 2017).

Fig. 14: Granary Square Fountain in London. Image credit - Culture Whisper.

E. Shading

Shading is a key measure to mitigate UHI because it leads to **the reduction of air and surface temperature and can therefore result in cooling benefits**. Simultaneously, it affects the thermal sensation and adaptation of pedestrians, mitigating heat stress.

Urban shading can be provided by adequate urban geometry and building/street orientation. Additional physical control to solar access can be achieved through horizontal and vertical shading structures or devices, as well as trees and vegetation.

Urban trees cool the environment mainly through shading and evapotranspiration. Leaves reflect and absorb solar radiation, preventing the radiation from being absorbed and stored in a surface (shading). The energy absorbed by a tree is then used for the plant's processes, including evapotranspiration, thus increasing the latent heat flux that transfers the heat to the atmosphere, resulting in the air cooling (Rahman and Ennos, 2016). While shading mostly affects the local microclimate, evapotranspiration is considered important for regional cooling (Rahman et al., 2018; Rahman and Ennos, 2016).

Fig. 15: The "Metropol Parasol" in Seville, the world's largest wooden structure. Image credit - Inhabitat.

KEY IDEAS

- There are multiple analytics and models to inform urban planning and infrastructure development resilient to future climate change.
- A robust integrated approach involving urban planners, architects, meteorologists, climatologists, geographers, economists and social scientists is necessary when developing UHI adaptation strategies.
- Measures for UHI mitigation are related to vegetation, urban geometry, materials and surfaces, water bodies and features, and shading.

8. Legal Barriers to Urban Heat Islands Mitigation Strategies

8.1 Legal Barriers

There are several legal barriers to deploying pilots and strategies to mitigate Urban Heat Islands in European cities and rural smart communities. These include:

- **Privacy and data protection laws**: The European Union has strict laws regarding data protection, such as the General Data Protection Regulation (GDPR), which can make it difficult to collect and use data in smart city projects.

- **Regulatory barriers**: Different cities and regions in the EU have different regulations and requirements for deploying new technology. This can make it difficult to roll out pilot projects on a larger scale, as each city or region may have its own unique set of rules and regulations that must be followed. For example, some cities may have specific regulations regarding the use of drones, while others may have more restrictive regulations on the use of cameras in public spaces. These regulatory barriers can make it difficult for companies and organizations to develop and deploy smart city projects that are consistent across different cities and regions.

- **Liability and safety concerns**: When deploying new technology in public spaces, there are potential liability and safety concerns that must be addressed. For example, if a self-driving car were to be involved in an accident, there may be questions about who is responsible for the accident. Additionally, there may be concerns about the safety of the technology, particularly if it is being used in a way that it has not been tested or validated. These concerns can make it difficult to secure funding and insurance for pilot projects, as investors and insurers may be hesitant to invest in or insure a project that carries significant liability or safety risks.

- **Procurement laws**: EU countries have different procurement laws and regulations which can make it difficult for companies to bid for and win contracts for smart city projects.

- **Interoperability**: lack of standardization of infrastructure and software across EU countries can make it difficult to ensure that different smart city systems can work together effectively.

These barriers can be overcome by developing clear regulations and guidelines, securing funding, and building partnerships between public and private sector organizations. To mitigate these concerns, it's important to conduct thorough testing and evaluation of the technology before deployment, to develop clear guidelines and regulations for the use of the technology, and to establish clear liability and safety protocols. Additionally, partnerships between public and private sector organizations can help to mitigate these concerns by sharing the risk and responsibilities.

There may be specific regulations or guidelines that govern the use of certain strategies or pilots regarding urban heat island. For example, there are legal regulations for installing sensors in European cities. The European Union has strict laws and regulations regarding data protection, such as the General Data Protection Regulation (GDPR), which applies to the collection, processing, and storage of personal data. These regulations can have an impact on the deployment of sensors in European cities, as they can limit the types of data that can be collected, how it can be used, and how long it can be stored.

Additionally, there are regulations and laws that govern the installation of sensors in public spaces. For example, there may be regulations that prohibit the installation of cameras in certain areas, or that require certain types of notifications to be provided to the public before sensors are installed.

Furthermore, different cities and regions may have their own regulations regarding the installation of sensors in public spaces, so it's important to check the specific regulations that apply in the location where you plan to install the sensors.

To comply with these regulations, it's important to conduct a thorough **data protection impact assessment (DPIA)** before the deployment of sensors, to ensure that the data collected, processed and stored complies with the GDPR and other regulations, to provide clear information to the public about the sensors, and to establish clear protocols for data management, security and retention.

8.2 Institutional Barriers

Barriers in this field include:

- Lack of consumer acceptance: the lack of acceptance by the consumer or the customer creates the need for their education to expand awareness about sustainability, which is still quite limited.
- Lack of regulatory incentives: the challenge of the lack of regulatory incentives is associated with the government, which often fails to stimulate business with public policy, adequate regulation and incentives for sustainability. Stronger legislative pressure and supportive economic incentives are needed to achieve a sustainable economy.
- Institutional fragmentation: it represents another important barrier. Different departments/organisations usually work in line with their own vision, legal frameworks and procedures, and use their own sectorial language.

8.3 Organizational culture

Barriers in this field include:

- Difficulty in reconciling resources and the actors involved: lack of partners and low availability of materials, lack of information exchange between supply chain actors, and conflicting interests between supply chain actors.
- Lack of scaling up sustainable startups: the main barrier to deploying and scaling up a climate solution is the need for a mature value chain. A startup needs to consider many different players and stakeholders to successfully launch a product. Furthermore, scaling up climate tech often requires enormously large capital. This is often facilitated by financing mechanisms structured as project- or asset-based investments provided by debt or infrastructure investors or via dedicated large scale climate tech financiers. The barriers to companies' scale up can exist even after a successful pilot, when technical risks have been overcome and unit economics are promising.

KEY IDEAS

- There are several legal and institutional barriers, as well as barriers related to the organizational culture, to deploying pilots and strategies to mitigate UHI.
- These barriers can be overcome by developing clear regulations and guidelines, securing funding, and building partnerships between public and private sector organizations.

9. Case Studies: What will be needed in the future?

9.1 Urban Projects

A. eCitySevilla (Spain)

- Public-private partnership initiative led by the Andalusian Regional Government, the Seville City Council, the Cartuja Science and Technology Park (PCT Cartuja) and Endesa.
- Proposes the development of an open, digital, decarbonised and sustainable ecosystem city model on the island of La Cartuja by 2025.

Fig. 16: eCitySevilla. Source: Sevilla municipality.

B. Vauban Sustainable Urban District (Freiburg, Germany)

- Based on the city government's aim of restoring an old military barracks based on ecological and social cohesion criteria
- Creation of more than 40 cooperative housing groups and creation of participation initiatives related to climate, consumption and gender
- Bioclimatic architecture criteria: green facades, greening, construction using local wood, building with high energy efficiency, renewable energies, rainwater collecting mechanisms, etc.

Fig. 17: Vauban ecodistrict. Source: Vauban municipality.

C. Climate Shelters (Barcelona, Spain)

- The City of Barcelona identified schoolyards as an underutilized resource since they were only used by the school population, during school time. The rest of the time, most schoolyards were not accessible to the surrounding community.

- Through a project funded by the Urban Innovation Actions of the European Commission, the City of Barcelona turned through carefully selected interventions, 11 school yards to “cool islands”, termed as Climate Shelters.

- The Climate Shelters were added to the Schoolyards Open to the Neighborhood Program in operation since 2011, namely a municipal service that makes the courtyards of the city’s schools, leisure, educational and shared spaces for families, children and adults outside school hours, on weekends and during school holidays.

- This was accomplished by means of blue and green interventions at the selected school buildings and their yards. These measures included:
  - Blue interventions: inclusion of points providing water, such as drinking fountains or unique places for children to play with water.
  - Green interventions: more green space, improvements in vegetation, creation of shade with green walls, more garden space, trees, green pergolas and fencing.

Fig. 18: Blue and green interventions, the first one in the Climate Shelter at School Ramon Casas and the second one in Font d'en Fargas. Source: Urban Innovative Actions.

- As a result, 1,000 square metres of natural space was regained, with vegetation in playgrounds and the creation of 2,213 square meters of new shade using pergolas and awnings. In addition, 74 trees were planted and 26 new water sources were installed.

D. RESILIO - Resilience nEtwork of Smart Innovative cLimate-adaptative rOoftops (Amsterdam, The Netherlands)

- The RESILIO project aims to address critical urban climate challenges related to flooding, heat, water supply, energy consumption and urban livability by repurposing the rooftops of climate-vulnerable neighbourhoods of Amsterdam.

- The project has taken 12,683 m2 of rooftop space and turned it into smart blue-green roofs. With this project, four different building complexes in Amsterdam neighborhoods acquired smart blue-green roofs – as well as the Tropenmuseum. Smart blue-green roofs can retain excess rainwater and provide a place to nature, adding biodiversity and creating a future-proof city at the same time.

- The roofs have a "smart flow control" that anticipates heavy rain or drought, releasing or retaining water accordingly. The roofs are connected in a network, enabling remote regulation of rooftop water levels based on weather forecasts and water management settings.

Fig. 19: Smart blue-green roof in Amsterdam. Source: Resilio.

E. Green Bus Stops (Poland)

- Four cities in Poland have chosen to use the so-called Green Bus Stop as a Nature Based Solution to reuse rainwater as a resource and contribute to the reduction of UHI effect.
- Each bus-stop is covered with a plant-based green roof with a water retention layer – such a roof stops up to 90% of the stormwater falling on its surface. During dry weather, the water is used by the plants and evaporated, making space for the next fallout.
- Part of the water, which is not used on the roof, together with the excess stormwater from the surrounding sidewalk, is retained in a vegetated retention-infiltration box in the back of the shelter.
- Green Bus Stop emits less heat than the traditional counterpart does, at times as much as 10°C less.

Fig. 20: Green Bus Stop in Białystok. Source: Bialystok City Office.

9.2 Start-ups and Initiatives

A. ECOTEN Urban Comfort (Czech Republic). Helping urban developers build more resilient cities

- Data-driven approach to help cities adjust by designing greener and cooler cities.
- Conducts urban heat vulnerability assessments (and identifies critical hotspots) and conducts urban microclimate simulations to assess the impacts of potential urban projects.

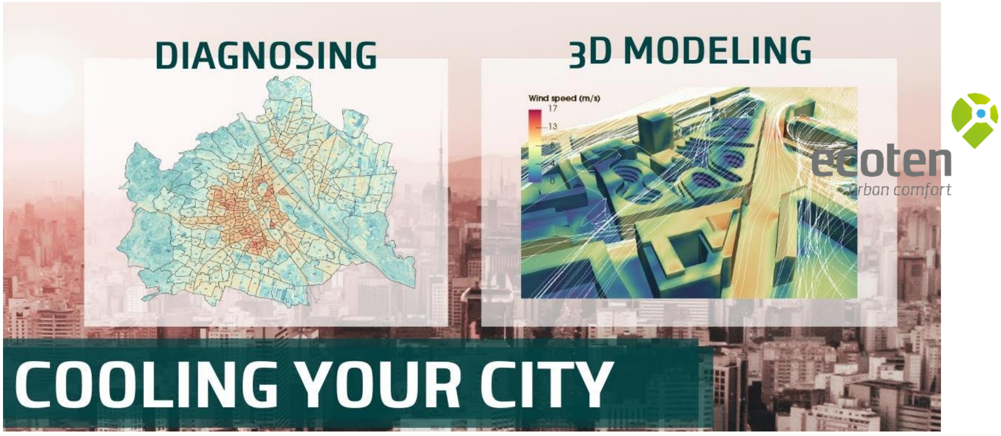


Fig. 21: Ecoten approach. Source: Ecoten.

B. Urban Canopee (France). Greening the Cities

- Deploys plant canopies at key locations in urban areas.
- These canopies combat heat, restore urban biodiversity, fight air pollution, and improve the quality of life for citizens.

Fig. 22: Urban Canopee Solution. Source: Urban Canopee.

C. Cbalance (India). Recycling plastic into insulation

- Works with communities to pioneer passive design solutions.
- Some of these turn waste into materials that prevent heat absorption. i.e. Discarded plastic packaging can be recycled into sheets and insulation boards.

Fig. 23: Cbalance solution. Source: Cbalance.

D. MetroPolder (The Netherlands). Rainwater as a resource

- Metropolder's innovation tackles both extreme heat and heavy rainfall by capturing water in a special layer on flat roofs, preventing urban flooding and later releasing water to cool buildings during periods of excessive heat.

Fig. 24: A roof garden terrace in Amsterdam. Source: MetroPolder

E. SUGi (international). Native, diverse pocket forests

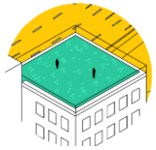
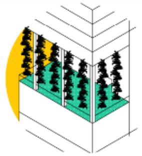
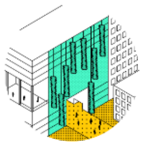
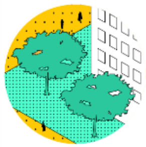
- In May 2019, SUGi launched as a global platform fully dedicated to biodiversity building, ecosystem restoration and reconnecting people to Nature through the creation of ultra-dense, biodiverse forests of native species primarily in urban areas.
- With 142 pocket forests planted in 28 cities we have reconnected 19,500 youth and community members to nature. The social impact of creating forests in cities is considerable, as are the environmental benefits, yet there is much more that can and must be done to grow this effort exponentially.

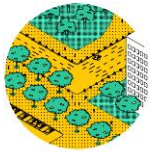
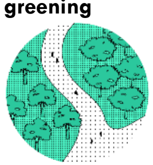
SUGi

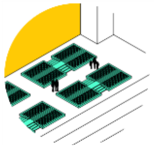
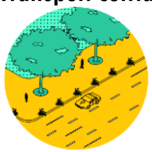
Fig. 25: SUGi Project. Source: SUGi

Annex. Strategies and Processes to reduce UHI

1. Vegetation

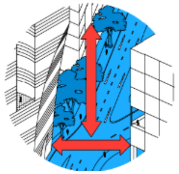
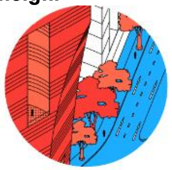
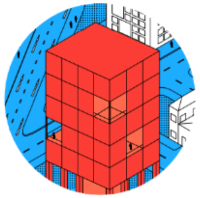
Measure	Description	UHI effect	Urban planning
Green roofs 	Incorporating green roofs involves placing a vegetative layer such as plants, shrubs, grass, and/or trees on building rooftops. They are also called 'rooftop gardens' or 'eco roofs'. Green roofs can be installed as a thin layer (around 5 cm) of groundcover up to a thick layer (around 1m) of intensive vegetation and trees. The thickness depends on the chosen soil type, drainage system, and vegetation species.	This strategy allows for the reduction of the urban heat accumulation due to a lowering of the temperature of roof surfaces. Similarly, nearby air temperature is also influenced by evapotranspiration. It produces benefits in terms of UHI mitigation and the reduction of building energy consumption.	Implementation should be aided by the development of building codes and energy efficiency guidelines. Green roofs can be developed both in public and private buildings.
Vertical greenery 	Vertical greenery is defined as the growing of vegetative elements on the external facade of the building envelope. There are two kinds of systems: a support system that allows plants to climb through them, and a carrier system where plants can settle and develop.	These systems allow for a reduction of the external surface temperature of the building façades, especially in the case where intense sun radiation occurs, such as on the south facing façades. Consequently, the temperature inside the building can remain more stable, and thus there is a reduction in the building energy consumption for cooling. Similarly, there is a reduction of the nearby air temperature providing benefits for pedestrians' thermal comfort.	Implementation should be aided by the development of building codes and energy efficiency guidelines. Adequate greenery systems should be selected in accordance to the building structure, the maintenance required, and safety. They could be developed both at public and private buildings at low costs.
Green walls/facades 	Green facades are vegetative layers such as small plants, grass and/or moss attached to external building façades. They are also called 'living walls' and 'vertical gardens'. Green façades can be considered as an alternative to insulating construction materials and reducing indoor overheating.	The strategy allows for a reduction in the temperature of façades, especially those exposed to intense sun radiation, such as the south facing façades. Consequently, the temperature inside the building can remain more stable and thus there is a reduction in the energy consumption required for cooling indoors. Similarly, there is a reduction of the nearby air temperature providing benefits of thermal comfort for pedestrians.	Implementation should be aided by the development of building codes and energy efficiency guidelines. Green walls/façades can be developed both in public and private buildings.
Vegetation around buildings 	Arranging adequate vegetation elements around buildings can provide shade to pedestrians, building and ground surfaces. The effect can vary depending on the vegetation coverage, size and distribution.	Vegetation can absorb the incoming solar radiation and thus reduce heat accumulation in urban materials. At the same time, it provides shadowing, especially trees. Similar to green façade, the reduction of solar radiation (shade) in buildings will reduce the energy demand for indoor cooling.	In planning, it is required that urban design considers carefully the exposure of buildings to direct solar radiation. On the whole, urban design needs to look for thermal pleasure by developing an urban asymmetrical thermal environment dominated by cool spots in urban spaces (Emmanuel, 2016) and at the same time enabling low-energy cooling within indoors.
Selective Planting	Planting vegetation in selective areas can provide beneficial shade but also obstruct the wind flow. This measure concerns choosing the more effective	Vegetation allows for the following: a reduction in urban heat accumulation; shadowing that increases pedestrian thermal comfort; and reduction in building energy consumption.	Implementation should be aided by the development of building codes and energy efficiency guidelines. New development or retrofit should consider the disposal of

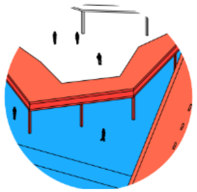
	vegetation species as well as the optimal orientation and arrangement.	Combination of the different types of vegetation species and the way they are arranged can improve the thermal performance of the surrounding considering their ability to influence the urban energy balance.	vegetation in a way that can provide the highest environmental benefits. In any case, any urban greening programme implemented would need to be appropriately designed to get the most benefit out of reducing temperature (Bowler et al., 2010).
Green pavements 	This measure reduces the amount of artificial material on urban pavements with the replacement of natural soil elements with grass. But it can also be installed by using permeable pavers, previous concrete or porous asphalt in order to increase the permeability of the pavement.	Any urban greening programme implemented would need to be appropriately designed to achieve the full benefit of reducing temperature (Bowler et al., 2010). It allows for the reduction of urban heat accumulation by decreasing pavement temperature, thus influencing pedestrians' thermal comfort and to a large extent the UHI.	Implementation should be focused on areas/pavements with little shadowing (lowrise building development, for example) because the accumulation of heat can rise in pavements under these conditions.
Infrastructure greenery 	This measure covers elements that are not part of natural growing vegetation. Greenery can be added on existing infrastructure such as bridges, tunnels, highways and bus stations.	It allows for the reduction of the urban heat accumulation by decreasing surface temperature, and thus influencing pedestrians' thermal comfort.	Implementation should be focused on areas/pavements with little shadowing because the accumulation of heat can rise in pavements with these conditions. Additionally, the development of small green urban areas that are located strategically or grouped around buildings should be encouraged. These are more easily implemented when retrofitting in comparison with the development of big urban parks inside urban areas (Wong and Chen, 2009).
Macroscale urban greening 	Macro scale urban greening concerns the large-scale increase of the presence of vegetation in urban areas focusing on big urban parks, forests and natural reservoirs. They can be located at the edge or in central areas of the city with different effects in the local climate. They are also called 'cold islands'.	Areas like forests and green belts do not only assure a better thermal perception inside them, but can also provide coolness to nearby urban areas, thus helping to regulate the accumulation of heat in the whole urban area.	Implementation of macroscale urban greening should be considered carefully and in relation to general climate patterns (such as wind pattern) to maximise the cooling benefits that could extend to the entire urban area. The collaboration among several ministries is crucial for the successful implementation of urban greening on a large scale.
Local scale urban greening 	Local urban greening involves the increase of the presence of midsize parks inside the urban area to provide areas of thermal comfort for leisure and recreation. They are commonly located close to residential areas or along seashores with a compact or linear shape.	Urban greening in local contexts is expected to provide thermal comfort within them, but little effect is expected far away from their boundaries. The combination of vegetation, shadowing and adequate ventilation can significantly increase the outdoor thermal comfort with respect to the nearby artificialised area.	The implementation of local urban greening should be carefully considered and in relation to the urban extension. These areas should be considered as providing thermal comfort inside them. They could be developed within specific urban development guidelines that enforce their presence in every new planning/project.
Microscale urban greening	Microscale urban greening can be used to increase small vegetation presence inside the urban area. In addition to having vegetation around buildings, other uses can be pocket parks and green	Despite the benefits on outdoor thermal comfort that can only occur in a small area when implemented adequately and/or interconnecting different microscale greening along the city, the effects on UHI could actually increase.	There can be two kinds of implementation: first, in developed areas where urban retrofitting is possible to improve the thermal comfort along pedestrian paths and in other pedestrian areas; second, in new urban areas to interconnect

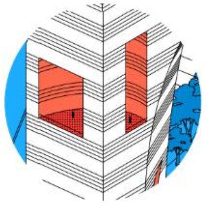
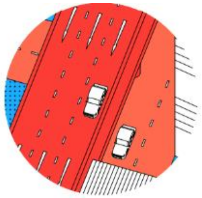
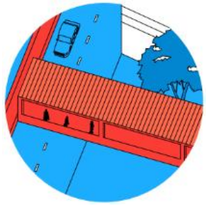
	courtyards.		parks and bigger vegetation areas to create suitable thermal comfort pathways along the whole urban area.
Green parking lots 	This concerns reducing the amount of artificial material in parking lots while substituting them with ground vegetation (natural soil and grass) and/or trees and other vegetative infrastructure	The use of vegetative elements and/or soils with higher albedo has the effect of reducing the urban heat accumulation compared to conventional dark asphalt at parking lots. By decreasing the pavement temperature and extending the use of tree shadows, the heat accumulated by the cars can also be reduced.	Implementation should be focused on parking lots with little shadowing (low-rise building developments) where heat accumulation could be higher.
Tree species 	The selection of adequate species should be related to environmental tolerances, functional requirements, and urban design requirements in order for trees to obtain the best results for generating outdoor thermal comfort. For the environmental tolerance, aspects like climate, geology and topography have to be taken into consideration.	Different positive effects on heat accumulation can be achieved depending on not only the number of trees per square meter, but also their typology, size and adaptation to tropical areas. The previous mitigation measures have shown that trees can benefit the urban climate, but with varying results depending on how they are conditioned by their location and also by their actual characteristics.	It is required that urban design takes into careful consideration the exposure to direct solar radiation. On the whole, the aim is to look for thermal pleasure by developing an urban asymmetrical thermal environment dominated by cool spots in urban spaces (Emmanuel, 2016) and also enabling low-energy cooling indoors.
Urban farming 	Urban farms concern the practice of growing or producing food within urban areas. It can be installed in under-utilised urban spaces including rooftops, abandoned buildings and vacant lots. Urban agriculture has different climatic opportunities and constraints compared to rural agriculture.	Urban farms can serve as green islands within the urban landscape that can offer shade and protect impervious surfaces from the effects of solar radiation. Like other urban greenery, urban farms can produce similar local thermal comfort benefits and if highly extended to a relevant part of the urban area, it can lower the UHI effect and thus reduce building energy consumption for cooling.	Urban farming presents many benefits and opportunities. It helps to green the city, increase the amount of food grown and produced locally, thus preventing CO_2 emissions in food transport from distant producers, and improving food security for this land-scarce island city. Suitable building codes, guidelines for new/ retrofit areas and/or economic policy can help develop green farming spaces.
Transport corridors 	The vegetation arrangement along transport corridors can provide shade to the infrastructure surface. The effect can vary depending on the vegetation density, height and species. But it is also key to combine the reduction of incoming solar radiation with the natural ventilation capacity of these spaces.	Vegetation can absorb incoming solar radiation and thus reduce heat accumulation in urban materials. At the same time, it provides shadowing (in the case of trees). Thus, considering local pedestrian outdoor thermal comfort, an increase in the number of trees makes sense. Transport corridors should be carefully designed with respect to UHI.	In planning for arranging vegetation along transport corridors, the exposure to direct solar radiation and wind enhancement should be considered carefully. A combination of different heights of vegetation elements together with their strategic location can allow for suitable airflow inside the transport corridor and thus pose higher benefits for this mitigation measure. T

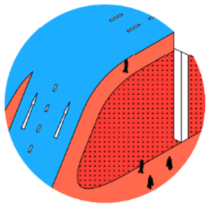
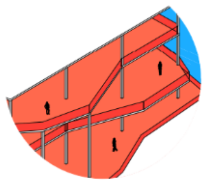
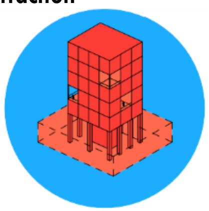
2. Urban Geometry

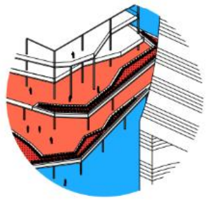
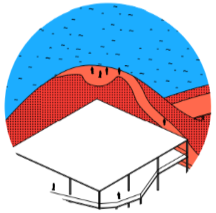
Measure	Description	UHI effect	Urban planning
Sky view factor	The sky view factor (SVF) is defined as the ratio of the radiation received by a planar surface to the radiation emitted by the entire hemispheric environment. It is calculated as the fraction of sky visible from the ground. SVF is a dimensionless value that ranges from 0 to 1. For	SVF conditions the amount of radiation received at the ground level during daytime (e.g. solar radiation) as well as the release of accumulated urban heat during the night (e.g. nocturnal cooling). Lower SVF can provide more shadow inside the street canyon during daytime and thus curtail the rise of	Implementation should be aided by the development of building codes and energy efficiency guidelines to ensure that solar heat gain is reduced. However, this should be balanced with indoor artificial light demand, which also requires a significant amount of energy.

	instance, an SVF of 1 means that the sky is completely visible and there are no obstacles around.	ground temperature. However, trapping of the outgoing radiation during night-time can occur and thus the decrease of ground temperature will be lower during this time. Lower SVF can worsen the UHI during night-time but improve outdoor thermal comfort during daytime due to shade provided by urban elements. SVF also has a relevant influence on lowering surface temperature and thus reducing building energy consumption.	
Aspect ratio 	Aspect ratio (H/W) is the most important geometrical characteristic of a street canyon and is defined as the ratio of the canyon height (H) to the canyon width (W). It is usually calculated by dividing the mean height of buildings by the width of the street.	Similar to the Sky View Factor (SVF), aspect ratio conditions the incoming and outgoing radiation and thus the energy heat flux at the lowest level of a street canyon. The combination of low buildings and wide streets (or lower aspect ratio) can increase the entrance of wind flowing above the buildings and thus help remove urban accumulated heat and air pollutants. Such street canyons can also improve the nocturnal cooling of the ground surface. On the other hand, urban canyons with high aspect ratio can provide more shade during daytime and thus improve thermal comfort and reduce building energy consumption.	This measure can be combined with others such as passive design techniques for lasting comfort. It is important to evaluate the different options of the urban canyon aspect ratio to find the best fit that provides shading and increases wind flows. According to Mesa et al. (2011), the optimum ratio of the distance between buildings and the building height is between 2 and 3 (aspect ratio 1). The resulting aspect ratio may also affect the intensity and quality level of natural illumination reaching indoor spaces.
Mean building / tree height 	The relation between building and tree height will condition the amount of façade that is shaded by the trees and thus control the overheating of its surface	Trees reduce direct solar insolation thereby decreasing the surface temperature, both of building façades and in the tree surroundings. This way a reduction in UHI and an increase in local thermal comfort is expected together with benefits of indoor cooling energy demand.	Implementation should be aided by the development of building codes and energy efficiency guidelines. Adequate tree heights should be implemented in each area and other issues such as natural lighting should be considered.
Building form 	Building form refers to the geometrical configuration and shape of a building or of multiple buildings. It can be linear, block or isolated punctual, and can be arranged in many different combinations.	The building form in combination with the arrangements of neighbouring buildings can contribute significantly to the formation of wind streams and the removal of urban heat accumulation through ventilation. Depending on the building form, it can also provide shade to itself or to its urban context and thus influence the energy consumption, reduce CO_2 emission and improve outdoor thermal comfort.	It is important that urban design considers the different options regarding building layout and façade orientation. The building form should be defined in relation to the direct solar radiation and thus shade the façades that are mainly exposed to the sun. This way, higher indoor and outdoor comfort can be achieved, plus indoor energy demand can be reduced. This is essential in deciding the layout of buildings and the internal distribution in relation to the different occupation times during the day.
Variation between building heights	The act of varying between different building heights and building forms (e.g. stepping building heights or podium structures) can improve wind capture with benefits of outdoor thermal comfort.	Wind speed varies with altitude that increases its intensity exponentially. Local outdoor thermal comfort can be enhanced by adequate air movement. In this sense, the variation between low- and high-rise buildings allows for increasing wind velocity due to the air dynamics between buildings.	New development or building retrofit should consider arranging buildings according to ascending heights with respect to wind direction to allow adequate wind to reach the rear blocks. An option would be to stagger building heights and void decks to increase the airflow. Also, downwash wind (bring upper wind to the ground level) triggered by the building geometry and layout allows for the ventilation of streets and generates air movement into

			the buildings.
Wider streets 	By widening the streets, the exchange of air inside the street canyons can be generated and increased at the same time. Allowing more air to come in creates effective wind corridors in the dense urban fabric.	The higher the air movement inside a street canyon, the higher the release of urban heat accumulation that will happen, thus reducing the UHI effect and building energy demand. Additionally, it permits a higher influence of non-urban breezes in the inner part of the city. Of course, outdoor thermal comfort can improve locally with increasing wind speed and air pollutants will have better dispersion conditions.	The implementation of street widening should be carried out in new developments with the help of building codes and urban design guidelines. Void decks at the ground floor of buildings or at different levels such as sky gardens can also increase the building permeability, in case streets are not wide enough and thus encourage the air flow through and around the buildings.
Avoid obstruction 	Obstructing the breezeway with buildings or other urban elements can block most of the wind to pedestrians thus affecting comfort and air quality. It can also minimise the air volume near the pedestrian level, which affects air quality. The effect of building layout, especially in terms of building site coverage, has a greater impact than building height on the pedestrian wind environment.	Any obstruction or stagnation of natural air movement might lead to a decrease in outdoor thermal comfort and an increase in UHI. To maximise the wind availability to pedestrians, towers should preferably be adjacent to the podium edge that faces the main pedestrian area/street so as to enable most of the downwash wind to reach the street level.	The obstructions can be avoided by stepping building heights in rows so as to create better wind at higher levels. Adopting a terraced podium design to direct downward airflow can help enhance the air movement at the pedestrian level and disperse the pollutants emitted by vehicles. Another option could be to align streets in parallel or up to 30° to the prevailing wind direction in an array of streets to maximise the penetration of wind through the district. Also aligning the longer frontage of building plots in parallel to the wind direction and introducing non-building areas and setbacks are appropriate measures.
Open spaces along sea shore 	Open spaces along the seashore enhance the amount of wind entering the urban area with the effect of improving outdoor thermal comfort. In general, seashores are considered prime areas in a city with high density and are often excluded from public use.	The waterfront sites are the gateways of sea breezes and this can be enhanced for benefits of UHI and outdoor thermal comfort. They help regulate the urban climate by incorporating cold air within the urban fabric.	According to urban planning prospect, the open spaces along the seashore should face the sea to offer residents beachside enjoyment while being exposed to maximum wind from the open sea to create a positive thermal sensation. To achieve this, incompatible land uses that obstruct the continuity of harbour front promenade and major infrastructure projects should be avoided. Also, an integrated network of open spaces and pedestrian pathways can allow for the better movement of air in a dense urban area.
Building porosity	Building porosity can be achieved by generating adequate openings or gaps in buildings, either in horizontal or vertical direction. This strategy can maximise the air permeability of the urban area and minimise its impact on wind capture and air flow	Compact building blocks create stagnant air that worsens outdoor thermal comfort. In the tropics, a decrease in wind speed from 1.0 m/s to 0.3 m/s is equal to 1.9°C temperature increase, and outdoor thermal comfort under typical summer conditions requires 1.6 m/s wind speed. Therefore, according to	The provision of permeability closer to the pedestrian level is far more important than that at high levels as it helps to remove pollutants and heat generated at ground level. The permeability can be increased by creating voids in building blocks at ground level to improve natural ventilation for

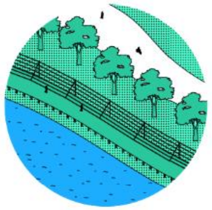
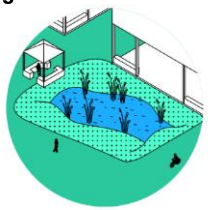
	reduction.	Yuan and Ng (2012) building setbacks and building permeability are helpful in improving the pedestrian-level wind environment.	pedestrians and thus their comfort. Combining voids with appropriate wing walls permits air to flow through the openings of the buildings. Midlevel voids are especially relevant for very deep canyons or extremely tall building blocks.
Street axes orientation 	Choosing the appropriate geometry and the orientation of street canyons can improve outdoor and indoor environments, solar access inside and outside the buildings, the permeability to airflow for urban ventilation, and the potential for cooling of the whole urban system.	Street geometry and orientation influence the amount of solar radiation received by street surfaces and also airflow in urban canyons, which significantly affects local thermal comfort and building energy consumption. Streets aligned to breezeways can promote air movement into and within the urban areas, thus reducing UHI. An array of main streets, wide main avenues and/or breezeways aligned up to 30° to the prevailing wind direction maximises the penetration of prevailing winds and reduces the UHI effect.	This strategy should be considered during the first phase of the planning of a new development. It cannot be incorporated in urban retrofitting. The effort should be placed on the widening of streets orientated along the prevailing wind direction. Also, shortening the length of the street grid perpendicular to the prevailing wind direction minimises stagnation. It is important to explore the urban breezeway patterns to optimise the arrangement of both the street and corridor networks.
Well-ventilated sidewalks 	Well-ventilated pedestrian walkways can be achieved by aligning them parallel to the prevailing wind and positioning them in adequate locations.	The reduction in prevailing wind speed due to urbanisation reduces ventilation in walkways and can cause discomfort. Underpasses, sidewalks, skywalks and overpasses should be orientated and located in relation to the wind flow patterns, since wind flows are better at certain levels. At the same time, these pedestrian walkways should be protected from diagonal rain and sun radiation.	Pedestrian trajectories inside the urban area should be taken into consideration in the early stages of planning. Also, the technical aspects of walkways should be considered, such as materials used for paving. Multilevel pedestrian links and elevated walkways are important components of alternative walkway system that help in increasing pedestrian outdoor comfort. In high-density urban areas, carefully-designed walkway systems create a relatively pedestrian-friendly environment that also needs to distance people from vehicles, pollution and noise.
Building arrangement 	The building arrangement refers to the adequate location of buildings with respect to each other and thus in relation to the prevailing winds to improve ventilation as well as shade where required.	A possible cause of increase in UHI is an improper building arrangement that can reduce the wind speed and thus increase the thermal capacity of the city. It is important that the axis of the buildings should be parallel to the prevailing wind to avoid sea breeze obstruction. Inadequate arrangement can reduce wind speed and have an impact on building energy consumption. Similarly, exhausted heat from air conditioning has to be taken into consideration while arranging a group of buildings.	It is necessary to include these issues in the first stage of urban planning. An effective arrangement of buildings to improve wind ventilation is to stagger the arrangement of the blocks such that the rear blocks are able to receive the wind penetrating through the space between the blocks in the front row. The building arrangement can direct or redirect the wind flows. Generally, buildings with smaller footprints and low-rise buildings should also be considered to improve ventilation in the urban area.
Open spaces at road junctions	The prevailing wind travelling along breezeways and major roads can penetrate deep into the district by the appropriate linking of open spaces. Such linkage and alignment can take place at road junctions in such a way	Linking open spaces with road junctions can produce higher benefits in reducing urban temperatures and improving thermal comfort outdoors. Outdoor thermal comfort can be improved as this linkage will provide abundant wind to pedestrians and	An effective linkage of open spaces and road junctions can enhance suitable ventilation paths. In any case, the buildings along breezeways or ventilation corridors should be lowrise to avoid breezeway obstruction.

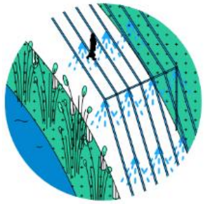
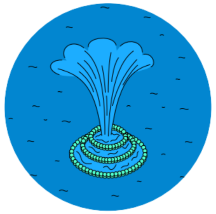
	as to form breezeways or ventilation corridors.	cyclists crossing these junctions or to people resting in the open spaces.	
Guide wind flows with urban elements 	Guiding and increasing the wind flow through specific urban elements such as void decks can improve the wind volume near the ground and the urban air ventilation.	Introducing void decks and improving the building permeability on the ground not only improves the wind condition at the pedestrian level but it also adds value in mitigating UHI by lowering the air temperature.	The provision of building permeability nearer to the pedestrian level is far more important than that at high levels to improve the pedestrian comfort due to the stack effect. This can be achieved by creating voids at ground level to improve ventilation for pedestrians and the residential units at the lower floors.
Passive cooling systems 	Passive cooling systems are design techniques that prevent heat from entering into the building or promote heat removal from the building envelope or open spaces through natural cooling. Cost-effective sources of passive cooling could be the orientation and arrangement of buildings and vegetation, water bodies and reflective coatings, but also the use and combination of open and semi-open spaces allowing cross-ventilation.	Higher UHI is expected if there is little emphasis on integrating passive cooling systems in the urban and building design. By utilising only mechanical systems such as air conditioners or chillers as primary sources for improving indoor thermal comfort, there would be adverse impacts on UHI and outdoor thermal comfort.	New neighbourhood planning should include passive techniques such as improved building arrangement, porosity, vegetation and coatings to reduce urban heat accumulation. Also in the case of urban retrofitting, certain passive cooling systems could be considered.
Building surface fraction 	The Building Surface Fraction (BSF) is the ratio between the horizontal area of buildings (building footprint) on a given area and the total area. BSF is considered a physical parameter to measure Local Climate Zones (Stewart & Oke, 2012).	High density influences the ground space and the space between buildings. Lowering the BSF will provide more open space around the building volume and therefore decrease the air temperature by avoiding heat accumulation during the day as well as heat release during the night (Buchholz and Kossmann 2015). This will facilitate greater natural ventilation of pedestrian spaces and improvement in the outdoor thermal comfort.	Planners take into consideration the Gross Plot Ratio (GPR), which measures the ratio of the Gross Floor Area (GFA) of a building or various buildings to the land area of the site. By taking into consideration the surface fraction, planners can estimate the heat intensity caused by lowering or increasing the BSF.
Green plot ratio	The Green Plot Ratio (GnPR) is a three-dimensional ratio between the greenery in a given area and the total area. It is measured through the Leaf Area Index (LAI). It includes vertical and horizontal landscaping, lawns and	This strategy gives incentives to increase the amount of greenery in urban areas. Increasing the greenery and integrating it into the architectural design can provide cooling to the immediate surrounding environment and the surface	GnPR is part of BCA's Green Mark since 2005 and rates different building typologies by the amount and type of surrounding greenery such as grass, bush or tree.

	trees, raised planters and urban farms.	temperature. Introducing building greenery on walls, balconies, sky terraces and roofs has a significant effect on the outdoor thermal comfort and in mitigating the UHI.	
Topography 	The topography can be an integral part of the urban fabric, which is not a direct component of microclimate but an indirect one.	The combination between the elevation of the terrain and the urban fabric influences the microclimatic phenomena such as wind drafts and rainfall, generating an indirect effect on UHI and outdoor thermal comfort. The effect of topography in UHI can be more appreciated when a topographic depression is found (Serrano et al. 2003) and also during daytime hours (Geiger et al. 1995 and Nitis et al. 2005).	Wall et al. (2015) shows evidence of urban design projects where natural and human made topographical features such as hills, buildings and vegetation were introduced to induce cool winds into the urban fabric.

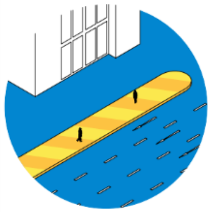
3. Water bodies & features

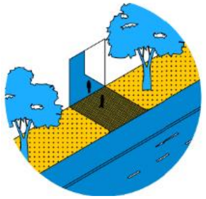
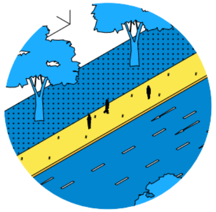
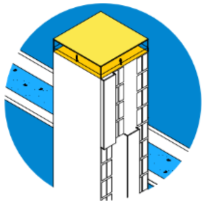
Measure	Description	UHI effect	Urban planning
Cool sinks 	Natural surface water accumulation can act as a cool sink to prevent the overheating of urban surfaces.	Large water masses can absorb thermal energy from the incoming solar radiation due to its heat capacity. Also, water evaporation is a sink for sun radiated energy. Thus, a mass of water can reduce the accumulation of heat and thus contribute to reduced UHI and improved thermal comfort. Additionally, if water bodies are sufficiently extended by, for example several square kilometres, local breezes can be developed and wind speed increased with benefits in thermal comfort and urban heat removal.	Implementation should be considered at an inter-ministerial context. Different agents should be involved in the design and implementation of this measure in relation to other requirements. Thus, the planning of new developments can consider the possibility of strategic natural water accumulation, which if combined with local wind flow patterns, can benefit nearby outdoor thermal comfort.
Blue and green spaces	Combining blue and green mitigation strategies in urban areas can bring about integrated solutions and distinct benefits from their characteristics.	Water (blue) and vegetation (green) strategies can affect climate variables differently and thus the UHI effect. Differences between both do not only refer to the amount of energy dissipated but also on their suitability through the day. For example, water can have a nocturnal warming effect during certain periods of the year. Also, vegetation can provide shade during daytime and improve thermal comfort but during night-time it will trap heat at surface level and worsen nocturnal urban heat island.	Knowing the limitations of each mitigation measure and the benefit of combining them is crucial for developing ad-hoc urban design to protect and enhance the wellbeing of inhabitants by optimising ecosystem services. Thus, urban planning guidelines that include these issues would help their implementation.

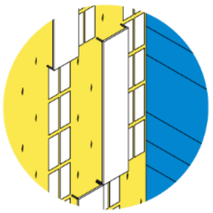
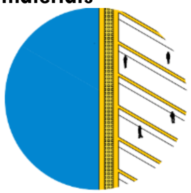
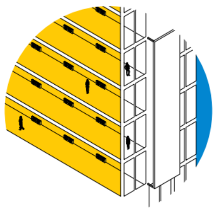
			
Wetlands 	Wetlands are the link between land and water and they contribute towards flood control, carbon sink and shoreline stability. This measure concerns the conservation of natural water surfaces with high presence of vegetation and negligible surface overheating.	Water has negligible diurnal temperature variation compared to land surface and thus it does not accumulate heat during daytime hours. In this context, the proximity to wetlands with a high presence of vegetation can be more comfortable.	Care should be taken not only when developing natural areas that can provide thermal comfort, but also the surroundings where their effect can be extended, for example, cool air transportation due to wind.
Water catchment areas 	Water catchment area is an area of land integrated into the natural landscape that collects rainwater and drains off into other water bodies. The accumulation of water catchment areas as a pre-emptive measure can prevent the overheating of urban surfaces.	Large water masses can absorb thermal energy from the incoming solar radiation due to its heat capacity. Also, water evaporation is a sink for sun radiated energy. Thus, extending water catchment areas can increase the non-heated surfaces and hence contribute to reducing UHI and improving the thermal comfort of residents outdoors.	Implementation should be considered at an inter-ministerial context. Different agents should be involved in the design and implementation of this measure in relation to other requirements. Thus, the planning of new developments can consider the possibility of strategic water accumulation.
Ponds on roofs / ground floor 	Ponds are an accumulation of water that prevent the overheating of urban surfaces. They can be located on ground floor areas or on building roofs.	Water can absorb thermal energy from the incoming solar radiation due to its heat capacity. Also, water evaporation is a sink for sun radiated energy. Thus, a mass of water can lessen the accumulation of heat and thus contribute to reducing UHI. Additionally, reducing roof surface temperatures with the use of water bodies would lower energy demand, especially in low-rise buildings.	The implementation of water features on rooftops or ground floor should be aided by the development of building codes and energy efficiency guidelines. Also, the planning of new developments or urban retrofit can consider the possibility of strategic water accumulation both from a public and private perspective. In this sense, including the interaction of local wind with the water features would improve its performance regarding thermal comfort.
Evaporative cooling	Evaporative cooling systems are devices that cool the air through the evaporation of water. It can increase locally the levels of humidity through water misting and/or spray.	Evaporative cooling dampens the positive effect on thermal comfort by eliminating heat or reducing temperature on the surface of the body's skin. In hot environments, evaporative	Since this measure provides benefits to the outdoor environment, the planning of new developments or urban retrofit could consider the possibility of including it locally so

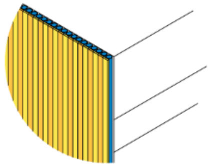
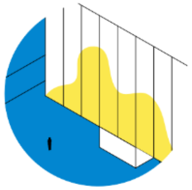
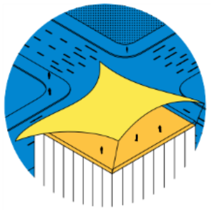
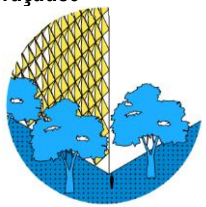
		cooling can play a role in creating a calming effect.	as to create cool spots that enable the enjoyment of the outdoors, both in public and private areas.
Fountains 	Fountains are watering surfaces to prevent overheating and increase locally the levels of humidity.	Water can prevent urban surfaces from heating due to its heat capacity and the evaporation process. Thus, a fountain can be considered a heat sink. In this sense, it can improve thermal comfort in the close surroundings similar to other water features, depending on its size, shape and water movement characteristics.	Strategic locations for fountains providing spray water are necessary if thermal comfort benefits are to be expected. One important consideration is the wind environment since it conditions the transport and impact of water spray

4. Materials & surfaces

Measure	Description	UHI effect	Urban planning
Cool pavements 	Cool pavements are made of materials that reduce their surface temperature by reflecting a significant percentage of solar radiation and releasing thermal heat into the environment. These surfaces are usually a light colour, or white.	Cool pavements are characterised by high albedo (high solar reflectance) and high thermal emittance. Consequently, this reduces the urban heat accumulation responsible for UHI phenomena, especially in hot climates. However, this measure could worsen local outdoor thermal comfort. The main positive effects of these materials are two-fold: one, reducing solar radiation absorbed by the pavements during the day, and two, releasing absorbed thermal heat into the atmosphere readily.	Cool pavements could be obtained by implementing lighter coloured asphalt on streets and roads and also by the use of cool tiles or special coatings on urban pavements. An incorrect implementation of this measure, especially in high urban density areas such as urban canyons, could cause outdoor visual and thermal discomfort for pedestrians and drivers as well as an increase of cooling loads in surrounding buildings. Nonetheless, cool pavements could be developed in both public and private spaces.
Permeable pavements	Water retentive and porous pavement systems, which include additional voids compared to conventional pavements, allow water to flow into the ground or into water holding fillers. This helps to store runoff so as to avoid pooling or ponding on the pavement surface. From a thermal perspective, these pavements also enhance water evaporation and therefore remain cooler than conventional pavements.	A permeable pavement measure provides benefits for pedestrians' thermal comfort allowing a reduction of the surface temperature of the pavements due to water evaporation and reduction in overheated material. When applied on a large scale, it simultaneously contributes to UHI mitigation and also flooding risk reduction. It can also contribute to pollution control from surface runoff from roads and parking areas, and help with noise reduction.	This type of solution has become an important and integral part of sustainable urban drainage systems. Common applications can be public and private, such as vehicular access, parking, pedestrian access and bicycle trails (Scholz and Grabowiecki, 2007). Implementation varies greatly across specific designs, and can be integrated with vegetation factors.

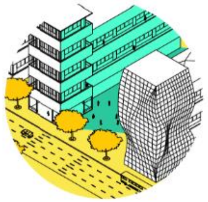
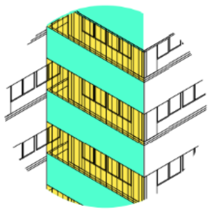
			
Photocatalytic cool pavements 	Cool pavements are surfaces that have been treated, blended, coated, sprayed (before, during and/or after installation) with specific mixtures or additives that help them remain clean, and maintain a high level of solar reflectance over time. Generally, these treatments are based on photocatalytic properties.	Solar reflectance usually decreases over time, as soiling from traffic darkens the surfaces. Improving the self-cleaning capability of pavements and maintaining a high level of solar reflectance with photocatalytic treatments allows the original thermal and visual performance of the pavements to be retained. This helps maintain low values of surface temperature for pavements exposed to intense sun radiation and similarly, helps maintain low nearby air temperature values to improve pedestrian thermal comfort.	If implementation of photocatalytic cool pavements is not regulated under any standards, it can be implemented both for private and public pavements, or in renovated or new pavement scenarios.
Cool roofs 	Cool roofs are typically white or lightly coloured reflecting surfaces that are able to decrease their surface temperature and consequently heat transferred into the buildings below. They can be useful for reducing cooling energy consumption and energy costs in buildings.	Cool roofs can increase the albedo of the urban environment if widely applied, presenting a relatively high heat island mitigation potential. Cool roofs are characterised by high solar reflectance, but also by high thermal emittance. These positive effects reduce building energy consumption for cooling - thanks to their capability for increasing thermal losses and decreasing corresponding heat gains during sunny days (Santamouris, 2014; Akbari et al., 2006).	The implementation of a cool roof measure is considered financially and technically viable, providing a cost-effective solution to increase building energy efficiency. It can be implemented both on flat and sloping roofs using cool solutions such as natural cool gravels, cool membranes in single ply or liquid mixtures, cool coatings, cool tiles and more (Pisello et al., 2014; Pisello et al., 2015).
Cool façades 	Cool façades are covering layers of building façades that limit the absorption of solar radiance. They help reduce the surface temperature of façades and cut both the heat transferred into the building, and the energy consumption needed for interior cooling.	The benefit of this solution consists mainly in increasing solar reflectivity and promoting emission accumulated heat using high thermal emissivity. The result is a reduction of both the building energy consumption for cooling and the temperature of the air in the cool façades proximity. The analysis of thermal effects on buildings and outdoor dense urban environments has shown interesting prospects for urban heat island mitigation (Doya et al., 2012). Thus, an improvement in outdoor thermal comfort and UHI is expected by the implementation of this measure on a large scale.	The implementation of this measure is considered financially and technically viable, especially for south-oriented façades. It could be implemented by following specific façade design to avoid visual and thermal discomfort for passers-by.
Photocatalytic cool buildings	These are cool building envelopes such as cool roofs and cool façades that have been treated, blended, coated, sprayed with specific mixtures or additives that help building envelope surfaces remain clean and maintain a	Solar reflectance of cool roofs and cool façades decreases over time, as deposition from environmental agents darkens the surfaces. An improved self-cleaning capability can preserve a high level of solar reflectance to keep the	The implementation of photocatalytic cool surfaces can be regulated by standards. The treatments can be white or light coloured and they can be implemented in both private and public buildings, and in building envelopes to be renovated

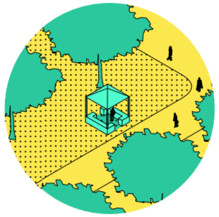
	high level of solar reflectance unaltered in time. Generally, these treatments are based on photocatalytic reactions and they can be applied before, during and/or after installation.	original thermal and visual performance of such surfaces. This helps maintain low surface temperatures and reduce the potential building energy consumption particularly in hot climates where air conditioning is essential. The positive effects of this strategy in relation to the UHI phenomenon consist of limiting the potential increase of the phenomenon intensity and undesirable correlated effects.	or that are new.
Retro-reflective materials 	Retro-reflective materials are directionally reflective surfaces (non-diffusive surfaces) characterised by high albedo and the ability to reflect solar radiation back towards its source.	Retro-reflective materials contribute to the mitigation of extreme local overheating and UHI effects by lowering building cooling loads and electricity consumption (Synnefa et al., 2006). The decrease of building and urban surface temperatures, and consequently urban ambient temperatures, influence pedestrian thermal comfort in a positive way.	Suitable applications in dense urban environments need to consider the negative effects such as overheating and glare in nearby buildings. Implementation should be focused on roofs, façades, and pavements paying attention to the directionality of the reflected radiation.
Phase change materials 	Phase change materials (PCMs) store and release massive latent heat during phase transition within a certain temperature range by increasing the building inertia and stabilising indoor air temperature.	PCMs help cut heat penetration into buildings and reduce the overall energy consumption, for both cooling and heating. It is considered a significant technology for the global warming solution (Lu et al. 2014). Indirectly, this solution will help mitigate UHIs and consequently improve the outdoor thermal comfort.	The integration of this measure needs to be done at building scale, incorporating the PCMs into the components of the building envelope, such as roofs, walls, floors, and transparent surfaces and so on. The efficiency and selection of PCMs are subject to the local climate where they are applied, since the transition temperature can vary.
Desiccant systems 	Desiccant systems control moisture and use latent cooling to maintain a comfortable and healthy indoor environment. By absorbing water vapour from the air, the dehumidifying effect moves the workload from latent cooling to sensible cooling and delivers improvements in building energy efficiency.	A desiccant (hygroscopic material) is energy-efficient for dehumidification in airconditioning systems in buildings (Gaoming Ge and Niu 2011). Desiccants remove moisture to reduce humidity and improve both air quality and energy efficiency. These systems offer thermal comfort in hot and humid climates along with lower primary energy resource consumption, compared to conventional cooling systems. The energy consumption savings allow reduced energy impact on the outdoor environment and therefore indirectly contribute to improving the outdoor thermal comfort and mitigating the UHI.	Not applicable as this solution concerns indoor application.
Water cooling façade systems	Water cooling façade systems transfer heat by evapo-transpiration outside the buildings by means of water integrated within the building façades. Evaporative cooling	Water cooling façade systems allow a reduction in urban heat accumulation and consequent emissions from a building by decreasing the surface temperature. This has a	Implementation should be focused on south-facing façades in particular where performance is enhanced by more intense solar radiation. Specific evaporative cooling solutions can be

	is a heat dissipation technique.	consequent influence on pedestrian thermal comfort when applied at pedestrian level.	chosen and adapted for the purpose, in accordance with the architectural design of the building.
Thermochromic / selective materials 	This approach is suitable for building envelope application using reflective materials based on nanotechnological additives, such as thermochromic or selective materials. These respond thermally to their environment, changing colour (with reversibility) from darker to lighter tones according to the temperature increase. This passive cooling technique enables a decrease in heat gain by facilitating the elimination of excess heat in the indoor environment of a building to maintain high levels of thermal comfort.	Thermochromic systems allow the prevention of heat gains inside a building. The use of thermochromic coatings can both contribute to energy savings and provide a thermally comfortable building environment (Ma et al., 2001). They also contribute to improvements in the urban microclimate.	Implementation should be focused on building envelope and urban structures in areas characterised by non-negligible air temperature variation. In this sense, including this aspect in building codes could help with their implementation.
Dynamic and active roofs 	This measure concerns roofs that are characterised by the dynamic adaptation to environmental conditions, using manual, automatic or hybrid systems. The key purpose of these systems is to cool the roof	The advantage of this kind of dynamic measure is the ability to use roofs to adapt to the environmental conditions. This adaptation helps the roof maintain the optimal surface temperature and the building to exhibit better performance in terms of indoor cooling demand. This reduces CO2 emissions from cooling systems. The implementation of this kind of solution within the city could mitigate the UHI phenomenon and, as a consequence, have a positive impact on the outdoor thermal comfort.	Moveable systems can be applied to the roof, according to the local regulation on dynamic and active systems. The principle of functioning can differ from one solution to another (automatic systems, water systems, manual systems, hybrid systems, etc.).
Dynamic and active façades 	This approach uses manual, automatic or hybrid system building façades that can dynamically change their configuration to let the building adapt to the weather conditions. The optimal adaptation improves the thermal-energy performance of the building.	The UHI mitigation, and consequently the improvement of outdoor thermal comfort, can be reached thanks to the use of dynamic building façades characterised by active systems that are able to improve the thermal-energy performance of the building envelope. Indeed, when the heat flux entering the building is reduced, the cooling energy consumption will be reduced accordingly, and less emissions would be released into the atmosphere by the cooling systems.	Implementation is related to building façades and can therefore be considered for both private and public applications. These solutions can be integrated into existing buildings or developed for new constructions.
Building envelope performance	This measure improves the building envelope performance to minimise heat losses or heat gains through the use of high thermal-energy strategies such as specifying thick conventional insulation.	These solutions eliminate the risk of over-heating of the buildings during extreme heat periods. Therefore, the indoor cooling needs would be reduced, as well as the correlated emissions and heat released into the outdoor	Implementation should focus on building roofs and façades and with the help of adequate building codes. Both public and private buildings can be improved from the application of high performing building envelopes. Some strategies can

		environment. The greater the use of this measure within a city, the greater the benefit for the urban environment in terms of UHI mitigation and improvement in outdoor thermal comfort.	be also applied on both new constructions and retrofit applications.

5. Shading

Measure	Description	UHI effect	Urban planning
Building orientation 	Buildings can be positioned in relation to variations in the sun's path as well as prevailing wind patterns. An adequate orientation can increase the building performance and provide shade on nearby outdoor structures such as sidewalks, public spaces and streets,	Optimised building orientation can lower the sun exposure and therefore minimise solar heat gains through the façades. Depending on the building orientation, direct, diffuse, and reflected radiation can be blocked, limiting short-wave radiation on surrounding/ local outdoor spaces. Simultaneously, it can also decrease the surface temperature, contributing to the short-wave radiation reduction (Lin 2016). The orientation can also contribute to the shading of outdoor spaces and therefore increase the pedestrians' thermal comfort and reduce the air temperature.	The main orientation of the building should be within 30° of south. Houses oriented east or south will benefit from the morning sun. Those orientated west or south will catch the late afternoon sun – which can help delay the evening heating period. A location on a south facing slope optimises solar access whilst minimising overshadowing from adjacent buildings. It also allows for higher density planning.
Shading on buildings 	Building elements as shading devices can be installed outside or inside, on or around the building envelope. They can be fixed elements, such as canopies, brise-soleils, horizontal or vertical louvers, blinds, roof overhang, egg-crate; or moveable elements, such as sun baffles and shutters (Giguere, 2009).	These elements function to control direct solar radiation as well as block and diffuse the reflective radiation of building envelopes. They limit the heat gains and consequently improve the thermal comfort of both indoor and outdoor environments. They also increase the building energy performance by reducing the building peak cooling load, and therefore reducing the UHI effect.	Windows in façades facing east and west should be minimised and shading devices should be integrated to reduce solar heat gain. The most common shading elements used in the tropics are horizontal overhangs to block high-angle sunshine during midday and vertical fins to protect from low-angle sunshine during the morning and afternoon (BCA, 2010).
Permanent shading devices	Permanent shading devices are solid and fixed structures. They are horizontal or vertical shades that protect people from harsh sunlight all day. Some types of fixed devices are urban pergolas, shade sails, framed canopies, shelters, or even solar cells applied on façades. They are mainly permanent structures.	Shading devices can control the intensity of solar radiation, but should not obstruct the breezeway and allow a refreshing sensation to guarantee comfort. The effect of this measure depends on the material, geometry, dimension and location of the device. It is imperative to study the sun-path to define the type and properties of the shading device.	Fixed devices can be applied to protect walkways, transport stops, park accesses, fixed urban furniture, or playgrounds. It is important that the design of fixed shading devices can balance the amount of shade and natural light.

			
Moveable shading devices 	Moveable shading devices are operable, manual and automated shades. They allow users to adjust the spatial properties according to personal needs. Some types of mobile devices are autonomous canopies and temporary tents.	This measure fulfils similar purposes as the fixed shading device. It can adapt to the sky conditions, solar angle and time of the day, reducing direct sun exposure during extreme weather conditions. Additionally, it offers spatial and temporal flexibility, but is limited in the sense of dimension, material and durability. It can have a positive impact on thermal comfort, especially in areas where permanent structures are not allowed or needed.	Mobile devices are commonly light and simple to install. They can be applied in areas where additional shading is needed during the daytime, for example in parks, sports fields, or temporary public spaces. During night-time they can be removed. This allows flexibility and variety of shaded and sunlit areas all-day round.
Smart shading devices 	Smart shading refers to shading devices that apply materials to transform their properties by external stimuli, also called 'shape shifting materials'. Their transformation is reversible and can be repeated.	Smart materials can change colour, shape or density according to the temperature, humidity and light of the outside environment. Smart shading devices can adapt to the climatic condition and therefore control the solar heat gain.	This type of measure can be implemented in many scales, from roofs for public spaces to entire building façades.
Shaded pedestrian spaces	Shading or the protection against direct sunlight of pedestrian spaces can be provided by buildings, canopies or trees. Important locations of shaded spaces are schools, hospitals, elderly facilities, transit stops, parks and plazas, recreational spaces, food centres and shopping areas.	Shading of outdoor spaces can effectively reduce the air and surface temperature while enhancing the thermal satisfaction of pedestrians. Increased shading on street level can control the amount of solar radiation absorbed by the ground floor surfaces.	The type of shading depends on the location, size, and function of the outdoor space. Different types of shading can have different impacts on pedestrians.
Shaded bicycle lanes	The shading of bicycle lanes along designated lanes or along parks can be provided by buildings, trees, canopies or other existing infrastructure, such as bridges or elevated highways. They can shield cyclists from direct sunlight and high air temperatures, and help them have a comfortable ride, thus promoting active mobility.	Trees or permanent covers can provide shade along bicycle corridors. Such covers can block the direct solar radiation and protect from rain, and therefore contributing to cycling comfort.	The location and orientation of the bicycle routes during planning are crucial to provide sufficient wind breeze and sun shade. An example is to locate bicycle lanes under wide infrastructure structures that provide sufficient shade length and protection from heavy rainfall.

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Food Waste

1. Background

Over the past two decades the predictability of food production experienced during the second half of the twentieth century has been becoming less certain. Climate change, population growth, environmental degradation and consumption patterns are just some of the issues driving continual change within the system.

The way we produce food today is a significant driver of both climate change and biodiversity loss. It relies upon ever-increasing quantities of synthetic fertilisers, pesticides, fossil fuels, fresh water, and other finite resources. These are a source of pollution and damage to ecosystems and human health. The heavy use of antibiotics in farming is also linked to disease-causing microorganisms becoming resistant to medications.

The problems in food consumption transcend food waste, as over half of the adult population in Europe are overweight, and nearly 33 million people in Europe cannot afford a quality meal every second day (Eurostat 2021). These figures reveal the relevant impact of food waste on the health of our planet and its inhabitants. They also show a pressing need to prevent and reduce food waste to make the transition to a resource efficient Europe.

1.1 Food Waste and Loss History

Our present is a product of the past. Conservation techniques, consumerism, capitalism, world exploration and the everlasting quest for growth come forward throughout food waste's history, but *how did humans come to create a yearly food loss phenomenon of ~2.5 billion tons per year (⅓ of all food produced)*[1]*?*

Historical research shows that humans around the Dead Sea of Jordan were the first in the world to develop systematic large-scale food storage, around the year 12.000 BC. 2000 years later, the Neolithic Revolution implied the transition from hunter-gatherer to agricultural activities: the crops yielded surpluses that needed storage.

In the beginning of the 17th century, agricultural innovations accelerated food production, which originated the first documented structural food surpluses. Farmers were no longer bound to local markets which freed them from lowering their prices or even discarding produce.

With the industrial revolution (1900) food cost even less and was more easily available, so it was more easily wasted. With lack of waste removal, diseases were easily spread in large cities and then the food waste disposal was addressed as a health problem: the first garbage delivery wagons date from the late XIX century. On the other side, other means of conservation were invented such as cans, widely used in wars.

The conservation problem was common for meat, vegetables, fruits until the 1930s when the mass production of home refrigerators started, alongside refrigerated storages and means of distribution (such as train wagons). Food waste reduced as leftovers could be stored longer.

During the second half of last century, agriculture was achieving ever higher levels of production. The main explanations are the relentless technological updates and farmers' extreme specialisation that has its origins on international trade. This has clear consequences for the environment. By the end of last

[1] Global Food waste in 2022 https://www.greenly.earth/en-us/blog/ecology-news/global-food-waste-in-2022

century, the first environmental movements started alerting on the implications of global warming, but there was a lack of knowledge about food or food waste implication on that problem.

The Food and Agriculture Organisation of the United Nations, created after WWII, has amongst their main goals they have the incision in food systems; reducing food waste, boosting sustainability, inclusion and efficiency and tackling health issues related to food.

1.2 Is food loss the same as food waste?

The two terms are related but distinct. Food waste, according to the Food and Agriculture Organization (FAO) of the United Nations, is "the discard of edible foods at the retail and consumer levels." In other words, food waste happens downstream, during either the distribution stage (for example, as food makes its way from a retailer's warehouse to a store shelf) or the consumption stage (such as people throwing out leftovers). Food loss, on the other hand, happens upstream: the FAO defines it as "the decrease in edible food mass at the production, post-harvest, and processing stages of the food chain."

> **"Food waste occurs at retail and households, unlike food lost, that occurs along the food supply chain up to, but not including, the retail level. This definition excludes food destined to other economic uses (such as animal feeding) and inedible parts of the food" (FAO)**

However there is a broader definition[2], which defines food waste as any food removed from the food supply chain to be recovered or disposed of. It includes food wasted at any single level of the production process and also inedible parts of food (skin or bones). The aim beyond this broad definition is to support the development of resource efficient and sustainable food systems in the EU.

Regulatory bodies and industry groups alike have taken steps to address both food waste and food loss. In fact, the United Nations' Sustainable Development Goal 12, which focuses on ensuring sustainable consumption and production patterns, includes target 12.3 to "halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains" by 2030. Meeting this goal would cause a 38% reduction in the carbon footprint of food loss and waste, equivalent to the GHG emissions of Japan.

KEY IDEAS

- There are a wide range of challenges in our food systems: a growing population, growing competition and scarcity of land, water and energy for food production, overconsumption, food waste and climate change among others.
- Food waste means discard of edible foods at the retail and consumer levels, while food loss is the decrease in edible food mass at the production, post-harvest, and processing stages.
- Food waste is more common in contexts of resource abundance and to poor conservation methods.
- Food waste implies the waste of economic and natural resources

[2] Fusions EU http://www.eu-fusions.org/

1.3 How food waste affect the food system?

Food waste is an issue that affects all aspects of the food system, a complex web of activities involving the production, processing, transport, and consumption.

Food systems account for over one-third of global CO_2 emissions, considering the way we produce, process, package, transport, and consume food (UN, 2021). In the EU, eighty-eight million tonnes of food waste are generated each year with associated costs estimated at €143 billion and around 20% of produced food is lost or wasted. Moreover, considering the food wasted in homes, restaurants, and shops, and the food lost on farms and in supply chains, a third of the total food produced in the world is never eaten, with 8-10% of global CO_2 emissions associated with unconsumed food (UNEP, 2021).

Fig. 01: Our Food System Source: https://www.food.systems/

Our current linear model, also known as the "make, use, and dispose" model, is based on the idea that resources are extracted, used to create a product, and then discarded once the product is no longer needed. This model is inefficient, wasteful, and unsustainable for several reasons:

- Waste: The linear model generates a lot of waste, as products are designed for single use and are disposed of once they are no longer needed. This waste often ends up in landfills, where it takes up space and can have negative environmental impacts.
- Resource depletion: The linear model relies on the extraction of new resources to create products, which can lead to the depletion of finite resources and contribute to environmental degradation.
- Inefficiency: The linear model is inefficient, as it does not take into account the value of the materials and resources that go into a product once it has been used. This results in the loss of valuable materials that could be used again.

We need to move from this to a circular food system where we use resources more efficiently and re-use side and waste streams. The circular model is based on the principles of sustainability and seeks to keep resources in use for as long as possible, extract the maximum value from them while in use, and then recover and regenerate products and materials at the end of their useful lives. This model is more efficient, less wasteful, and more sustainable than the linear model, as it seeks to minimize waste, reduce resource depletion, and make the most efficient use of resources.

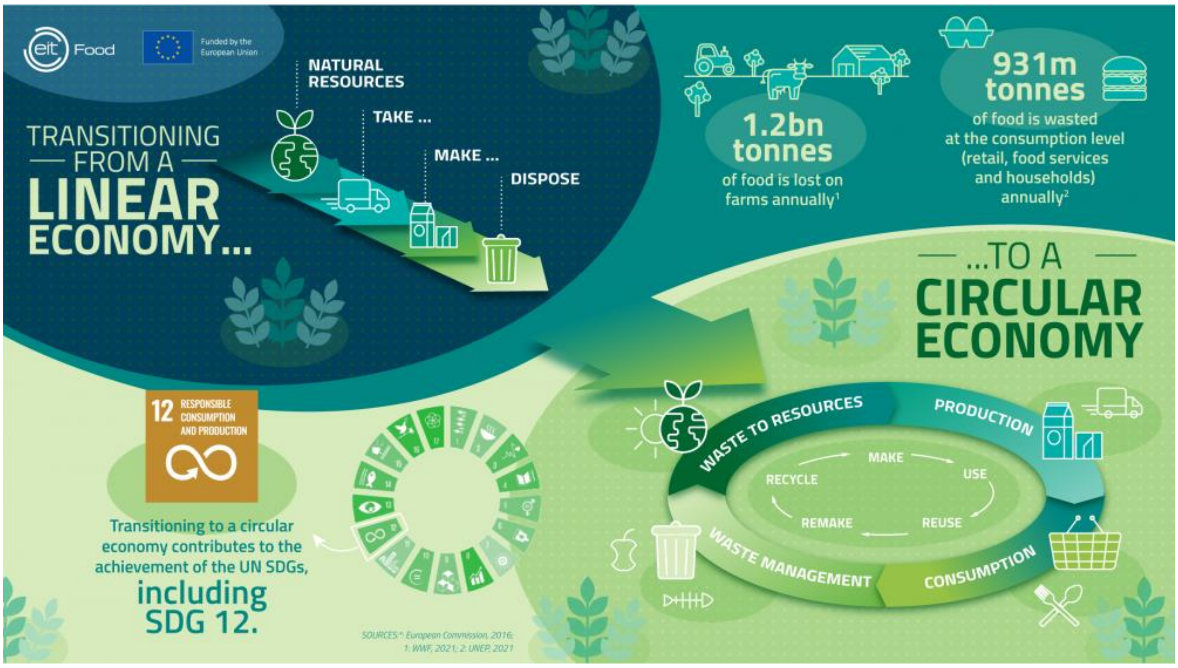


Fig. 02: From linear to circular economy. Source: https://www.eitfood.eu

2. Effects: Why do we care about Food Waste?

First of all, the fact that food waste exists means that there have been used more resources than the ones needed for alimentation purposes, and at the same time, more waste has been generated. It happens that food is not equally distributed, meaning that while in some contexts food is being wasted, in some others, that could be a few metres apart, people are starving. Having this in mind, the effects of food waste can be divided into:

2.1 Human Health

One of the global active challenges is feeding: the United Nations Food and Agriculture Organisation (FAO) estimates that about 815 million people (10.7% of world's population), were suffering from chronic undernourishment in 2016. At the same time, one-third of all the food produced in the world goes to waste.

2.2 Air Quality and Greenhouse Gases

Wasting food is not only an ethical and economic issue but it also depletes the environment of limited natural resources. When food goes to the landfill and rots, it produces methane—a greenhouse gas even more potent than carbon dioxide. According to FAO, food waste has a global carbon footprint of about 7% of all global greenhouse gas (GHG) emissions caused by humans. At the same time, trees that produce the oxygen we breathe are being cut down in favour of land to grow or dispose of food.

2.3 Water Quality

According to the World Resources Institute, an environmental think tank, inside the 1.3 billion tons of food wasted every year worldwide, there are over 170 trillion (1012) litres of water. This represents a waste of 24% of all water used for agriculture, already being the sector that consumes more water worldwide (around 70% of freshwater withdrawals).

Fruits and vegetables are the largest source of water loss and waste, mainly as a result of extremely high wastage levels (over 50%). Even despite the water cycle, the water-stressed regions that produce fruits and vegetables aren't necessarily going to get their water back (NPR, 2013). Also some of the water will be retained and poured in dumps. Intensive animal feeding operations, with big quantities of animal waste can infiltrate water and make it pollute.

2.3 Habitat destruction

Food waste can contribute to habitat destruction through the use of land, water, and other resources that are required to produce food. For example, the production of livestock requires large amounts of land and water, and the expansion of livestock production can lead to deforestation and the destruction of natural habitats. In addition, the use of pesticides and fertilizers in food production can contaminate soil and water, and can harm wildlife and other forms of biodiversity.

2.4 Biodiversity

The vast majority of wasted food is fruits and vegetables, and this wastage attracts wildlife, which can be harmed by these decaying foods. Litter can also draw large wildlife such as brown bears, wolves or wild boar, feeding them and approaching them to other species, ecosystems or even towns and cities.

Each ecosystem has its food chain, with its prey and predators. Large wastage of food can lead to increased numbers of one, which can then put the second in the chain out of balance. An example for this is fishery dumps, with over 7 billion tons of waste dumped into the ocean every year. This attracts seagulls, who feed on this fish, so easily getting feeded and reproduced. This exponential growth takes the ecosystem out of its natural balance.

2.5 Energy Use

Food systems consume about 30% of available global energy and out of this, 38% is utilised to produce food that is either lost or wasted (FAO, 2015). More than 70% of this energy is consumed on the transportation and distribution chain.

There is also an ethical dimension to food waste, as it involves the unnecessary use of resources and the waste of food that could be used to feed people in need.

KEY IDEAS

- Food Waste is a global challenge with consequences in many instances.
- The products containing a higher percentage of water are the ones more attached to waste (more water consumption and GHG emissions).
- Excessive wastage levels disrupt trophic chains and can poison soils and water.

3. Food Waste in Europe

Industrialised and higher-income countries see more food loss and waste relative to other countries. In most industrialised countries, approximately half of total food waste is incurred at the consumption stage of the value chain, by individuals. Food waste also has a huge environmental impact, accounting for 8-10% of global greenhouse gas emissions (UNEP Food Waste Index 2021) and about 6% of total EU greenhouse gas emissions (WWF). In the EU, households generate more than half of the total food waste (55%) in the EU with 71% of food waste arising at household, food service and retail (Eurostat, 2022). Around 88 million tonnes of food waste are generated annually in the EU alone, with associated costs estimated at €143 billion.

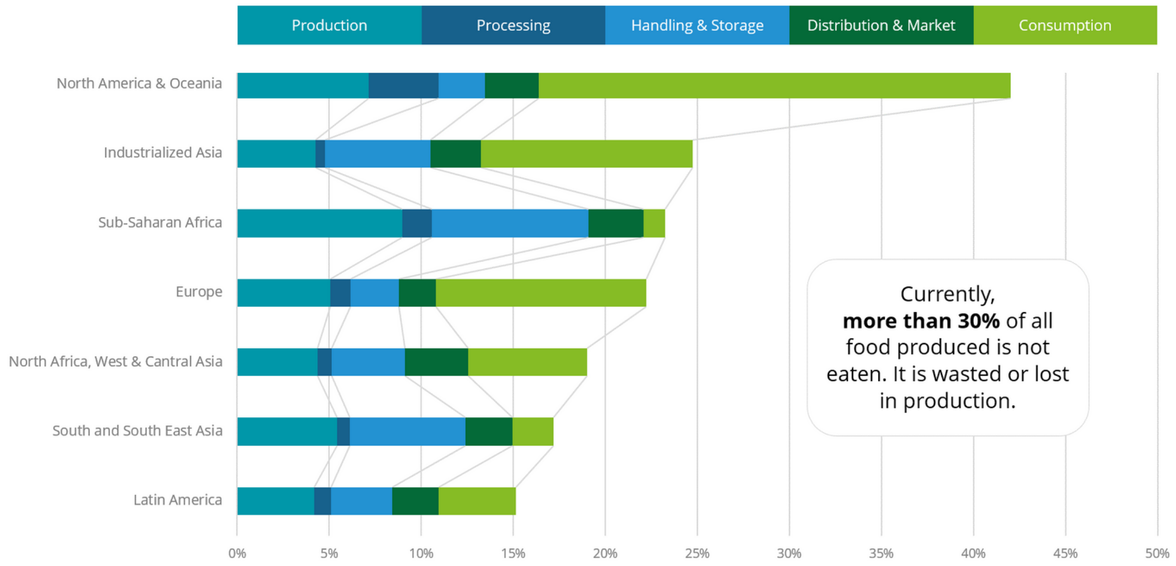


Fig. 03: Food waste and loss across the globe. Source: Deloitte https://bit.ly/3VdVQoH

In the European Union, 32,6 million people (7.3 % of the entire EU population) cannot afford a quality meal (including meat, chicken, fish or a vegetarian equivalent) every second day. The highest values are located in Bulgaria and Romania (above 19%) and the lowest in the Netherlands, Ireland and Cyprus, with shares lower than 2% (Eurostat, 2021).

Eurostat estimates that nearly 57 million tonnes of food waste (127 kg/inhabitant) are generated annually with an associated market value estimated at 130 billion euros. Around 10% of food made available to EU consumers (at retail, food services and households) may be wasted (Eurostat, 2022). As shown in the figure below, households are clearly the food chain stage where more food is wasted (55%), followed by the processing stage (18%) and primary production (11%). Restaurants and food services account for the 9% and around the 7% of the share belongs to retail.

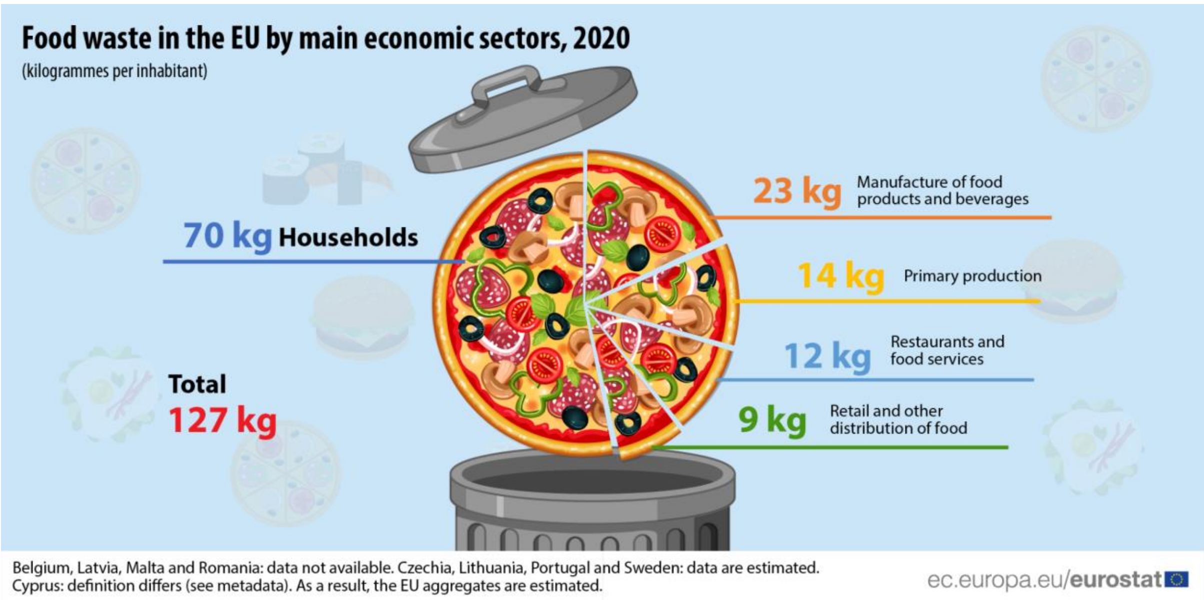


Fig. 04: Distribution of the Food Waste generated per inhabitant in Europe. Source: Eurostat.

Regarding the national distribution of food waste, Eurostat retrieves this data from 2020, with the first publication being made in October 2022. The countries with higher waste in kilos per inhabitant are

Cyprus (397), Denmark, Greece and Portugal and at the end of the table there are Slovenia (68), Croatia and Slovakia.

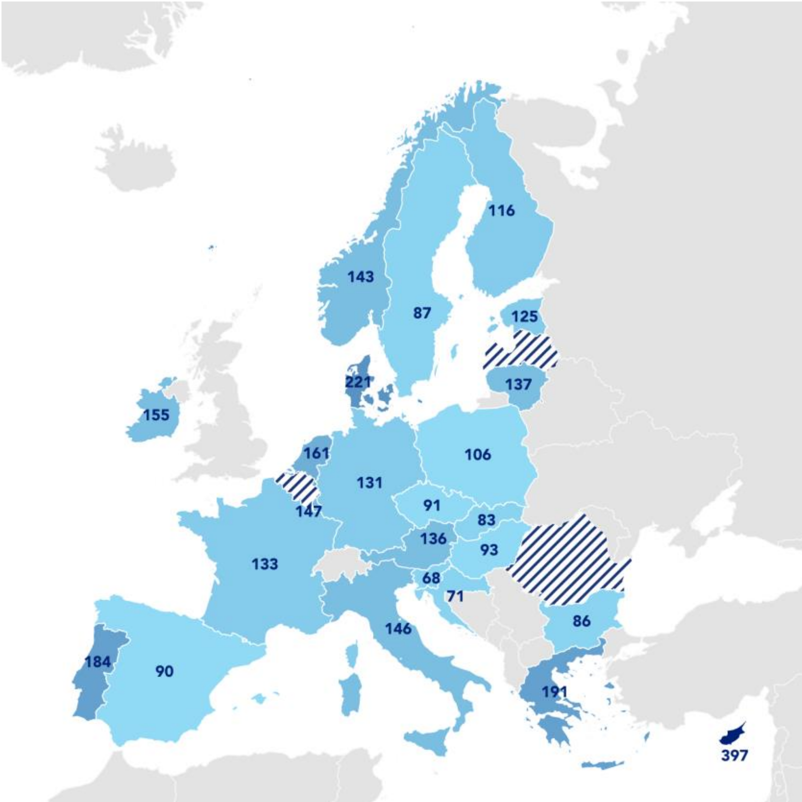


Fig. 05: Total food waste in kilos per inhabitant. 2020. Own creation. Source: Eurostat.

When it comes to a sectoral distribution, the following figure shows an unequal share amongst the member states. In Cyprus or Bulgaria, the greatest loss happens in primary production, in Portugal or Slovakia, the greatest share happens at Households and finally, Ireland and Cyprus have considerable shares of waste at a retail and food services level.

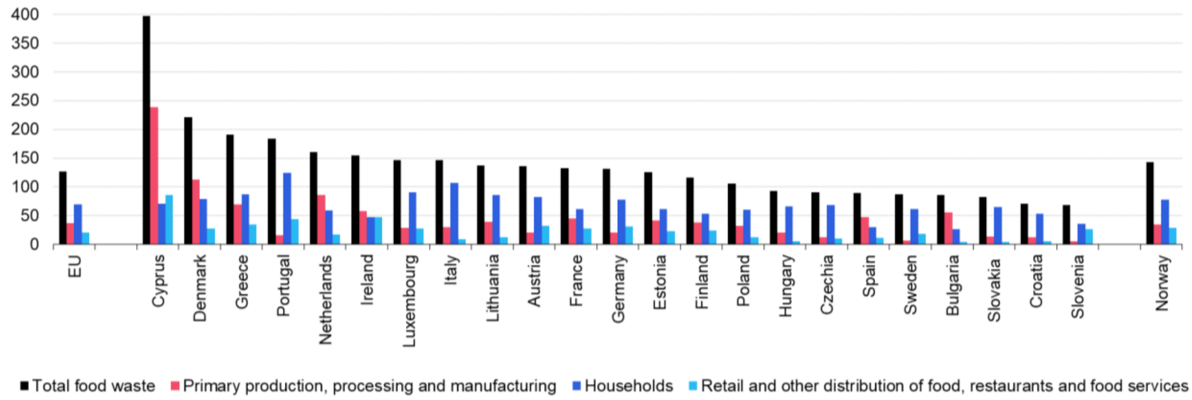


Fig. 06: Food waste by sector in kilos per inhabitant. 2020. Own creation. Source: Eurostat.

Tackling consumer food waste remains a challenge both in the EU and globally. Household food waste is nearly twice the amount of food waste arising from the sectors of primary production and manufacture of food products and beverages, in which strategies exist for reducing food waste, for instance with the use of discarded parts as by-products. Additionally, countries with a rather small population that are net exporters of raw and manufactured food products are showing high amounts of food waste, especially in the processing and manufacturing sector.

European Policies

The European Parliament has consistently fostered the reduction of food waste. Hereby there are different initiatives adopted by European institutions:

The EU Platform on Food Losses and Food Waste (FLW) was established in 2016, bringing together institutions, experts, international organisations and relevant stakeholders. This Platform aims to support all actors in: defining measures needed to prevent food waste; sharing best practice; and evaluating progress made over time.

In May 2018, the Waste Framework Directive was revised. It set some key requirements to tackle food waste that were already created or are expected to be during the next few years. The first of all is the establishment of a common methodology and quality requirements for the uniform measurement of food waste levels [link].

National prevention programmes, monitoring and implementation assessment were driven in a resolution of the European Parliament from January 2020 that calls for an EU-wide food waste reduction target of 50 % by 2030 based on a common methodology for measuring food waste. Member States are expected to report on national food waste levels from this year 2022 on.

As part of the European Green Deal action plan, the European Commission presented in May 2020 a 'Farm to Fork strategy' aimed at making food systems more sustainable. One of the targets included in the strategy is 'stepping up the fight against food waste', that is, cutting food waste by half with the help of legally binding EU-wide targets by 2023.

A Commission study published in 2018 estimated that 10% of food waste in the EU supply chain is linked to date marking. In this sense, there were introduced the 'best before' date (or 'date of minimum durability'), indicating the date until which the food retains its specific properties when properly stored, and the 'use by' date, indicating the last day on which the product is considered to be safe.

Member states have already taken steps to encourage food donation and other means of redistribution for human use and for the implementation of a waste hierarchy. Some examples are: reducing VAT rates for donated food, revising legislation promoting food donations and providing support to food banks and non-profit organisations that distribute donated food.

KEY IDEAS

- Food waste has different patterns all over the globe, affecting different stages of the food chain.
- In Europe more than half of the food is wasted at household level.
- The EU has set the 2030 deadline to reduce food waste by 50%.
- Both the European Green Deal action plan, and the 'Farm to Fork strategy' aim at making food systems more sustainable.

3.1 Case: Meat waste and its water footprint

Meat waste and food waste are closely related. Meat production is a particularly resource-intensive process, requiring significant amounts of land, water, and energy to raise and process animals. In addition, the production of meat is also a major contributor to greenhouse gas emissions, which contribute to climate change. As a result, meat waste can have significant environmental impacts.

Meat waste occurs at various stages of the food supply chain: in the production stage, a significant amount of waste is generated by culling and sorting animals, as well as by mortalities. In the processing stage, waste can be generated by trimming and processing meat cuts. In the distribution stage, waste is provided from spoilage and damage to meat products during transportation. At the retail level, waste can be generated by overstocking and stock rotation, and at the consumer level, waste can be generated by purchasing too much meat and not using it before it spoils.

The water footprint of meat production refers to the amount of water used to produce a given amount of meat. This varies depending on the type of animal and the production system. Beef production, for example, has a higher water footprint than pork or chicken production because it takes more water to produce feed for cows than for pigs or chickens. Additionally, intensive production systems, such as feedlots, have a higher water footprint than extensive systems, such as grass-fed beef. The water footprint of meat production can be reduced by improving the efficiency of water use in feed production, using more sustainable production methods, such as regenerative agriculture, and reducing meat consumption.

Meat waste is also closely related to food waste, as both issues are driven by similar factors, such as overproduction, overconsumption, and poor distribution and storage practices. In addition, the consumption of meat is a major contributor to food waste, as a large proportion of the food produced globally is used to feed animals raised for meat, rather than being directly consumed by humans. Efforts to reduce meat waste and food waste mostly relate to the reduction of meat consumption and the adoption of more sustainable consumption patterns.

Meat production framed in a circular economy includes sustainable and regenerative production methods, closed-loop systems, and the recovery and reuse of by-products. In this approach, the waste generated in the production of meat such as animal waste, bones, blood, and fat are seen as valuable resources that can be recycled and reused in other industries, instead of being discarded as waste. This can reduce the environmental impact of meat production, increase the efficiency of resource use, and create economic benefits through the creation of new revenue streams. This approach also considers fair labour practices, animal welfare and local sourcing to build resilient and sustainable communities.

3.2 Circular Economy for Food

As mentioned before, circular economy is a regenerative approach to a system capable of generating value and prosperity enlarging products' useful life and returning residues from the back to the start of the supply chain.

It is an economic model that aims to avoid waste and to preserve the value of resources (raw materials, energy and water) for as long as possible. The circular economy is based on three principles:

- Eliminate waste and pollution
  Currently, our economy works in a take-make-waste system. We take raw materials from the Earth, we make products from them, and eventually we throw them away as waste. Much of this waste ends up in landfills or incinerators and is lost. This system can not work in the long term because the resources on our planet are finite.

- Circulate products and materials (at their highest value)
  This means keeping materials in use, either as a product or, when that can no longer be used, as components or raw materials. This way, nothing becomes waste and the intrinsic value of products and materials is retained. There are a number of ways products and materials can be kept in circulation and it is helpful to think about two fundamental cycles – the technical cycle and the biological cycle.

  In the technical cycle, products are reused, repaired, remanufactured, and recycled. In the biological cycle, biodegradable materials are returned to the earth through processes like composting and anaerobic digestion

- Regenerate nature
  By shifting our economy from linear to circular, we shift the focus from extraction to regeneration. Instead of continuously degrading nature, we build natural capital. We employ

farming practices that allow nature to rebuild soils and increase biodiversity, and return biological materials to the earth. Currently, most of these materials are lost after use and the land used to grow them is depleted of nutrients.

A circular economy for food mimics natural systems of regeneration so that waste does not exist, but is instead feedstock for another cycle.

In a circular economy, organic resources such as those from food by-products, are free from contaminants and can safely be returned to the soil in the form of organic fertiliser. Some of these by-products can provide additional value before this happens by creating new food products, fabrics for the fashion industry, or as sources of bioenergy. These cycles regenerate living systems, such as soil, which provide renewable resources, and support biodiversity.

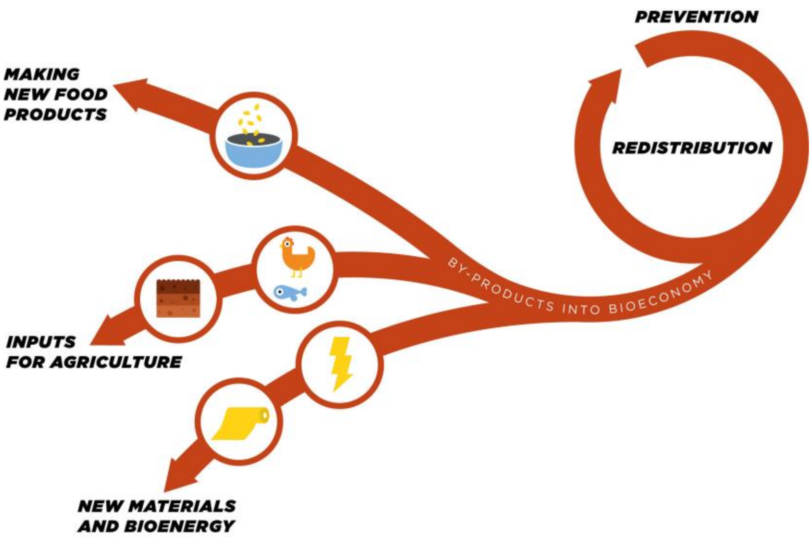


Fig. 07: Source: https://ellenmacarthurfoundation.org/

The goal of applying a circular economy approach to food waste is to decouple economic activity from the consumption of finite resources and create a resilient system that is good for business, people and the environment.

3.3 How to build a better food system?

There are many ways to build a better food system, and the specific approach will depend on the resources and goals of the community or organization. Some potential strategies include:

- **<u>Eliminate food waste</u>**

  Eliminating food waste is a step forward on solving other existing problems such as improving food security and nutrition, reducing greenhouse gas emissions, lowering pressure on water and land resources and increasing productivity and economic growth (Food and Agriculture Organisation, 2019). It also saves food for human consumption; brings savings for primary producers, companies and consumers; and lowers the environmental and climate impact of food production and consumption (European Commission, 2021). Eliminating or reducing food waste is an important way to improve the food system. This can be done through education, better storage and transportation infrastructure, and changes to food labeling and expiration dates.

- **<u>Ensure a regenerative food production</u>**
  Growing food while generating positive outcomes for nature such as healthy and stable soils, and improved local biodiversity, air or water quality is known as regenerative food

production. There are practices in local contexts such as using diverse crop varieties and cover crops, rotational grazing, and agroforestry that result in agricultural land that provides a habitat for a wide range of organisms. Allowing roots and stubble from harvested plants to break down on the land or reusing organic waste flows to create organic fertilisers are other examples of that. This results in agricultural land that more closely resembles natural ecosystems such as forests that provide habitat for a wide range of organisms.

Fig. 08: Source: https://ellenmacarthurfoundation.org/

And after the production stage, the challenge against food waste persists. There are measures such as the redistribution of food surplus to people who may need it and the reuse of inedible food and human waste as a base for new products.

- **Consume locally produced food**
  More than 40% of the world's irrigated cropland is located in peri-urban areas, yet the food produced on this land is often flown to consumers on the other side of the world while similar products are imported into neighbouring cities. By reconnecting towns and cities with local food production and balancing this with global supply, resilience can be built into the food supply chain.

Fig. 09: Source: https://ellenmacarthurfoundation.org/

On a smaller scale it supports local communities: by connecting people with local food production, smallholder farms can be preserved, benefitting both their communities and the environment. Additionally, smallholders use less resources and land, compared to large corporations and have the added benefit that green belts around the city contribute to cleaner air. Urban-rural relationships like this are increasingly being seen as a priority to build resilience into communities of all sizes.

Finally, it can report economic benefits first of all with the savings in transportation; second by using organic waste streams, which contain high levels of nitrogen and phosphorus; and third by using organic fertilisers instead of chemical alternatives (direct savings plus additional medical benefits).

- **Advocate for policy change**

Governments can play a role in shaping the food system through policies and regulations. Advocacy efforts can help to bring about changes that support a more sustainable and equitable food system.

KEY IDEAS

- The circular economy is an economic model that aims to reduce waste and promote the continuous use of resources.
- The circular economy is based on three principles: Eliminate waste and pollution; Circulate products and materials (at their highest value); Regenerate nature
- Food waste can be converted into food inputs for agriculture and new materials.
- The elimination of food waste improves food security and nutrition.
- A resilient supply-chain relies on food locally grown.

4. Cities as Catalysts for Change

Cities and food are inextricably linked. Ever since their genesis they are interconnected on the levels of production, processing, logistics and of course consumption. Today more than half of the global population lives in urban areas, this means that the choices made in cities can have a major impact on the food system.

Fig. 10: Source: https://ellenmacarthurfoundation.org/

Cities, and everyone within them, have a unique opportunity to spark a transformation towards a circular economy for food. Half of the world's population currently lives in cities. This number is expected to grow to 68% by 2050 at which stage 80% of the world's food will be eaten within cities.

In cities, consumption of food per person tends to be greater due to urban citizens earning higher average incomes than rural citizens. Yet, the high proportion of the food that flows into cities is processed or consumed in a way that creates organic waste in the form of discarded food, by-products or sewage.

The close proximity of citizens, retailers, and service providers (40% of cropland is within 20km of cities), makes new business models possible. Demand power, due to the sheer volumes of food eaten, means that city businesses and governments are ideally placed to influence the type of food that enters a city, and how and where it is produced.

Cities have the potential to create a more efficient and sustainable food system by rethinking the concept of food waste. Instead of viewing food waste as a byproduct to be disposed of, cities can adopt a circular approach that seeks to maximize the value of all food products. This can involve initiatives such as transforming food byproducts into new products, such as organic fertilizers and biomaterials, or using them as feedstocks for bioenergy. By doing so, cities can generate new revenue streams and help to design out the concept of waste altogether. As the main destination for much of the food produced, cities have a unique opportunity to lead the way in creating a more circular and sustainable food system.

KEY IDEAS

- 50% (and increasing) of the world's population is living in cities.
- In cities there is more food consumption and higher waste generation.
- Cities have the potential to become crucial in food waste transformation.

5. Design for Food

5.1 Historical Trends in Food and Conventional Architecture

Food architecture trends often follow similar patterns as those in traditional architecture because they both reflect the current trends and values of society. For example, during the mid-20th century, there was a trend towards brutalist concrete structures, especially tower blocks, shopping centres, and university buildings. At the same time, there was a proliferation of brutalist processed foods, such as TV dinners, sliced bread, meat spreads, and powdered drinks. These trends were driven by a focus on affordability and practicality, but they also resulted in a loss of connection to nature and traditional methods of food production.

Fig. 11: Brutalist building and brutalist processed food

At the end of the 20th century, architects inspired by postmodernism created unique buildings that defied our expectations of form and function. Around the same time, food architects inspired by molecular gastronomy created edible structures that challenged our expectations by using unusual ingredients or processes. These exquisite buildings and foods may have reflected deeper changes in society where a new class of affluent individuals were trying to distinguish themselves from the past. It is interesting that the swirling forms of post-modern architecture and the creamy emulsions and airy foams of molecular gastronomy both flourished in a period of conspicuous consumption as the financial markets frothed.

Fig. 12: End of 20th century examples of exquisite buildings and foods

The global economic recession in 2008 had an impact on both food and architecture, as there was a shift towards more sustainable, locally-sourced, and organic products in both areas. Architects began to use more locally-sourced, organic materials in their buildings, while chefs focused on using local and organic ingredients in their dishes. Urban planners also started designing compact, walkable neighborhoods that encouraged people to purchase smaller amounts of food at a time, which helped to reduce waste. These changes reflected a broader cultural trend towards sustainability and authenticity.

Fig. 13: Early 21th century changes towards more sustainable, locally-sourced, and organic products

5.2Circular Food design

In a circular economy, food products are designed to be healthy, right through from production to nutrition. New innovations, products and recipes can play their part in designing out of waste. Marketing can position delicious and healthy products as easy and accessible choices for people on a daily basis. Food brands, retailers, restaurants, schools, hospitals, and other providers can guide our food preferences and habits to support regenerative food systems.

Food designers can use the principles of the circular economy and apply them across all dimensions of food design, **from product concept, through ingredient selection and sourcing, to packaging**.

Regenerative design

Designing products with the goal of promoting and supporting the natural environment and setting targets for positive impacts on nature in the design process, can encourage product development teams to create items that have a positive and regenerative impact on the environment.

Ingredient selection and sourcing

Focus on achieving the best outcomes by taking into account which ingredients are included in formulations, how they are produced, and importantly, what role they play in regenerating the landscapes they are produced in.

Packaging

Three strategies can be used to help businesses achieve their circular economy goals for packaging: elimination, reuse, and material circulation.

Fig. 14: Source: Circular design for food, Ellen MacArthur Foundation, https://bit.ly/3jhEt8m

KEY IDEAS

- Our current food system conceptually still relates to the brutalist movement.
- Food is cheap and functional but with high environmental costs.
- In parallel, tendencies to real food and organic meals relate to sustainable building and neighborhoods.

6. Strategies to Reduce Food Waste

Many industrialized countries are implementing strategies to reduce food waste. These strategies may involve the use of new technologies to improve food storage and transportation; education campaigns to increase public awareness of food waste and how to reduce it; and policy changes that are led by institutions. These efforts can help to create a more sustainable and efficient food system. There are several trends in food waste reduction that are worth noting:

6.1 Government action

Many governments around the world are taking action to reduce food waste, such as:

- Implementing food waste reduction targets: Many governments have set targets to reduce food waste, such as the European Union's goal of halving food waste by 2030.

- Developing food waste reduction regulations: Governments can implement regulations that require businesses, such as grocery stores and restaurants, to reduce food waste. For example, France passed a law in 2016 that prohibited supermarkets from throwing away or destroying unsold food, and required them to donate it to charities or for animal feed.

- Funding food waste reduction initiatives: Governments can provide funding for initiatives that aim to reduce food waste, such as research into food waste prevention technologies or educational campaigns to raise awareness about the issue.

- Promoting composting: Governments can encourage the use of composting as a way to reduce food waste and improve soil health. This can be done through funding for composting infrastructure, education campaigns, and regulations that require businesses to compost food waste.

- Encouraging the use of surplus food: Governments can support initiatives that redistribute surplus food to those in need, such as food banks and soup kitchens. This helps to ensure that food that would otherwise go to waste is put to good use.

6.2 Increasing awareness

There is growing awareness of the problem of food waste, and more people are taking steps to reduce their own food waste. Here some examples of raising food waste awareness:

- Educational campaigns: Governments and non-profit organizations can create educational campaigns to teach people about the impact of food waste and how to reduce it. These campaigns can include information on how to store and prepare food to reduce waste, as well as the environmental and economic consequences of food waste.

- Social media campaigns: Social media platforms can be used to raise awareness about food waste and share tips and resources for reducing it.

- Labeling and marketing: Businesses can use labeling and marketing to communicate the environmental and social benefits of reducing food waste. For example, they can label products as being made with "ugly" produce (i.e. produce that may not meet traditional cosmetic standards but is still perfectly edible) to highlight the importance of reducing food waste.

- Community events: Governments and non-profits can host community events, such as food waste festivals or waste-free potlucks, to raise awareness about food waste and encourage people to take action.

- Partnerships with schools and universities: Governments and non-profits can partner with schools and universities to teach students about food waste and how to reduce it. This can be done through educational programs, field trips, and other activities.

6.3 Business action

Many businesses, particularly in the food and hospitality sectors, are taking steps to reduce food waste, such as:

- Implementing "first in, first out" systems to ensure that older products are used before they expire

- Applying portion control: Many restaurants serve large portions that can lead to excess food being thrown away. By implementing portion control, businesses can reduce the amount of food they serve and reduce waste.

- Donating excess food: Many businesses, especially restaurants and grocery stores, have programs in place to donate excess food to charities or food banks. This helps to ensure that food that would otherwise go to waste is put to good use.

- Composting: Many businesses, especially restaurants, generate large amounts of food waste that can be composted. Composting food waste helps to reduce waste and can also provide a source of organic matter for use in gardening and agriculture.

- Reducing packaging: Packaging can contribute to food waste by making it more difficult to store and transport food. Businesses can reduce packaging by using reusable containers or biodegradable materials.

- Using technology to improve supply chain management: Businesses can use technology, such as forecasting software and real-time data analysis, to improve their supply chain management and reduce waste by ensuring that food is produced and distributed in a more efficient and sustainable way.

6.4 Technology

The food-tech industry is one of the most developed sectors in the start-up world. Deeply immersed in the fourth industrial revolution, it has room to grow in fields such as bio-innovation, genetic editing, robotics, big data, artificial intelligence and machine learning.

Despite the pandemic, it experienced a 42% growth during 2020, something directly related to changes in consumer preferences. Since this is a sector in constant development, there are still new challenges for companies and start-ups in the industry, which must adapt to the trends of a market that is increasingly aware of the practices behind food production. As the industry grows, new technologies are emerging, bringing with them the development of key solutions and trends to enhance sustainability in the food industry:

- Food safety insight: Improving freshness tracking from farm to store by using sensors and machine-learning algorithms would provide stakeholders information on what to do to ensure freshness and prolong food life. It can improve their decisions about where food can be routed, when it should be displayed, and what the appropriate shelf life of a product is. Exponential increases in biological information contained in gene and protein databases will continue, using biosensors and diagnostics, to enhance productivity. Another approach is automating the interpretation of consumer feedback, achieving an early detection of potential food health issues, and preventing food loss.

- Food waste insight: A key challenge is to identify what is thrown out, how much, and where this food originates. Smart solutions are used in restaurants to identify wasted food, the menu items to which they relate and deduce why those are being thrown out. After the use of these technologies, the food services are able to more precisely predict food consumption and hereby cut down their food waste.

- Supply chain traceability: Many people demand more information about the food they're eating. The combination of interest in information and technological advancements will result in increasing traceability and sophisticated, multiple product channels from farm to shelf. Giving the final customers transparency in the safety and precedence of their food will result in less waste. Accordingly, blockchain technology is being used to digitally audit products, even in real time, with its databases that track all the processes, with information such as an ID, location, timestamp… allowing traceability.

- Make food for the future: New drying technologies are being developed in order to conserve produce (excess and discarded food) while conserving most of its nutritional value and extending its lifespan from some weeks up to 25 years. This technology eases conservation, reduces weight and volume and consequently pollution generated in transportation and storage. The next steps in this industry is to improve the energy efficiency of the drying process and transit to circularity.

- Develop smart farms: 70% of global water withdrawal is used by agriculture (World Bank). Smart farms are trending for their water use optimization, achieved by analysing soil moisture with IoT sensors or drone imagery for precision agriculture. Its demand is expected to grow and reach a market value of 34.1 billion dollars by 2026 and, more importantly, it will help to optimise costs, resources consumption and reduce the environmental impact of traditional practices.

6.5 Collaboration

There is increasing collaboration between different sectors, such as government, business, and civil society, to address food waste.

- Public-private partnerships: Governments can work with businesses to implement food waste reduction initiatives. For example, a government might partner with a grocery store chain to donate excess food to a food bank or provide funding for the store to implement food waste reduction strategies.

- Cross-sector coalitions: Governments, businesses, and non-profits can come together to form coalitions to address food waste. These coalitions can pool their resources and expertise to develop and implement food waste reduction strategies.

- Public education campaigns: Governments, businesses, and non-profits can collaborate on public education campaigns to raise awareness about food waste and encourage people to reduce it.

- Research partnerships: Governments, businesses, and universities can collaborate on research projects to develop new technologies and strategies to reduce food waste.

- Community-based initiatives: Governments, businesses, and non-profits can work with community organizations to implement food waste reduction initiatives at the local level. For example, a government might provide funding for a community group to start a composting program, or a business might donate excess food to a local food bank.

Overall, there is growing recognition of the problem of food waste and a number of efforts underway to address it.

6.6 Initiatives to reduce food waste targeted at different stages of the food system

The following initiatives are classified according to the food systems chain stage in which they can be applied.

Primary production

- Consumption of out graded and about to expire food.
- Short supply chains and regionalisation of food production.
- Storage improvements.
- Use of by-products for animal feed production.
- Taxation policies on food waste disposal.
- Access to modern equipment and techniques.
- Fishing: A policy reform and use of selective fishing gear.

Food processing and packaging

- Policies for resale/use of ‘sub-standard’ products.
- Application of date marks (more accurate date labelling).

Wholesale and logistics

- Electronic ordering systems and automatic storage management systems.
- Advanced packaging (conservation and transport techniques).
- Improve distribution (and redistribution to food banks) logistics.
- Incentives to reduce disposal and increase redistribution.
- Logistic more attentive to food safety
- Development of business models around imperfect produce.

Retail and markets

- Food donation & redistribution programmes
- Reduce prices on sell before /best before date products
- Alternative use of products
- Limits to price promotions with discounts on volumes
- Purchase per weight of fruit and vegetables
- Improve and guarantee food safety standards
- Improve refrigeration techniques
- Consumer awareness
- Improve organics collection services

Food Services

- Encourage consumption of leftovers and use of doggie bags
- Reduction of menu variety
- Improve demand forecasting and ordering systems
- Menu quantities based on hunger / size

Households

- Improve waste collection infrastructure
- Education programmes on diet and cooking
- Local composting facilities and services

Legal Barriers to Food Waste Circularity

There are several legal barriers to food waste circularity. For example food safety regulations can make it difficult to create novel food, repurpose or donate food that is past its expiration date, even if it is still safe to eat. Businesses may be hesitant to donate or repurpose food due to concerns about liability in the event of food-borne illness. Pre-market authorization of novel foods is required, as they must comply with consumer safety standards. If the novel foods are intended to replace another food, they must not differ in such a way that consumption of the novel food is nutritionally disadvantageous to the consumer. Regulations on food labelling and packaging are very strict both for novel foods and for repurpose food.

European zoning regulations may also put barriers for businesses and organizations to implement on-site food waste management programmes. These regulations can limit the use of land for certain activities, such as composting or anaerobic digestion, and may make it difficult to locate facilities that can process food waste on-site. Zoning regulations vary by country and region, therefore it is worth to consider:

- **Air quality regulations**- may limit the emissions of odours and pollutants that may be associated with composting or anaerobic digestion, and may make it difficult to operate facilities that process food waste on-site.
- **Noise regulations-** may limit the noise levels associated with composting or anaerobic digestion, and may make it difficult to operate facilities that process food waste on-site.
- **Waste management regulations-** may limit the amount of waste that can be processed on-site, and may make it difficult to compost or anaerobically digest food waste on-site.
- **Water quality regulations-** may limit the discharge of pollutants associated with composting or anaerobic digestion, and may make it difficult to operate facilities that process food waste on-site.
- **Building codes**- may limit the construction of facilities that process food waste on-site.
- **Fire safety regulations**- may can limit the use of certain types of materials in the construction of facilities that process food waste on-site.

Moreover, there are several legal barriers to deploying tech pilots in European cities and rural communities. These include:

- **Privacy and data protection laws**: European Union has strict laws regarding data protection, such as the General Data Protection Regulation (GDPR), which can make it difficult to collect and use data in smart city projects.
- **Regulatory barriers**: There are often different regulations and requirements for deploying technology in different cities and regions, which can make it difficult to roll out pilots on a larger scale.
- **Liability and safety concerns**: There are potential liability and safety concerns when deploying new technology in public spaces, which can make it difficult to secure funding and insurance for pilot projects.
- **Procurement laws**: EU countries have different procurement laws and regulations which can make it difficult for companies to bid for and win contracts for smart city projects.
- **Interoperability**: lack of standardization of infrastructure and software across EU countries can make it difficult to ensure that different smart city systems can work together effectively.

However, there are other European waste management regulations that aim to reduce the amount of waste generated and promote recycling and recovery of waste materials. Some examples of these regulations include:

- EU Waste Framework Directive (2008/98/EC): This directive sets out the overall framework for waste management in the EU, including the hierarchy of waste management options (prevention, preparing for re-use, recycling, recovery, and disposal) and targets for recycling and recovery of waste materials.
- EU Packaging and Packaging Waste Directive (94/62/EC): This directive sets targets for the recycling and recovery of packaging waste, and requires producers of packaging to take responsibility for the management of their packaging waste.
- EU Landfill Directive (1999/31/EC): This directive sets targets for the reduction of biodegradable municipal waste sent to landfills and sets standards for the design, operation and closure of landfills.
- EU End-of-Life Vehicles Directive (2000/53/EC): This directive requires vehicle manufacturers to take responsibility for the environmentally sound treatment of end-of-life vehicles.

- EU Battery Directive (2006/66/EC): This directive regulates the collection, treatment and recycling of batteries and accumulators, to minimize the impact of batteries on the environment.
- EU Waste Electrical and Electronic Equipment Directive (2012/19/EU): This directive regulates the collection, treatment and recycling of waste electrical and electronic equipment, to minimize the impact of waste on the environment.
- EU Circular Economy Package: This package of legislation adopted in 2019, set targets for recycling and recovery of municipal waste, packaging waste and specific waste streams, such as textiles, and established measures to reduce the generation of food waste.

All these regulations aim to encourage the use of sustainable waste management practices, such as reducing, reusing, recycling, and recovery, and to minimize the environmental impact of waste. They also establish targets for waste management and recycling that EU member states must meet and also create a legal framework for the prevention of waste, waste reduction and the implementation of the circular economy principles.

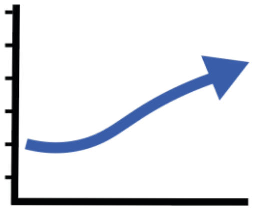
7. Conclusion: Future Scenarios for Food Waste

If the world population and economy continue to grow, it is likely that food production and consumption will increase. This can lead to more food waste, as well as more pressure on food systems to be more efficient. Climate change and other environmental challenges can also affect food production and distribution, leading to more food waste. However, technological advances can help reduce food waste by improving food storage and preservation methods, as well as making it easier for consumers to track and manage their food consumption.

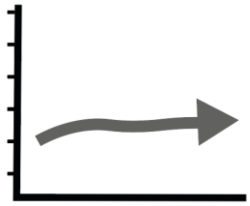
Social and cultural factors are key to reducing food waste, as changing social and cultural attitudes play a crucial role in shaping the future of food consumption. As people become more aware of the environmental and economic impacts of food waste, they are more likely to take steps to reduce it.

Government policies, regulations and laws can have a huge impact on food waste. Policies that incentivize or require the reduction of food waste can have a large impact on the problem.

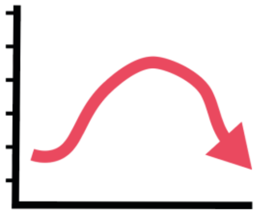
It is difficult to predict the exact future of food waste, as it will depend on a number of factors, however, here are a few potential future scenarios:



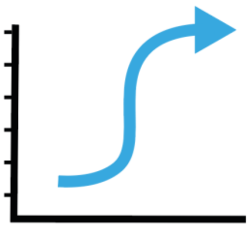
Continued progress:
If current trends continue, it is possible that food waste will continue to be reduced as awareness of the issue grows and more people and businesses take steps to reduce their own food waste.



Plateau:
It is possible that progress in reducing food waste may plateau at some point, as it becomes more difficult to make further gains. This could be due to a lack of incentives or technological limitations.



Reversal:
If efforts to reduce food waste are not sustained or if there is a significant increase in the global population, it is possible that food waste could increase in the future.



Radical change:
It is also possible that technological innovations or major shifts in societal values could lead to radical changes in the way food is produced, distributed, and consumed, resulting in significant reductions in food waste.

Overall, the future of food waste is uncertain, but it is important for individuals, businesses, and governments to continue working to reduce food waste and create more sustainable food systems.

8. Case Studies: What will be needed in the future?

Sunqiao Urban Agricultural District

Fig. 05: Sasaki Architechts

Sasaki is an international architecture firm working on urban agriculture. Their work includes the Sunqiao Urban Agricultural District, which is integrating vertical farming systems in public facilities in the area. This approach is a divergence from the theoretical skyscraper farms into more practical applications of urban farming. Also emphasized in the project, is the relationship between architect and municipalities, as this communication is pertinent to meaningful change. Through this dialogue, it can be discovered what spaces are most underused and the best fit for the installation of vertical farms or other practices. https://urbannext.net/how-food-will-reshape-our-cities/

Co-funded by
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Re-plate (California): Alleviating food insecurity

Replate manages the food donations of caterers, offices with meal services, brands with product overrun, farmers markets, restaurants and other surplus food generators. Every food donation is taken to a nearby nonprofit that works with people experiencing food insecurity.
The company leverages data, artificial intelligence, and agile programming to recover surplus food from vendors and deliver it directly to non-profit organisations.
https://www.re-plate.org/

Zero Waste Europe

The project has been set up to investigate practical ways to achieve zero waste to landfill in the South East of England. It will share the results with colleagues both in the UK and in relevant EU Member States. Zero waste in this context is an approach to supporting the sustainable use of resources by business to benefit both the economy and the environment. It concentrates on reducing, re-using, recycling and recovering energy from waste.
https://zerowasteeurope.eu

Bowery Farming

Fig. 06: Bowery Farming

Controlled Environment Agriculture is an important part of urban farming. CEA is farming in a controlled set of conditions including humidity, temperature, light, and nutrients. It is used in indoor farms so that multiple types of crops can grow in their ideal conditions in one building. Bowery Farming uses a combination between CEA and Vertical Farming in order to produce their crops. The latter takes advantage of tall warehouse type buildings to create stacks of crops. Bowery does not use soil but instead a mixture of hydroponic, aeroponic, and aquaponic methods. They also use LED lighting instead of relying on the sun for the necessary photosynthetic source.

Advantages:

Water Usage: Unlike outdoor farming, vertical farms can recirculate the water in their irrigation system to reduce water waste.

Arable Land: Bowery avoids issues caused by loss of arable land by converting industrial spaces into their indoor farms and staking their crops to multiply their yield per square foot.

Food System: These indoor farms are located outside of cities and can produce their crops year round. Therefore, there exists less risk for breakdowns in the food transportation system that harm communities.

Food Safety: E. coli outbreaks and other irrigation related health risks can be avoided.

The Bowery Farms grow only leafy greens and are just now branching into vine fruits such as strawberries. They are working on growing solutions for other types of farmed goods. Because of the current limitations on crops and the space and resources available to companies like Bowery Farming, indoor farming is not enough to feed the world. However, it can be one part of the global food systems challenges. https://boweryfarming.com/vertical-farming/

Veolia

Fig. 07: Veolia

Veolia is a for-profit business working on innovative ecological solutions in the industries of waste, water, and energy. They are partnering with organisations in a few major cities in order to develop urban farming practices and invest in a circular economy. They work with a food market in Brussels, Belgium and their roof garden of 2.000 sq metres of green houses and 2.000 sq metres of outdoor gardens. Through aquaponics, they produce over 30 metric tons of fish and 15 metric tons of tomatoes annually. Their mission is to contribute to the circular economy in Brussels and to provide for their community with as little waste as possible. Veolia also partners with Espaces and the Culticime project in an urban community garden atop a shopping centre in Île-de-France. This project provides jobs for people returning to the workforce. Their general focuses of all the projects they support are urban permaculture, aquaculture, and aquaponics.
https://www.veolia.com/en/solution/urban-farming-solution-helping-feed-cities

ReuSe Vanguard Project

Food and drinks account for the generation of 90% of waste of packaging, and much of it strictly responds to the needs of the distribution and sales chains, and does not guarantee the right to consume without producing waste.
This project has created an urban logistics service of reuse of containers for fresh food, supported with technological partners, which has allowed to create of hardware products (process automation gadgets like the autonomous return of packaging, the identification and registration of users and packaging, and the optimization of cleaning processes), and software (in logistics functions, database management, traceability, online payments, notifications).
https://zerowasteeurope.eu/our-work/implementation-activities/reuse-vanguard-project-rsvp/

Es im-perfect (Barcelona)

Fig. 08: Es im-perfect

Es im-perfect® is the range of products and the job placement company of the Espigoladors Foundation, an initiative that, since 2014, has acted on three social needs at the same time and connects them: fight against food loss and waste , guarantee the right to healthy and sustainable food for the entire population and create job opportunities for groups at risk of social exclusion.

https://esimperfect.com

Ottan Studio (Turkey): Upcycling food waste

Fig. 09: Ottan Studio

An impact startup focused on up-cycling green waste into high-quality materials to be used in interior design and industrial design products. Ottan Studio converts food and garden waste into bio-composite material from which it makes furniture, decorative items, and wall panelling.

https://www.ottanstudio.com/

BIO2CHP (Greece): Waste-to-energy strategy

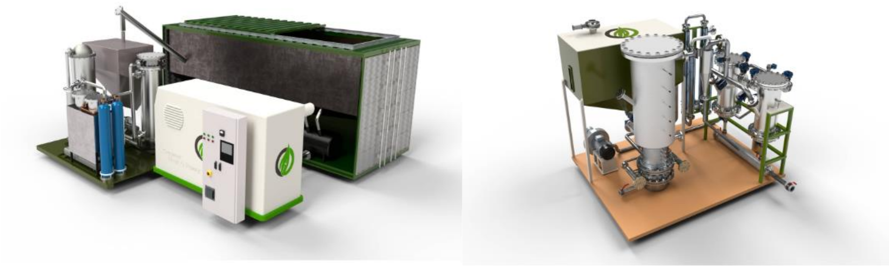

Fig. 10: BIO2CHP

Bio-based Energy Technologies P.C. (BIO2CHP) is a university spin-off company, established in 2017, with the main purpose of bringing to the market a technology which enables the use of raw residual biomass for the small-scale & on-site energy production. Utilises raw residual biomass feedstock from the agro-food industry – especially fruit waste, coffee grounds, and olive kernels – for small-scale, on-site electricity production.

http://www.bio2chp.com/

WeFood: the first-ever surplus food supermarket

Fig. 10: Source: WeFood.

This supermarket aims to cut down on the massive amounts of food wasted every year—700,000 metric tons in Denmark, and 1.3 billion metric tons around the world.a supermarket in Copenhagen. The supermarket has prices up to 50% lower than any other grocery store in the city, drawing both environmentally conscious shoppers and low-income individuals with limited budgets.

These initiatives benefit both consumers and the planet, preventing tons of food from ending up in landfills.

https://www.danchurchaid.org/about-danchurchaid/wefood

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Five benefits of a circular economy for food https://ellenmacarthurfoundation.org/articles/five-benefits-of-a-circular-economy-for-food

Food Architecture: Building A Better Food Supply https://www.ift.org/news-and-publications/food-technology-magazine/issues/2020/january/features/food-architecture-building-a-better-food-supply

Food waste has gone viral https://www2.deloitte.com/nl/nl/pages/consumer/articles/food-covid-19-food-waste-gone-viral.html

Food waste: the big picture https://www.hsph.harvard.edu/nutritionsource/sustainability/food-waste/

Food waste measurement https://food.ec.europa.eu/safety/food-waste/eu-actions-against-food-waste/food-waste-measurement_en

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Reducing food waste in the European Union https://www.europarl.europa.eu/RegData/etudes/BRIE/2020/659376/EPRS_BRI(2020)659376_EN.pdf

Regenerative Food production https://ellenmacarthurfoundation.org/regenerative-food-production

Statistics and resources for understanding food systems opportunities and challenges https://www.food.systems/

Technical Platform on the Measurement and Reduction of Food Loss and Waste https://www.fao.org/platform-food-loss-waste/en/

The coming food catastrophe https://www.economist.com/weeklyedition/2022-05-21

What Challenges in the Food System Are We Facing? https://www.futurelearn.com/info/courses/revolutionising-the-food-chain/0/steps/170874

When You Waste Food, You're Wasting Tons Of Water, Too
https://www.npr.org/sections/thesalt/2013/06/06/189192870/when-you-waste-food-youre-wasting-tons-of-water-too

Cities Network Engagement Roundtable 1

The first Cities Network Engagement Roundtable (CNER), named Empowering Changemakers event, for dissemination purposes, aimed to facilitate knowledge exchange and collaboration among experts from various sectors, focusing on the topics of Urban Heat Islands and Food Waste. The event featured parallel sessions where experts from the public and private sectors shared their insights and perspectives on these issues.

During these sessions, the experts highlighted the specific demands they have from both the public and private sectors. They emphasized the importance of innovative services that can contribute to addressing the challenges of Food Waste and Urban Heat Islands. Moreover, they discussed interesting trends in the food sector, such as the shift towards a circular economy model, and trends in city planning and design, particularly the movement towards cooling design and nature-based solutions.

In these parallel sessions, experts showcased innovative approaches and best practices for combating Urban Heat Islands and food waste. Examples included the creation of new, high-quality products from surplus food and the utilization of hyper-accurate AI technology to forecast heat waves and prevent food loss.

Given the presence of startup representatives in both sessions, insights were shared on various aspects. These included the significance of building a strong team, securing investment, and scaling technologies to enter the market. Additionally, the experts emphasized the importance of adopting a holistic approach when addressing challenges like food waste and Urban Heat Islands. This involved fostering connections not only with consumers but also with the local community, government entities at different levels, experts and researchers, and other businesses.

The event also facilitated private feedback sessions between Urban Experts, trainers, and learners. This unique opportunity allowed UrbanShift startups to receive in-depth sector knowledge and constructive feedback from industry experts, helping them refine their startup solutions.

The private sessions were specifically organized to enable UrbanShift entrepreneurs to pitch their start-up ideas, received expert feedback, and to address start-up questions to the experts. These sessions served as a reality check for startups, assessing their alignment with stakeholder expectations and evaluating the innovation and feasibility of their proposed solutions. By receiving this valuable feedback, startups could refine their ideas and strategies to better align with market demands and ensure long-term viability.

The event was conducted online through the Zoom platform and consisted of two parallel sessions: one focused on Urban Heat Islands and the other on Food Waste. The first part of the event (15:00-16:15 CET) was open to the public, while the second part (16:30-17:30 CET) was exclusively reserved for UrbanShift learners, mentors, coaches, and invited experts.

Co-funded by the European Union

URBAN SHIFT

Urban Shift: Empowering talents to address Food Waste and Urban Heat Island

Are you ready to unlock your full potential and make a real difference in the world? If so, we invite you to join us at **Urban Shift's parallel sessions on Urban Heat Island and Food Waste**, two of the most pressing challenges facing society today.

During these sessions, you'll learn from experts in both the public and private sectors as they share state-of-the-art economic, technical, and cross-sectoral viewpoints, as well as their demands, insights, and innovative approaches to tackling these critical issues. You'll gain invaluable knowledge from real-world case studies, including both successful and not-so-successful examples, and discover how you can leverage your skills and expertise to make a meaningful impact.

At Urban Shift, we believe that systemic change is possible, and we're dedicated to empowering individuals like you to drive that change forward. So why wait? **Join us on May 3rd at 3:00 pm (CET)** and become part of a movement that's shaping the future of our cities and our planet.

Schedule:

15:00- 15:15 Introduction to the parallel sessions (brief explanation of Urban Shift and the two challenges and the experts joining the Parallel sessions)
15:15-16:30 **Session on Food Waste** (3/4 experts - 10 minutes each + 5 minutes questions to each one)
15:15-16:30 **Session on UHI** (3/4 experts - 10 minutes each + 5 minutes questions to each one)

16:30-18:00 "Private" feedback session between Urban Experts and entrepreneurs to give real life feedback on the startups and on needs from industry (private sectors: enterprises and businesses) & city planning.
3 minutes pitch + 9/10 minutes feedback for each of the 7 start-ups

Figure 1 CNER announcement share to partners and stakeholder Social Media and other networks use

Figure 2 CNER- Empowering Changemakers announcement in Instagram

Experts addressing the Food Waste Challenge

Representing the public sector

Lidón Martrat (https://www.linkedin.com/in/lid%C3%B3n-martrat-02631514/), Coordinator of the Joint Office of the Regional Government of Catalonia & City Council of Barcelona for Sustainable Food

Gunilla Meurling (https://www.linkedin.com/in/gunilla-meurling-642bbb73/), Agronomist from the Barcelona Strategic Metropolitan Plan. Currently participating in CULTIVATE, an EU-funded project to increase public awareness and knowledge of Food Sharing initiatives (FSIs), to understand what drives or hampers their implementation and development.

Representing the research academic sector

Giorgia Tucci (https://www.linkedin.com/in/giorgia-tucci-859a086b/), PhD Architect, Professor in Urban Design and Planning at dAD - UniGe Founder of the website platform agrocities.com.

Emanuel Sommariva (https://rubrica.unige.it/personale/V0VOU15g), PhD Architect, Professor of Urban Design and Planning at the University of Genoa UNIGE-DAD Scientific Manager of Research Unit in EU project: Creative Food Cycles (2018–20) https://iaac.net/food-interactions-catalogue/

Representing the private sector

Amelie Vermeer (https://www.linkedin.com/in/amelie-vermeer), CEO of Spoontainable, start-up that produces and sells edible cutlery - with a focus on spoons - that is 100% made from sustainable raw materials. One of the 10 most innovative start-ups in Germany.

Ryan Edwards (https://www.linkedin.com/in/ryan-edwards-60324116/) CEO of Naked Innovations, designing, delivering and mentoring startup accelerators and incubators in the agrifood industry, with over 500 startups graduating through them.

Experts addressing the Urban Heat Island Challenge

Representing the public sector

Isabella Longo (https://www.linkedin.com/in/isabella-longo/?originalSubdomain=es), Project Director of BIT Habitat (Barcelona City Council). Project director with an engineering and urban planning background and an experience of more than 15 years in several fields: urban planning, design of innovative data-driven urban policies, economic development strategies, landscape and heritage dynamization, social and cultural innovation, content curation, events coordination and management.

Representing the research academic sector

Giulia Castellazzi (https://www.linkedin.com/in/giulia-castellazzi/), Urban Planner, MSc in Landscape Architecture. Landscape Architect and GIS analyst at LAND Research Lab. Project manager in UrbAIytics: an experimental sub-project of the H2020-funded project AI4Copernicus, a research focused on the Urban Heat Island effect in cities and implementation of Nature Based Solutions for climate adaptation.

Representing the private sector

Kambis Kohansal Vajargah (https://www.linkedin.com/in/kambis-kohansal-vajargah/) Head of Startup-Services at Austrian Federal Economic Chamber | StartupNOW, and European Digital Leader at the World Economic Forum. He is the Founding Partner of different start-ups, such as Freebiebox, an e-commerce startup offering a box of high quality giveaways that no one wants to throw away; Carployee, a MobilityTech startup that offers businesses a white-label carpooling platform for employee; and Partner Saturo, a FoodTech startup that offers Europe's first meal replacement product in a bottle. Kambis is the Former CMO & COO at primeCROWD, Austria's biggest network for startup investors. Focused on Venture Capital, FinTech, CleanTech, Big Data, HealthTech, Mobility, HR, FoodTech & Social Impact.

Oriol Biosca (https://www.linkedin.com/in/oriol-biosca-reig/), Head of Strategic Planning and Partner of MCRIT, MSc in Civil Engineering and in Transport Planning. Specialist in urban, regional, and strategic planning, sustainability, and environmental evaluation. Supports administrations and private institutions in the field of planning, strategic evaluation of infrastructure plans and projects, and transport policies, in Catalonia, Europe and Latin America.

Urban Challenges for Batch 2: Extreme Weather & Urban Mobility

Extreme Weather

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 3: 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.

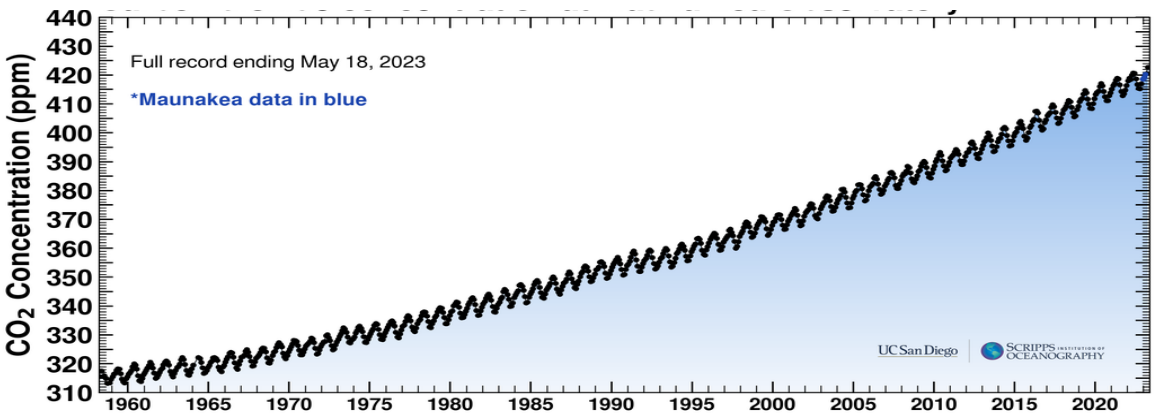


Figure 4: Carbon dioxide concentration at Mauna Lao Observatory. 1960-2020. Source: USCD, 2023.

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.

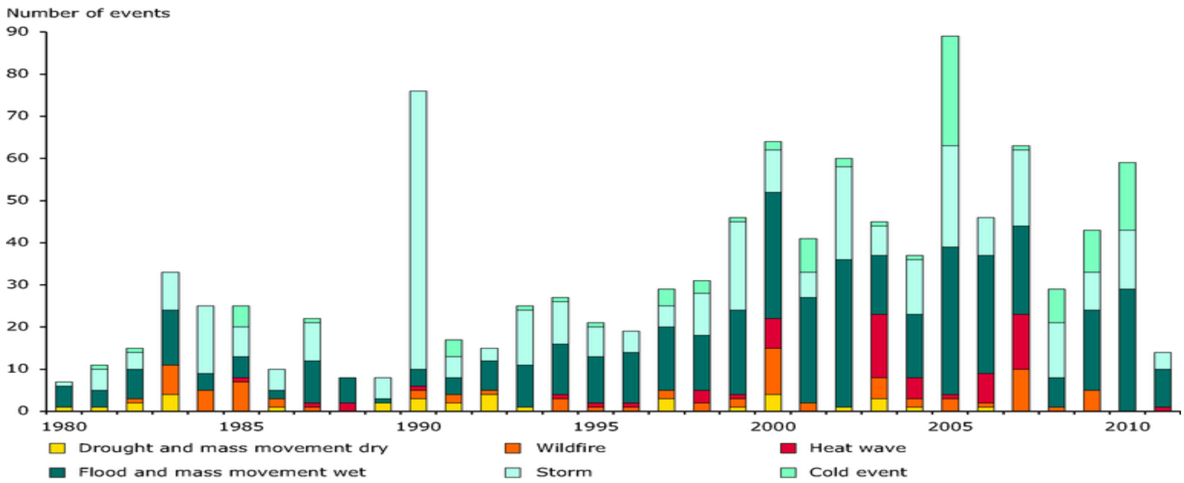


Figure 5: Number of reported extreme weather events and wildfire. 1980-2012. Source: EEA, 2016.

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[3].

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 (CO_2) 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

[3] 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).

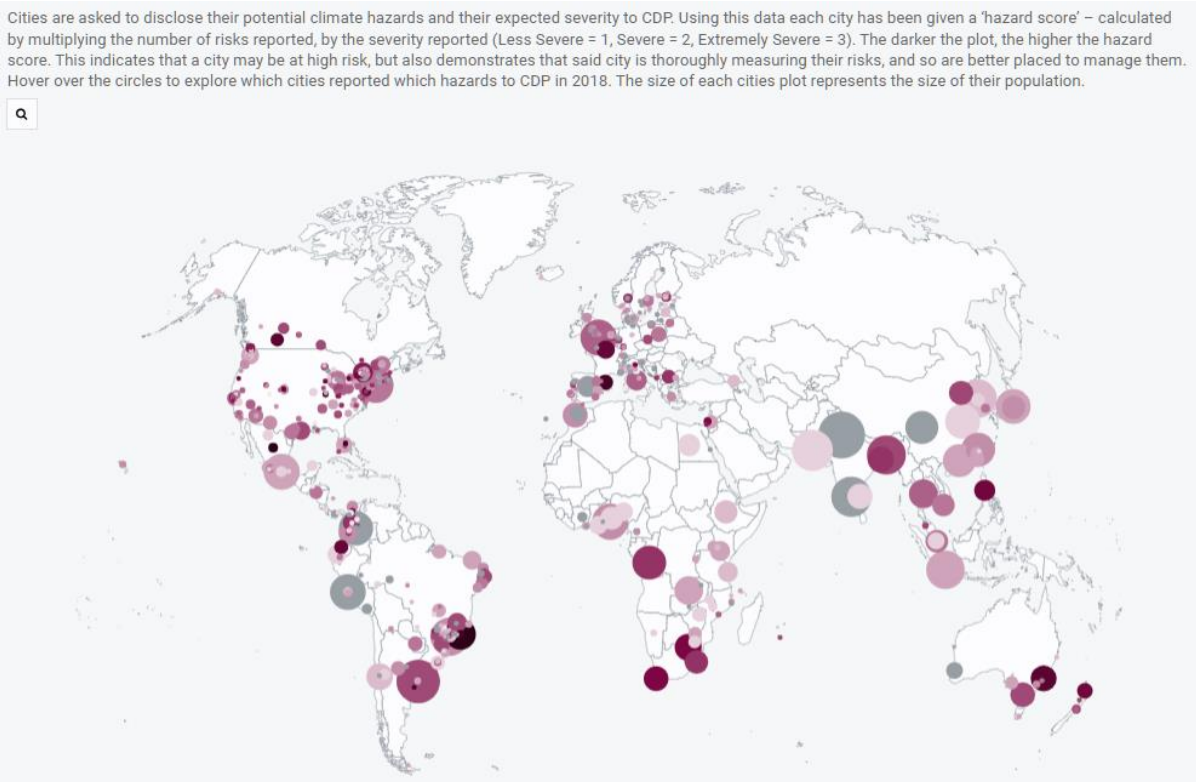


Figure 6: No city is safe, cities in all corners of the world are facing climate risks. Source: CDP, 2023.

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).

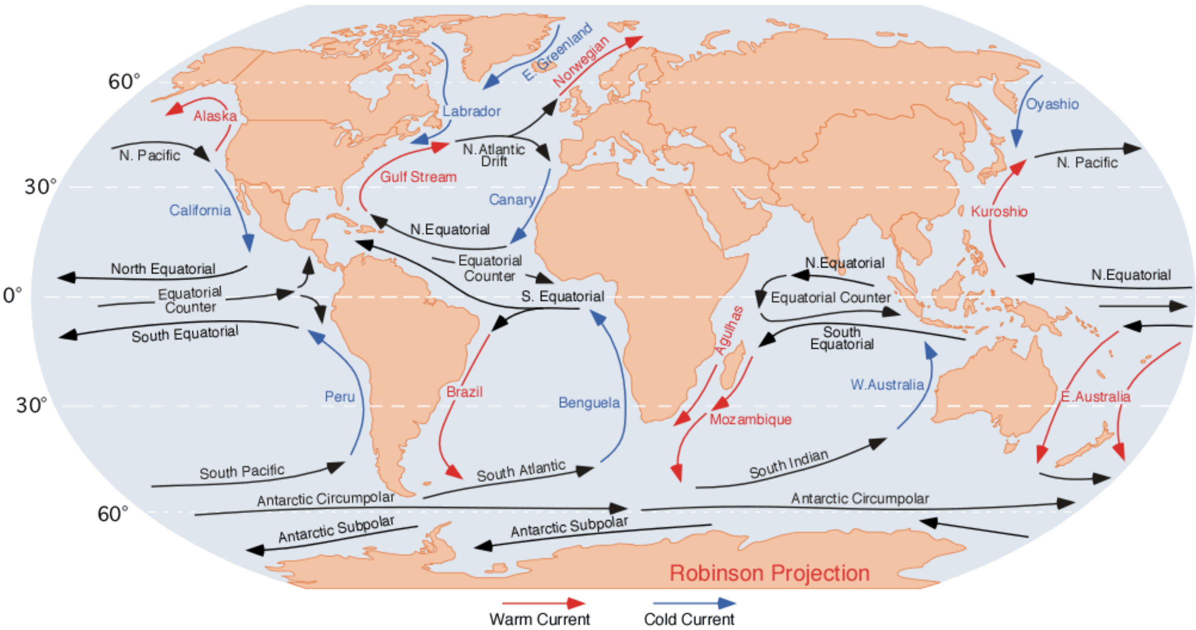


Figure 7: Depiction of Ocean Conveyor Belt, detailing the flow and temperature of ocean currents. Source: Ocean Motion.

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).

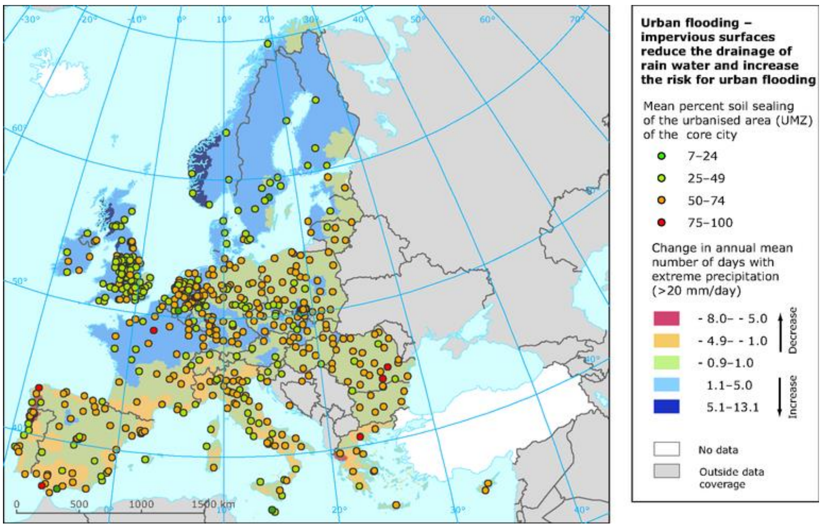


Figure 8: Increase in impervious surfaces and precipitation leads to higher chance of flooding. Source: EEA, 2012.

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.

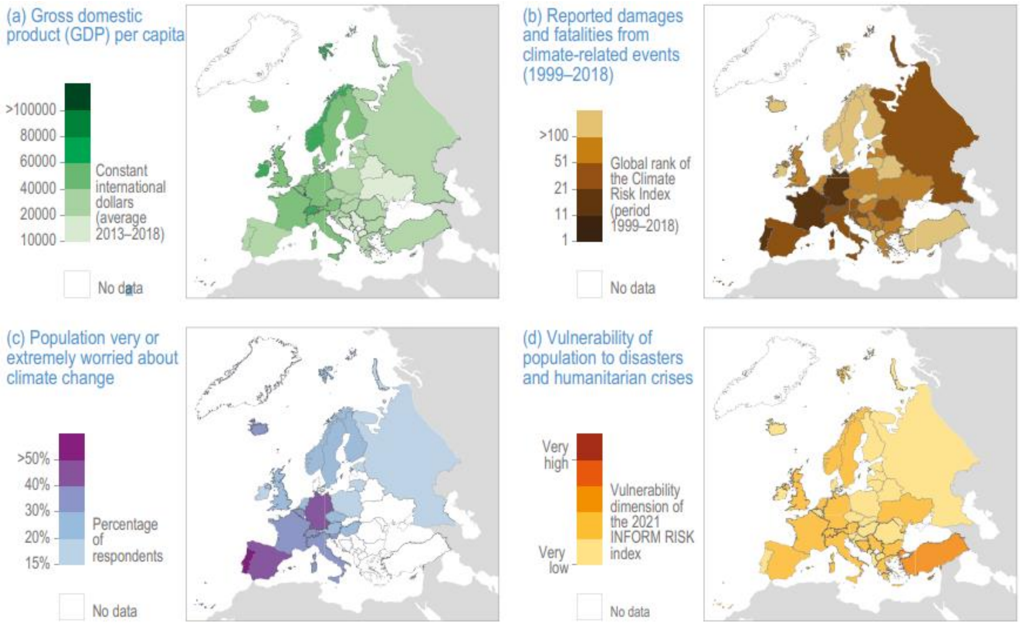


Figure 7: Damages to people and assets, vulnerability and adaptive capacity across Europe. Source: IPCC, 2021.

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).

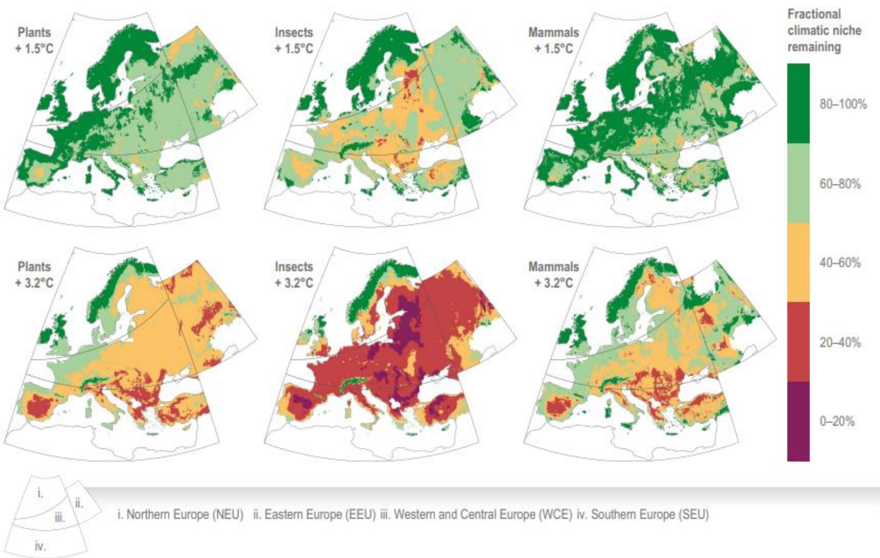


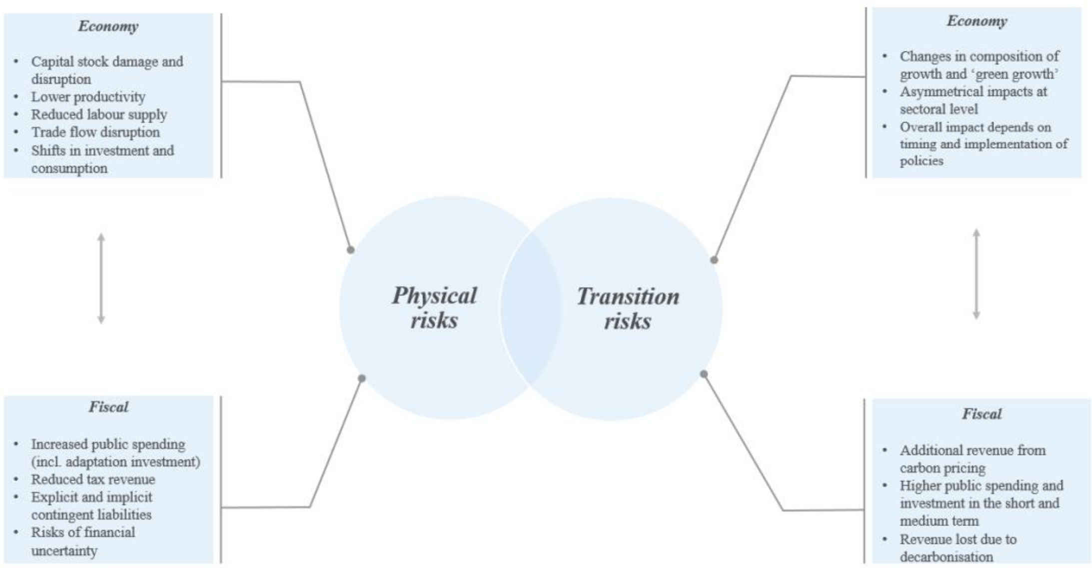
Figure 8: Species projected to remain in suitable climate conditions in Europe. Source: IPCC, 2021.

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.

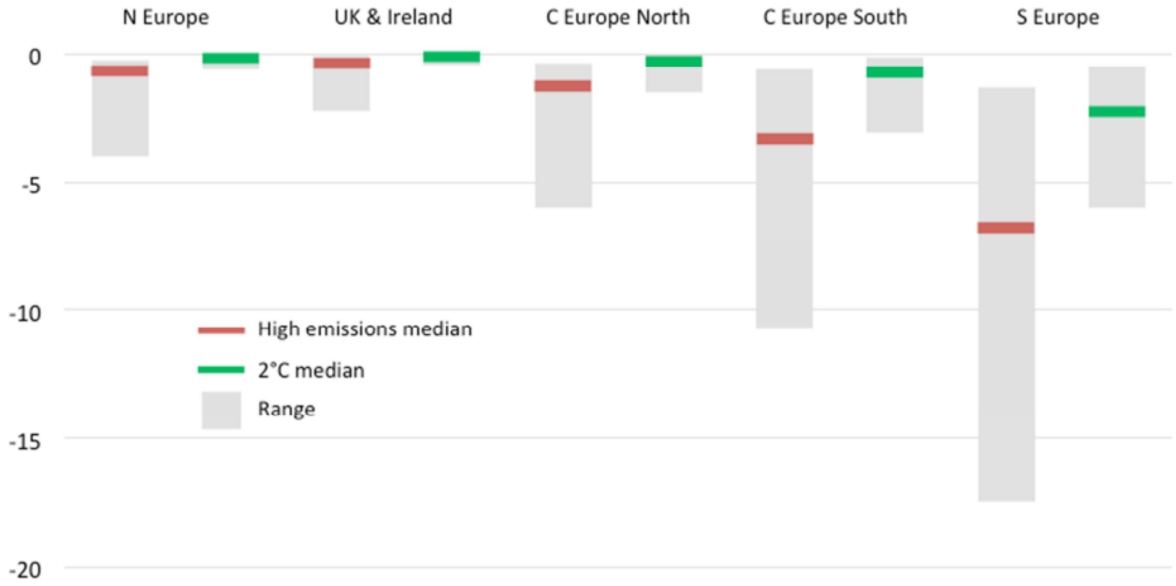


Figure 10: Regional differences from present (%) in daily average outdoor labour productivity due to climate change under a high warming scenario and a 2°C scenario respectively. Source: Climate impacts in Europe, JRC Science for Policy Report, 2018.

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.

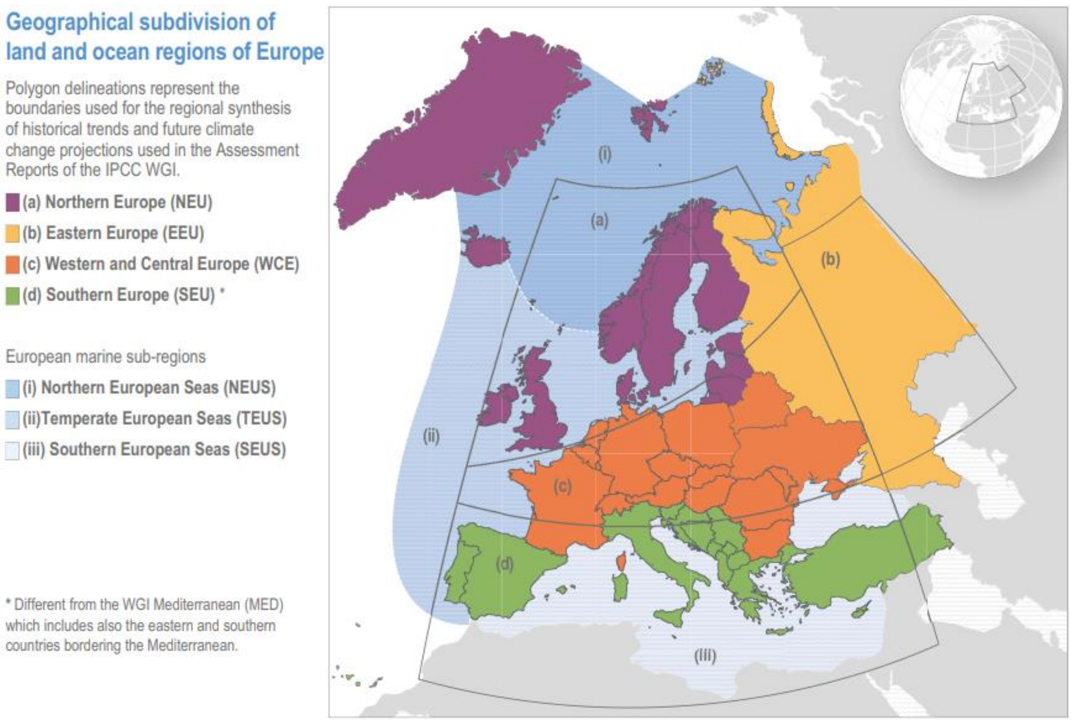


Figure 11: Map of Europe and its associated four subdivisions. Source: IPCC, 2021.

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.

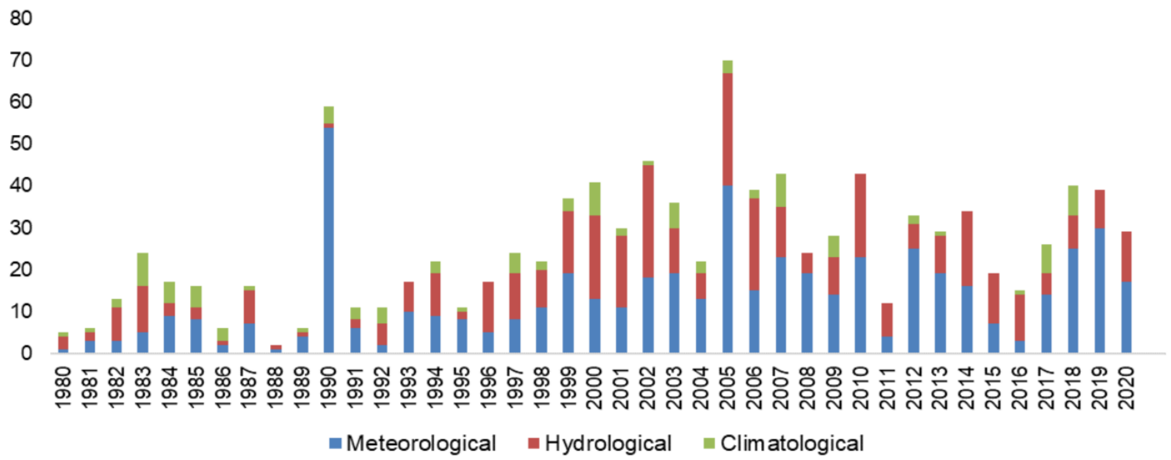
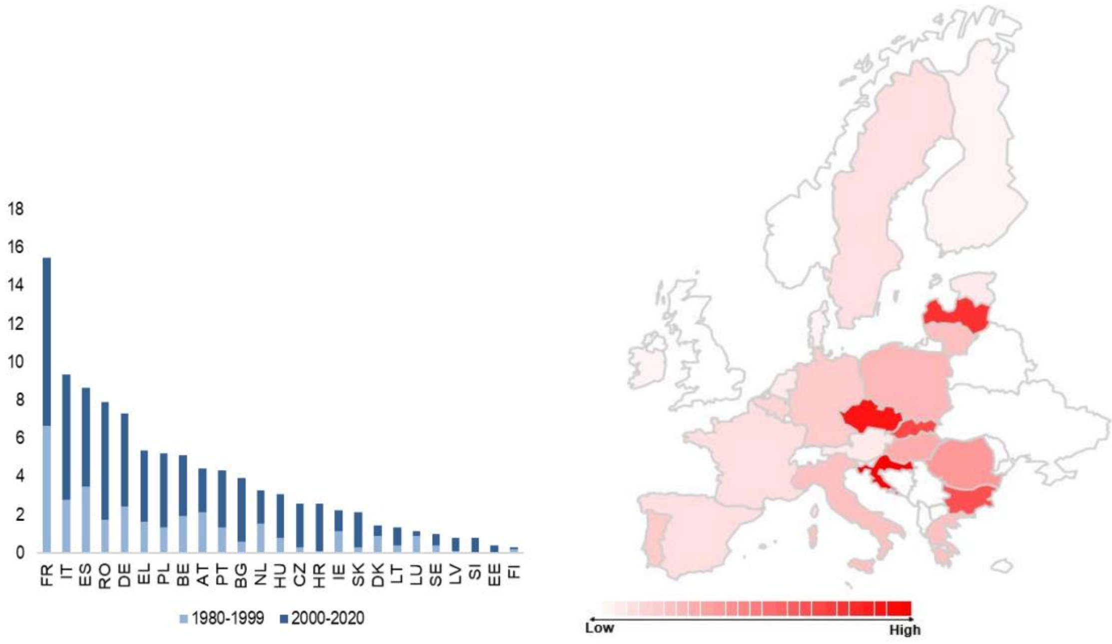


Figure 12: Number of weather- and climate-related events in the EU, by disaster subgroup. 1980-2020. Source: European Commission, based on The Emergency Events Database (EMDAT; CRED, UCLouvain), 2022.

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).

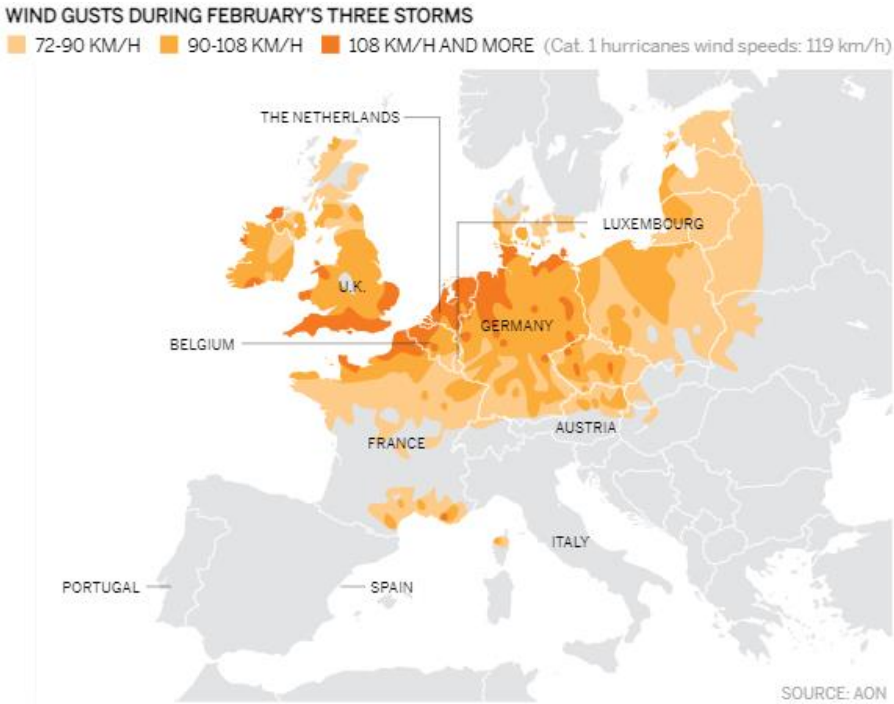


Figure 14: Wind gusts during February's three storms, 2022. Source: EU Copernicus Programme, 2022. Retrieved from https://www.milliman.com/en/extreme-weather-events-in-europe.

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, 2022b).

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).

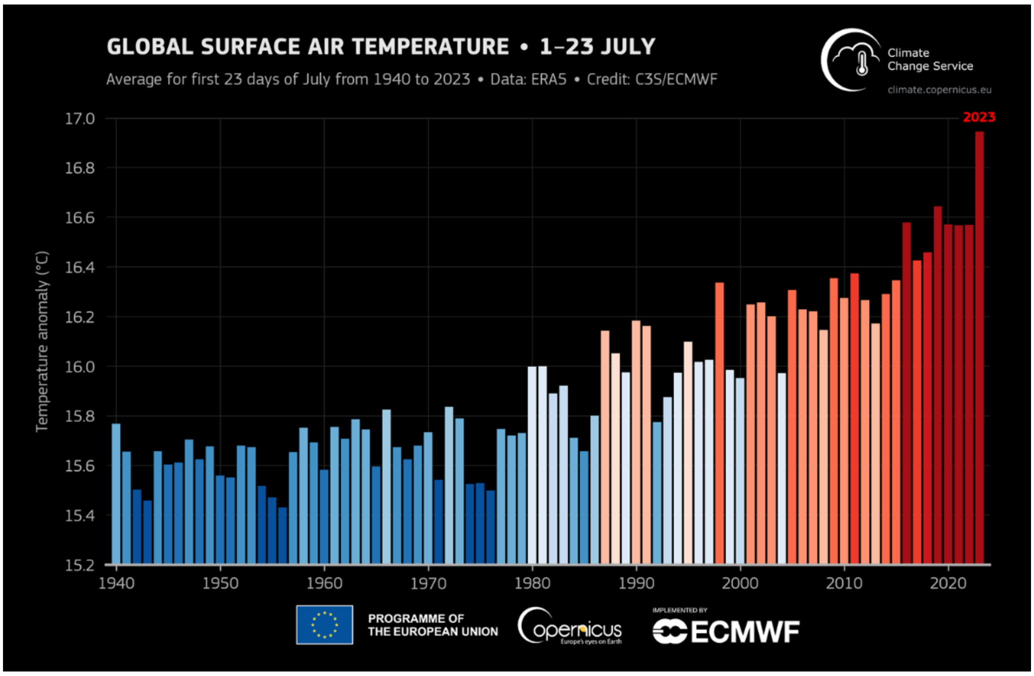


Figure 18: Globally averaged surface air temperature for the first 23 days of July for all months of July from 1940 to 2023. Data: ERA5. Credit: C3S/ECMWF. *Source: World Meteorological Organization*

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).

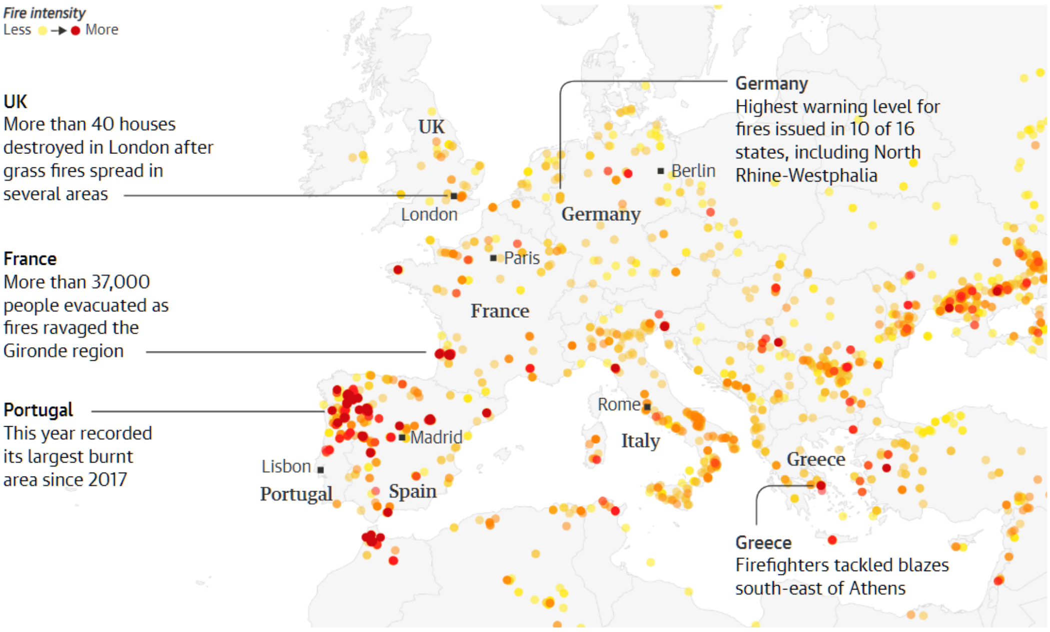


Figure 20: Map of European fires in 2022, categorized by intensity. Source: The Guardian, 2022.

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).

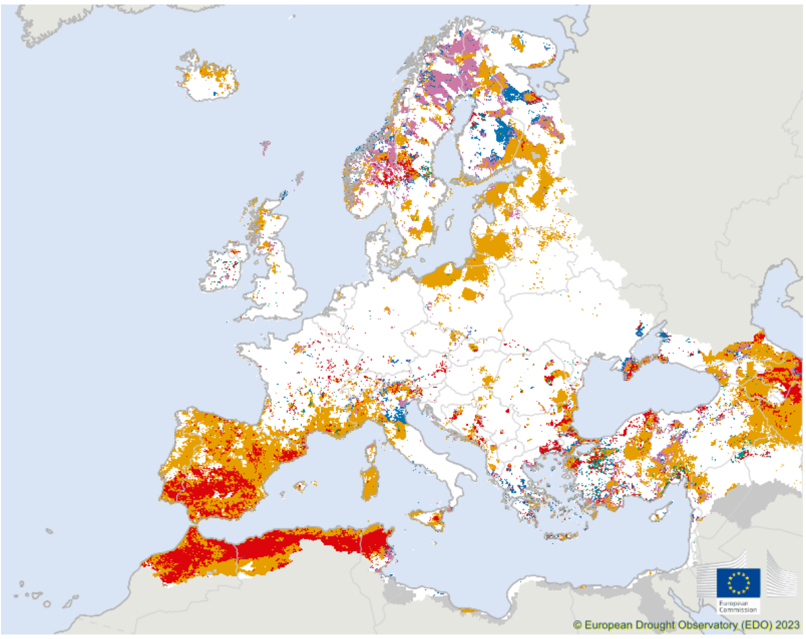


Figure 21: Situation of Combined Drought Indicator in Europe - 3rd ten-day period of May 2023. Source: JRC, 2023.

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.

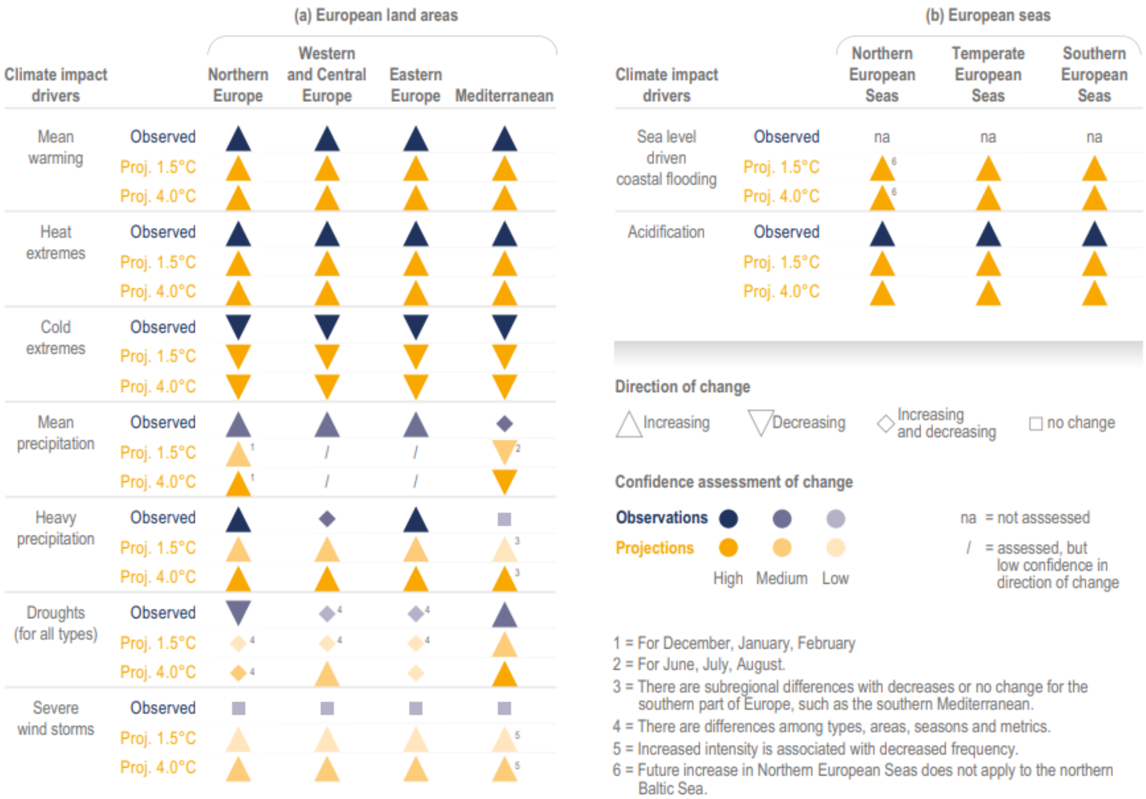


Figure 22: Observed and projected climate impact drivers for Europe – Observations from 1970-2019, Projected changes based on warming levels. Source: IPCC, 2021.

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).

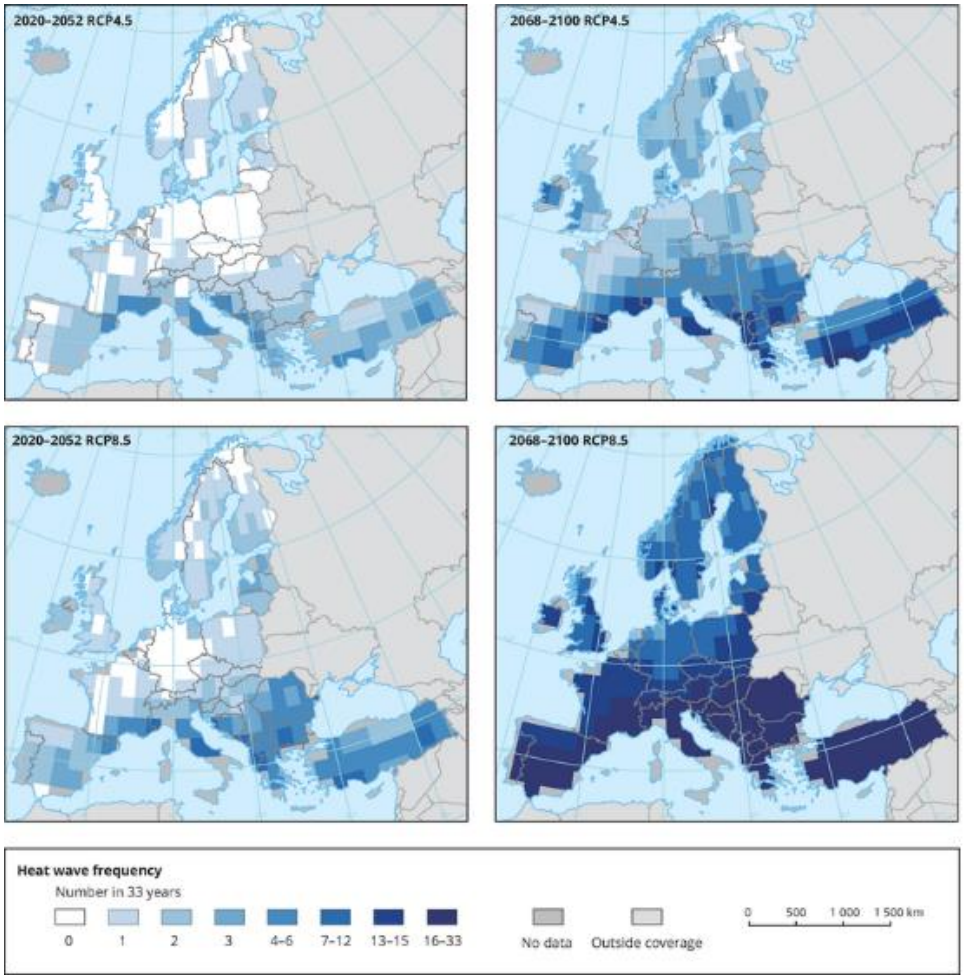


Figure 23: Number of extreme heat waves in future climates under two different climate forcing scenarios. EEA, 2022.

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.

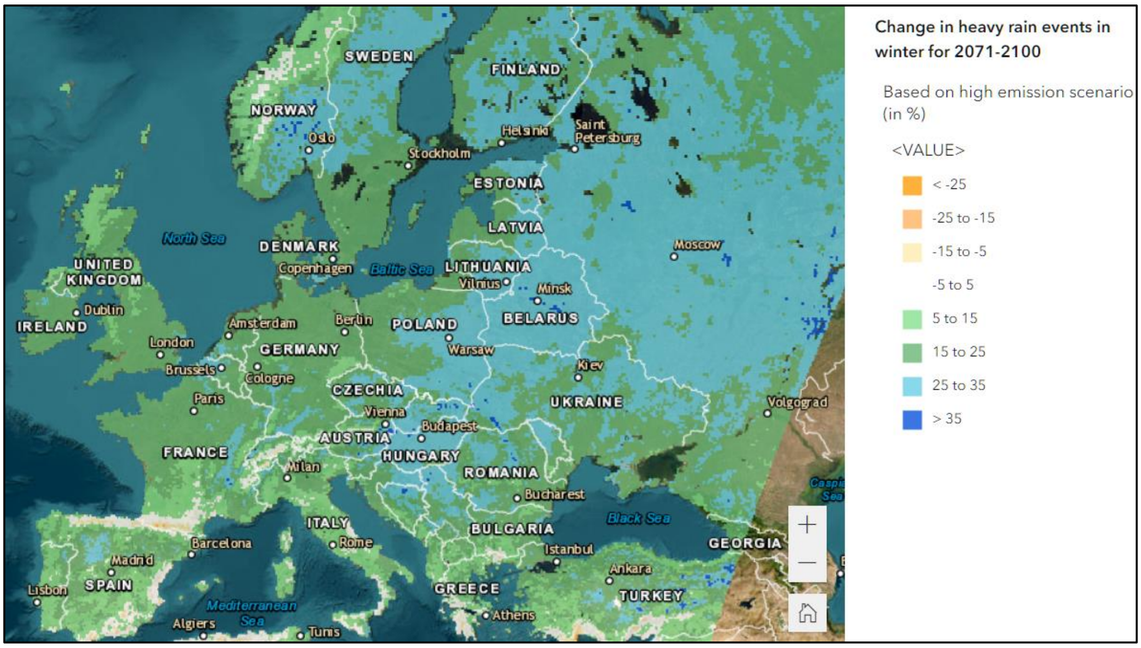


Figure 24: Projected change (%) in heavy rain in winters for a high emissions scenario (period 2071-2100, compared with 1971-2000). Source: Experience ArcGIS, EEA, 2023.

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.

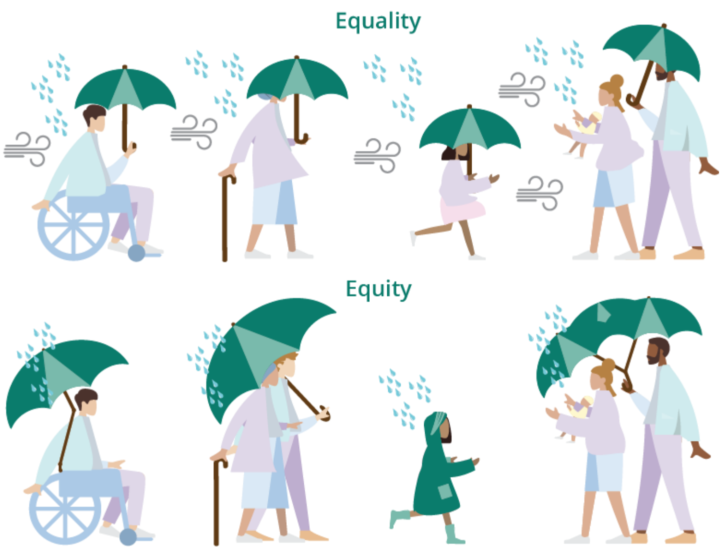


Figure 25: Juxtaposition of equality and equity. Source: EEA, 2022.

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.

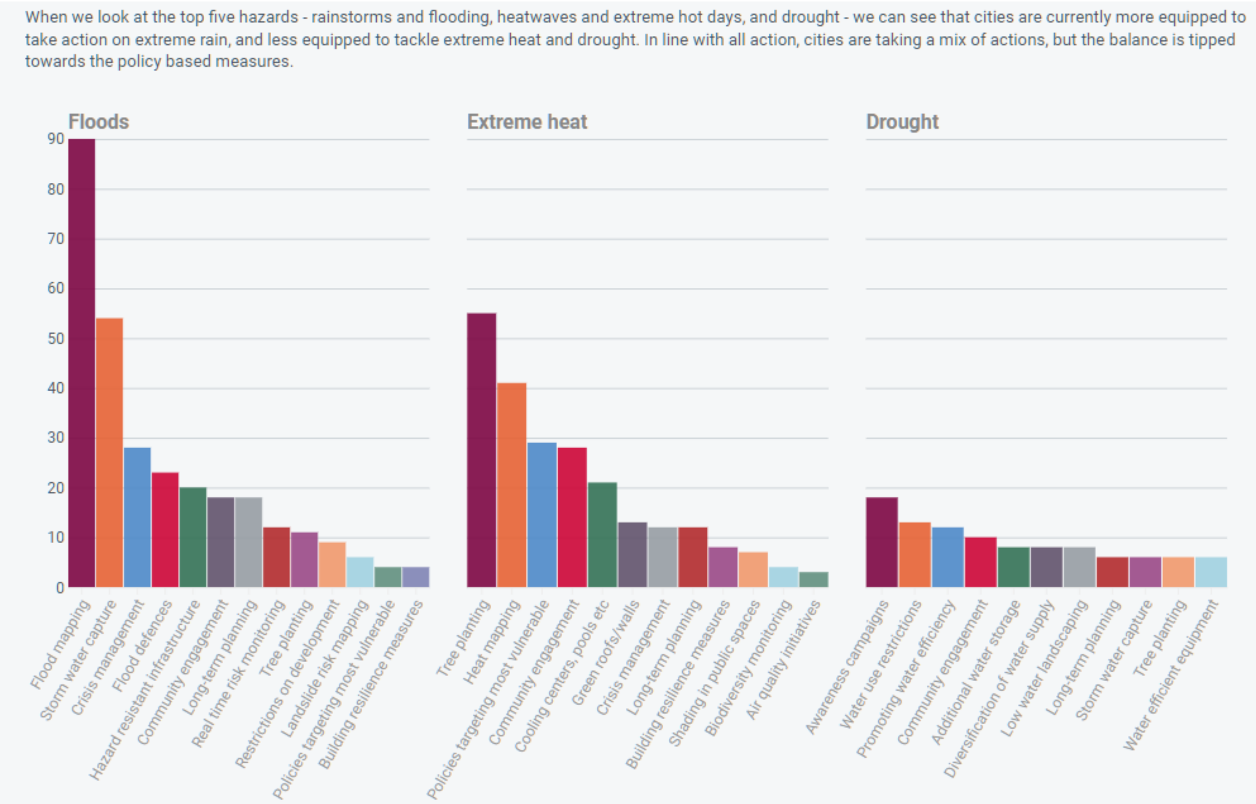


Figure 26: Policy based solutions are the current focus for cities, with infrastructure change taking a back seat. Source: CDP, 2023.

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).

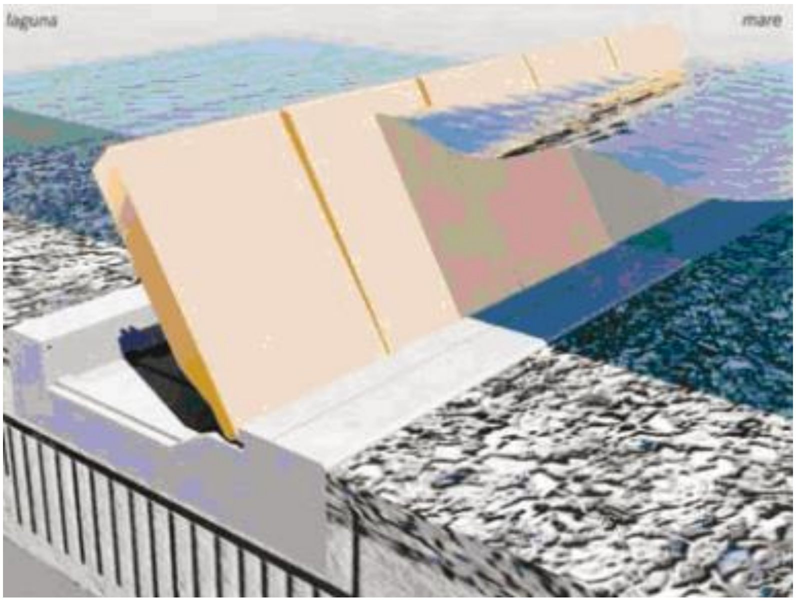


Figure 27: Smart barriers to shield La Serenissima from freak tide. Source: Agenzia Giornalistica Italia.

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).

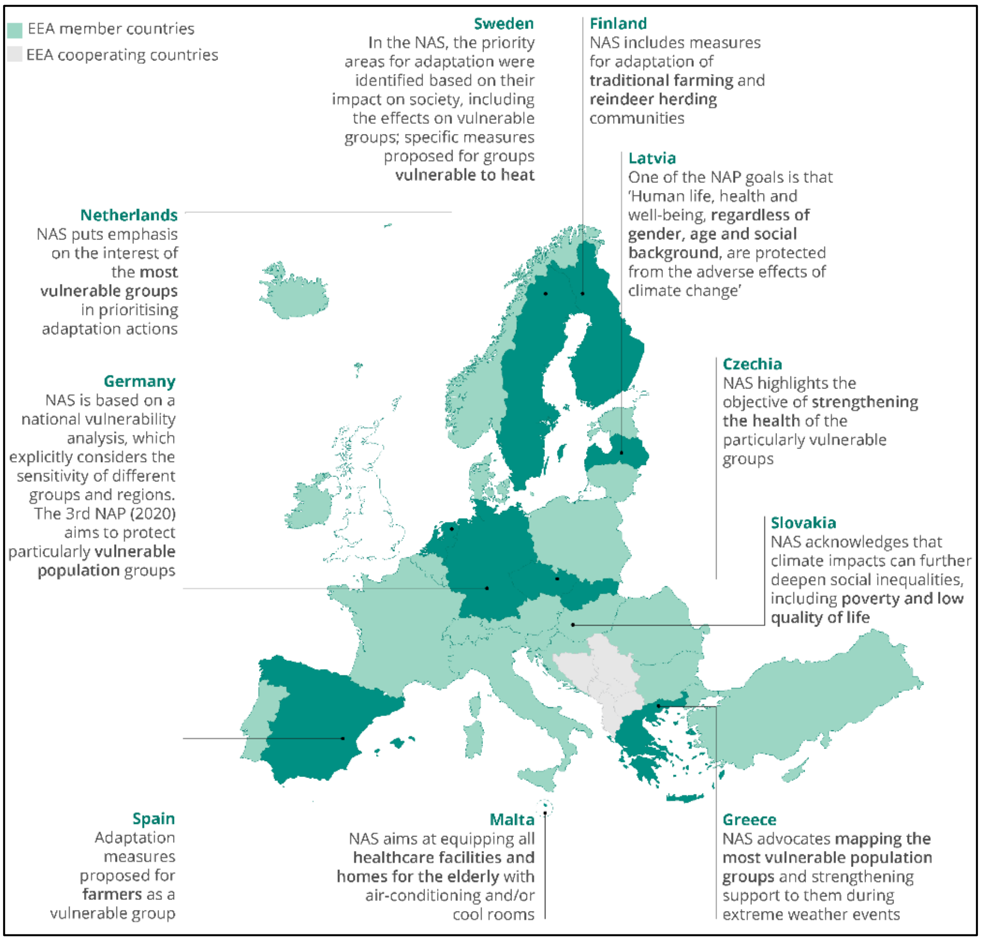


Figure 28: Examples of equity considerations in national adaptation policies.
Source: EEA, 2023. https://www.eea.europa.eu/publications/just-resilience-

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.

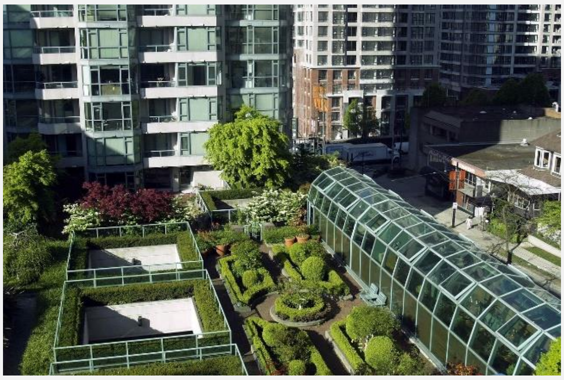



Figure 31: Rotterdam Park (left); Greening of roofs in Moscow (right). Source: IESE, 2019.

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.
i REACT	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:

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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Urban Mobility

9. Background

1.1 Mobility & Transport: interchangeable terms?

Transport and mobility are related concepts but have distinct meanings:

Transport refers to the physical movement of people, goods, or services from one location to another. It focuses on the means of transportation, such as vehicles (e.g., cars, buses, trains, airplanes), infrastructure (e.g., roads, railways, airports), and systems that enable the movement of people and goods. Transport is primarily concerned with the technical aspects of moving entities and ensuring efficient and safe transportation.

On the other hand, **mobility has a broader scope and encompasses the ability to move and access various destinations and opportunities**. It includes not only the physical act of transportation but also the social, economic, and behavioral aspects associated with movement. Mobility involves the choices people make regarding their travel patterns, the accessibility of transportation options, and the impact of transportation on quality of life, social inclusion, and environmental sustainability. Mobility also considers factors such as walking, cycling, and the use of public transportation, as well as the integration of different modes of transportation to create seamless travel experiences.

Definition
Mobility describes the way in which people and products move within and around cities, including the social, economic, and behavioral aspects associated with movement.

Table 2: Definition of mobility. Source: own elaboration.

In summary, transport focuses on the physical movement of people and goods, while mobility encompasses the broader concept of movement, including the social, economic, and behavioral aspects related to transportation choices and accessibility. Transport is a component of mobility, which encompasses a wider range of factors influencing movement and accessibility.

1.2 Europe's Mobility History

Mobility history in Europe has evolved over time, reflecting societal, technological, and economic changes. In ancient times, **mobility relied on walking and horseback riding**, limiting travel distances. The Roman Empire's road network enhanced mobility, enabling trade and cultural exchange.

During the Middle Ages, mobility primarily occurred through waterways, with rivers serving as vital transport arteries. Coastal shipping and maritime trade connected European regions, fostering economic growth and cultural interaction.

The Renaissance period witnessed **advancements in land-based mobility**, with the development of roads and the introduction of horse-drawn carriages. This expanded the range and comfort of travel for individuals.

The **Industrial Revolution in the 18th and 19th** centuries brought significant transformations. Steam-powered trains and locomotives revolutionized mobility, connecting cities, facilitating trade, and stimulating industrialization.

The 20th century saw the **rise of automobiles**, leading to a paradigm shift in mobility. Personal mobility became more accessible, as the mass production of cars and the development of road networks expanded travel possibilities.

Aviation also emerged as a transformative mode of mobility. The invention of airplanes and subsequent technological advancements enabled faster, long-distance travel, connecting Europe and the world.

In recent years, **Europe has been focusing on sustainable and multimodal mobility solutions**. Investment in public transportation systems, cycling infrastructure, and high-speed rail networks has increased. Efforts to promote walking, cycling, and public transport aim to reduce congestion, improve air quality, and foster healthier and more sustainable mobility options.

The history of mobility in Europe reflects a progression from limited mobility to the development of various modes of transportation. Europe continues to prioritize sustainable, accessible, and integrated mobility systems that enhance connectivity, environmental sustainability, and quality of life for its inhabitants.

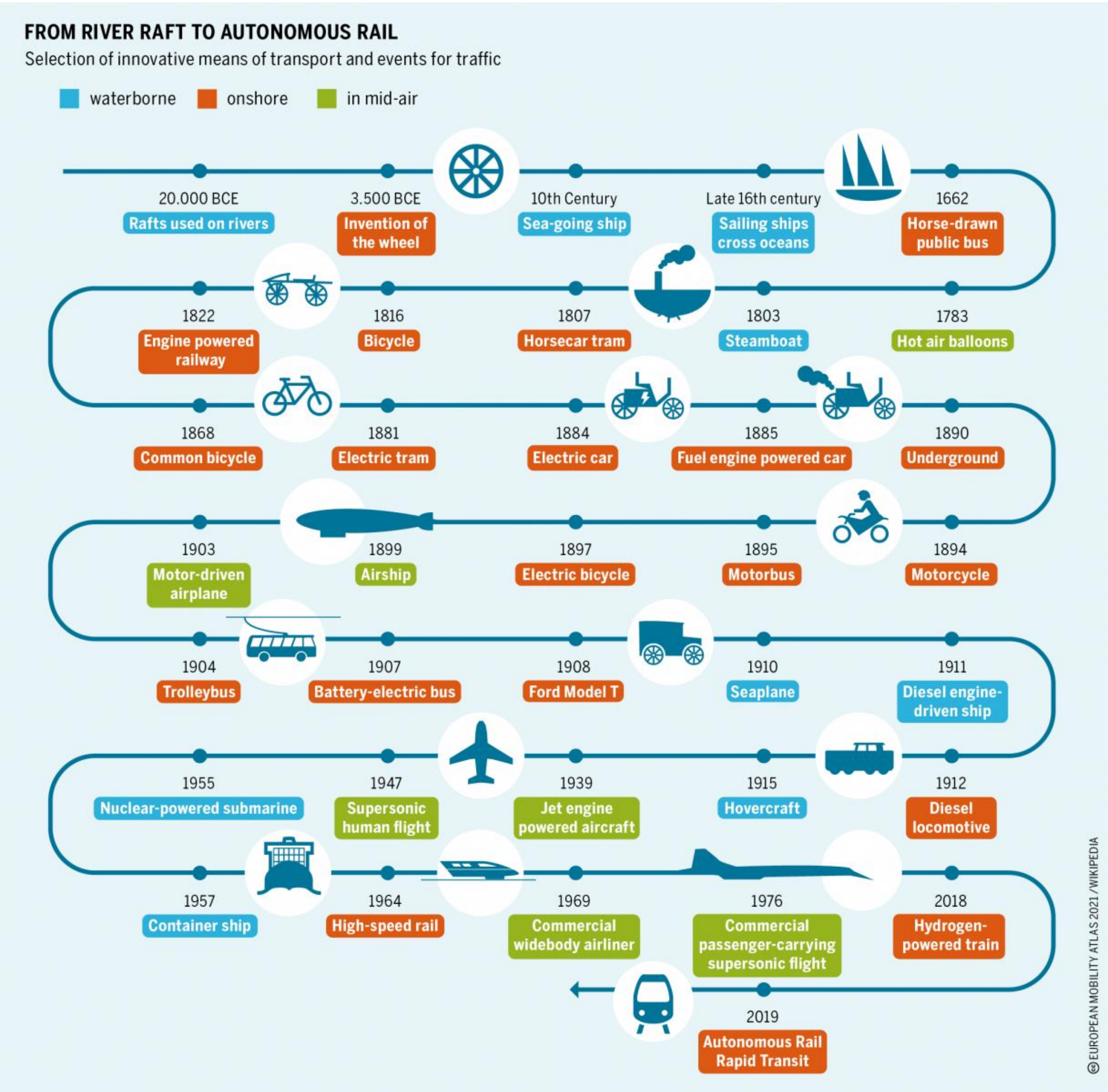

Figure 9: Innovations in the development of mobility triggered by entrepreneurial spirit or simply the desire for new ideas. Source: Heinrich-Böll-Stiftung European Union licence: CC-BY-SA 4.0

1.3 Towards Sustainable and Active Urban Mobility

Mobility of people and goods is one of the essential elements of sustainable urban and regional development. The way transport services and infrastructure are designed, operated and maintained, strongly characterizes the space they serve, with direct impact on safety, resilience and sustainability of communities, cities, and regions as well as on citizens' quality of life.

Currently, around 50% of the world population lives in cities; in the EU, that number jumps to 70% (EC, 2021). By 2050, two-thirds of the world population is expected to be urban-dwellers (CDP; International Transport Forum, 2021). As this number grows, so does the amount of people who use urban transportation. Be it walking, biking, driving, carpooling, riding the bus, or taking the metro, everyone commutes within and beyond the city limits every day. In 2005, an estimated 7.5 billion trips per day were made within cities worldwide. While such a high number of daily trips may make it seem so, mobility is not accessible to all and poses many challenges to the urban society. For example, just the cost of congestion is estimated to make up for around 1% of the EU´s GDP (i.e., €100 billion). Studies have shown that high levels of traffic also result in lower worker productivity.

To enhance accessibility, reduce carbon footprints, improve public health, and maximize economic productivity, cities need to develop and adopt sustainable transportation systems. This involves transitioning to active and micro mobility options, improving intermodality and mobility infrastructure, leveraging digital technology, optimizing energy usage, and promoting sustainable city logistics. Moreover, creating public realms and ensuring the accessibility of transportation services for all individuals, regardless of socio-economic factors, is crucial. These efforts aim to mitigate the ecological impact of urban mobility, reduce pollution, and create healthier and more liveable cities.

Urban mobility encompasses ten subcategories that are used as guidelines to improve it. These categories include active mobility, micro mobility, intermobility, mobility infrastructure, accessibility, city logistics, public realm, digital technology, energy, and ecological impact (EIT Urban Mobility, 2020).

	
Active Mobility	**Micro Mobility**
Active mobility is "a form of transport that only uses physical activity. The most common forms of active mobility are walking and cycling" (ECA, 2020).	Micro mobility is comprised of "very light vehicles (of a gross weight of less than 500 kg) equipped with an engine. It includes, among others, electric scooters, skateboards, and bicycles, as well as solowheels" (ECA, 2020).
	
Intermobility	**Mobility Infrastructure**
Intermobility combines the best qualities of various modes of transportation in the different parts of the cities to complete one trip (State of Green, 2016).	Mobility infrastructure encompasses the physical structures that facilitates and constrains the movements

	of people, things, information, and energy (Institut für ethnologische Forschung).
	
Digital Technology	**Energy**
Digital technology includes the use of artificial intelligence, 5G, sensors and smart infrastructure in mobility development and infrastructure construction.	The type of energy used in transportation systems is crucial to reducing the carbon footprint of mobility infrastructure.
	
City Logistics	**Public Realm**
City logistics encompass the movement of goods within a city, including services such as mail delivery and waste management (Intech Open, 2022).	Public realm represents a complex space of social interaction that is generally open and accessible to all citizens, and is seen as key to urban livelihood (EIT Urban Mobility, 2022a).
	
Ecological Impact	**Accessibility**
Ecological impact of mobility refers to the emissions, pollution, and other environmental dangers that may be produced because of transportation.	Accessibility of transportation refers to who can utilize it. Mobility for all aims to improve physical and geographic accessibility for target groups and vulnerable travellers.

Table 2: Definition of the different subcategories that play into mobility.

KEY IDEAS

- The history of mobility in Europe has undergone significant changes, driven by societal, technological, and economic factors.
- Different modes of transportation, from ancient walking and horseback riding to modern automobiles and airplanes, have shaped European mobility.
- The Industrial Revolution brought about transformative advancements, such as steam-powered trains and locomotives, revolutionizing mobility and connecting cities.
- In the 20th century, automobiles and road networks became dominant, enabling personal mobility on a large scale.
- Recent years have seen a shift towards sustainable and multimodal mobility solutions, focusing on investments in public transportation, cycling infrastructure, and promoting healthier and more environmentally friendly modes of transport.

10. Effects: Why do we care about Mobility?

The current transportation system and practices within cities have significant socio-environmental and economic impacts. These impacts encompass various factors, including greenhouse gas emissions, equity and access, air pollution, noise pollution and vibrations, energy consumption, land use and infrastructure, cultural heritage, water pollution, and economic implications. Understanding and addressing these challenges are crucial for developing sustainable and inclusive transportation systems.

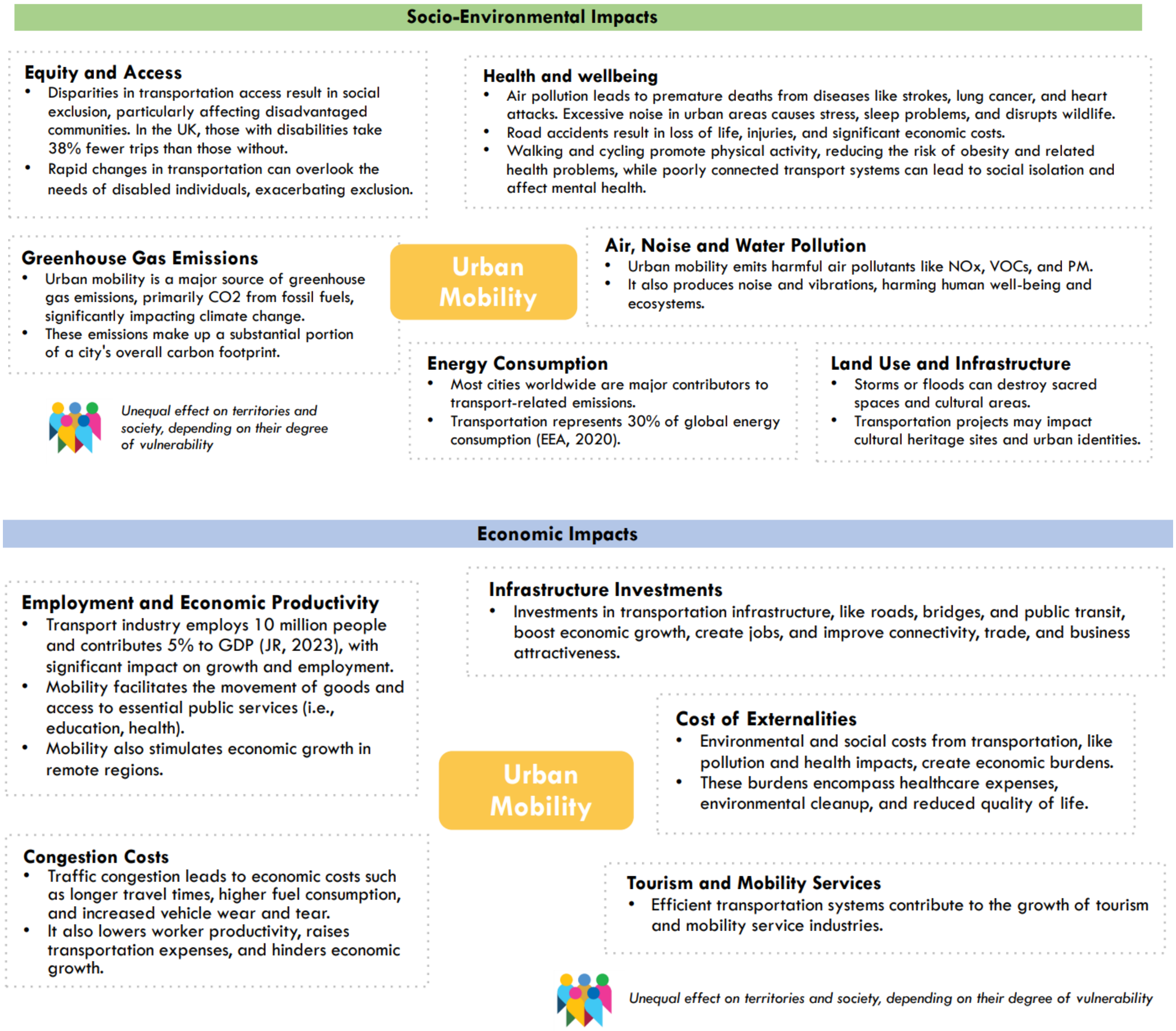

Figure 2: Socio-environmental and economic impacts.
Source: own elaboration.

Understanding and effectively managing the socio-environmental and economic impacts of mobility and transport are crucial for creating sustainable and inclusive transportation systems that promote economic prosperity, protect the environment, and enhance the well-being of communities.

KEY IDEAS

- Urban mobility has significant socio-environmental and economic impacts, including greenhouse gas emissions, air pollution, energy consumption, land use, and more.
- Equity and access are crucial aspects of urban mobility, ensuring that transportation services are affordable and accessible to all, regardless of socioeconomic factors.

- Transportation infrastructure and activities have adverse effects on air quality, noise levels, and ecosystems, impacting public health and well-being.
- Efficient and reliable transportation systems are vital for economic productivity, employment opportunities and trade facilitation.
- Sustainable transportation planning and practices are necessary to mitigate negative environmental and social impacts, promote social equity, and create liveable cities.

11. The Mobility Challenge in Europe

Europe is confronted with a range of interconnected demographic, public health, and environmental challenges that have implications for transport and mobility. These challenges include climate change, stagnating road deaths, increasing urbanization, air quality breaches in over 100 cities, rising obesity rates, and an aging population, between others.

3.1 Changing Climate

The challenges posed by urban mobility structures are exacerbated by climate change. Extreme weather events, intensified by global warming, can damage transportation infrastructure. Flooding risks impacting underground structures and surface infrastructure, leading to erosion and corrosion. Pluvial floods cause traffic disruptions, congestion, and decreased road safety. Heavy precipitation, hail, and high winds impact road transportation, increasing the risk of crashes and damage to vehicles. Wildfires and heat waves reduce visibility, worsen air quality, and pose health risks. Infrastructure damage, economic losses, and trade route disruptions are also expected.

Changes in the environment, such as melting permafrost, can further damage transport infrastructure. This impact is of particular concern in Nordic countries, as well as Russia, and parts of Canada and the US where the higher altitude and colder temperature has historically maintained high levels of permafrost (EEA, 2017). While milder winters may decrease damages and maintenance costs, longer shipping seasons may be offset by increased trade interruptions. Climate change significantly affects mobility and necessitates adaptation measures (EPA, 2022 a).

3.2 The Rise of Urbanisation

Over the next 30 years, nearly one in three European cities is projected to experience a **population increase of more than 10%.** This demographic growth is expected to lead to a surge in road traffic and greater utilization of underground and rail services, potentially straining their capacities.

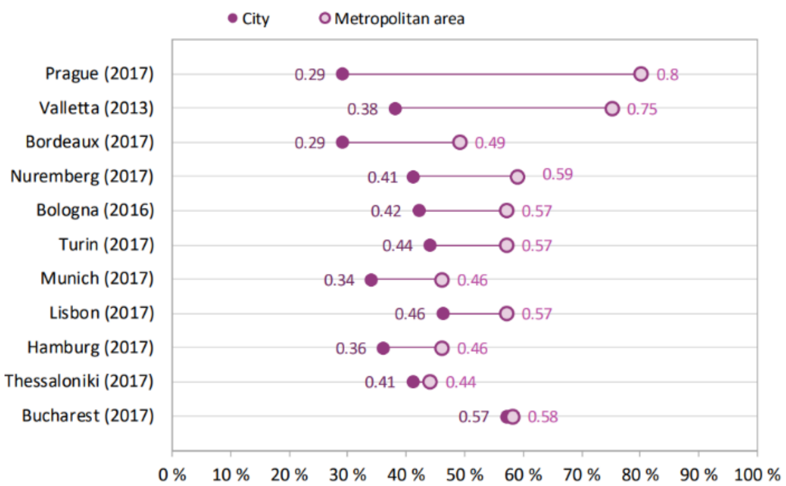

Figure 10: Modal share of private vehicles in 11 cities and metropolitan areas surrounding cities.
Source: ECA on replies to its survey on urban mobility.

Transport mode usage varies across countries, but several trends are consistent throughout Europe. **Cars remain the dominant mode of transport in the EU, accounting for 87% of all passenger kilometres travelled (Eurostat, 2022a).** However, within cities, people are increasingly opting for alternative transportation modes. Capital cities exhibit the lowest rates of car usage among residents, with significant variations observed among cities, ranging from over 70% in Lefkosia (CY) to less than 10% in Paris (FR) (European Union and UN-HABITAT, 2016).

Despite numerous initiatives and plans addressing mobility needs in Europe, much work remains to facilitate this shift. A study conducted by the European Court of Auditors (ECA) in 2020 revealed that out of 88 European cities analysed, only 27 provided data on modal share. Among those, only two cities, Antwerp and Bordeaux, demonstrated a significant decline in private car usage. Most areas experienced only slight reductions, and the majority witnessed an increase in private car usage, with Budapest experiencing an 80% rise (Figure 3). The study also highlighted that the modal share of private vehicles was typically considerably higher in the metropolitan areas surrounding cities than within the cities themselves (Figure 4). Without greater investment by cities in analyzing their modal transport and promoting the de-privatization of transport, it is unlikely that Europe will achieve its low emission mobility goals.

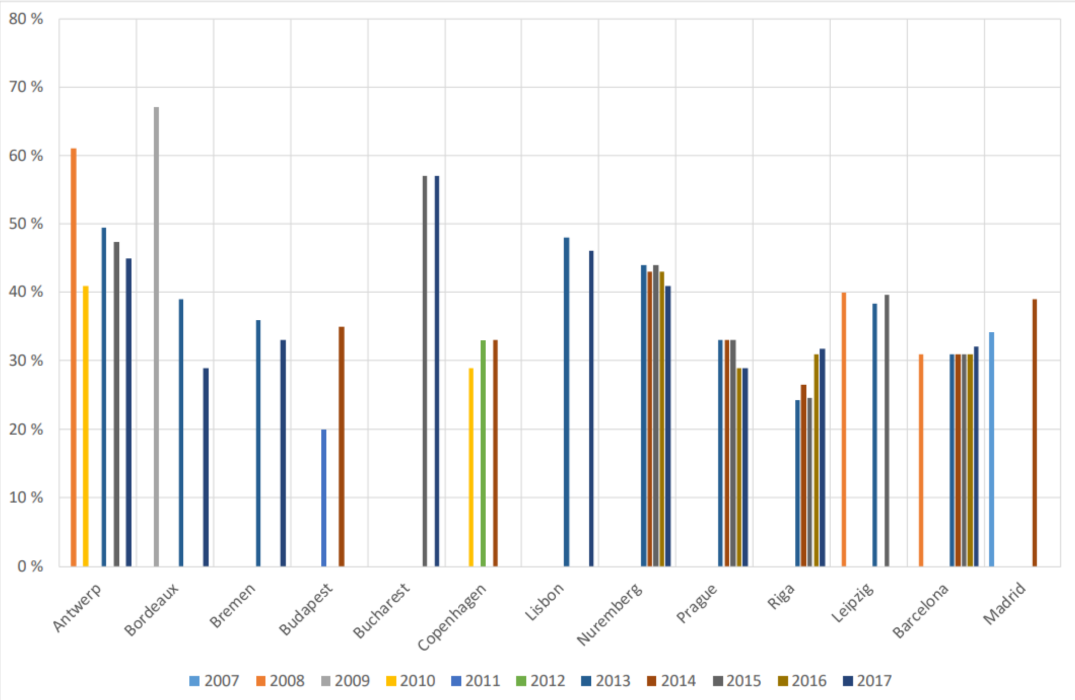

Figure 11: Modal share of private vehicles in 13 cities between 2007 and 2017.
Source: ECA analysis based on based data provided by cities and EPOMM.

3.3 Aging Population

The global society in which we all live is being transformed at an unprecedented pace. With fewer births and a greater proportion of people surviving into adulthood and then into later life, population ageing is now taking place in almost all the countries of the world.

This will also impact mobility as, according to the European Commission, specific age groups are more inclined to use certain modes of transportation than others. A study from the Netherlands found that **older**

generations spend the highest proportion of their journeys walking (34%), while 18- to 24-year-olds utilize public transport more than any other group. This low usage of public transport could be attributed to limited access.

	0-11	12-17	18-24	25-29	30-39	40-49	50-59	60-74	75+
Pedestrian	29%	18%	20%	19%	18%	17%	18%	25%	34%
Bicycle	29%	52%	23%	17%	20%	23%	22%	24%	17%
Moped/mofa	0%	3%	2%	1%	1%	1%	1%	0%	1%
Motorcycle/scooter	0%	0%	0%	0%	0%	0%	0%	0%	0%
Passenger car	40%	17%	37%	56%	56%	55%	54%	46%	38%
Bus	1%	5%	8%	2%	1%	1%	2%	2%	4%
Tram/metro	0%	1%	3%	2%	1%	1%	1%	1%	1%
Train	0%	2%	6%	3%	2%	2%	1%	1%	1%
Other	1%	1%	0%	0%	0%	0%	0%	1%	3%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%

Figure 12: Modal split by age group in the Netherlands. Source: Wegman & Aarts, 2005.

A 2012 report indicated that 20.4% of EU citizens experience 'high' or 'very high' levels of difficulty accessing public transport. This lack of access restricts their mobility within city centres and limits their ability to reach essential services such as jobs, schools, healthcare facilities, and stores, which represents a challenge for a society that is ageing (UITP, 2019).

3.4 Accessibility of Public Transport in Rural Areas

Efforts to improve public transport have focused on addressing ease of access, frequency, speed, and a high degree of connectivity within the public mobility network. EU funds have enabled cities to expand their public transport networks by investing in metro, tram lines, and railways. **While access to public transport is often high within cities, areas just outside of city limits often find themselves lacking access.** Many of these people commute into the city or to other suburbs daily and lacking the public transport coverage to get transport them, they must turn to other travel alternatives, such as private vehicles. Such trends reveal the need for increased public transport coverage beyond city centres.

Especially since public transport takes significantly longer, private transport is still a more efficient option for most travellers. Very few mobility plans have increased the use of public transport while decreasing private vehicle use. Such results demonstrate the need to not only make public transport more attractive, but to actively invest in dissuading people from using private transport as well (ECA, 2022).

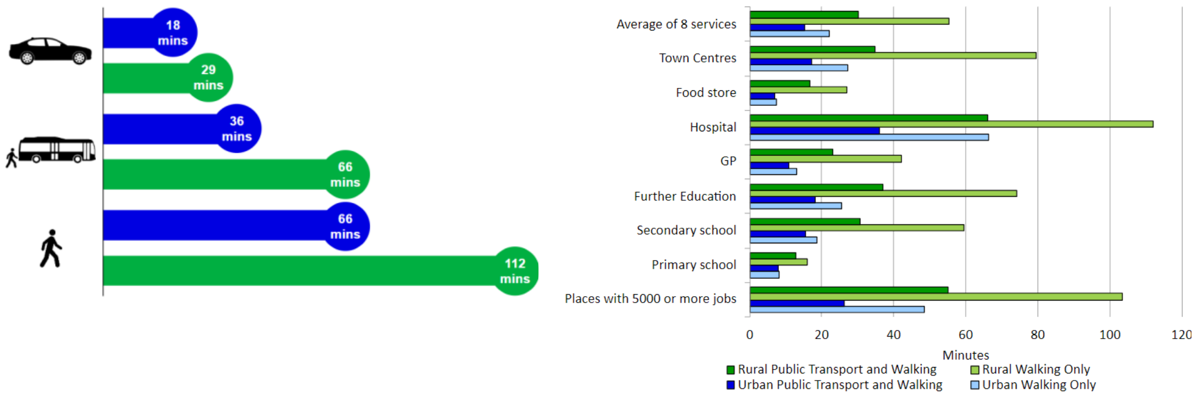

Figure 13: Average minimum travel time to reach the nearest key services by mode of travel, by Lower Super Output Area rural urban classification, in England, 2019. Source: Rural Accessibility 2019 Report.

3.5 The Escalating Scarcity of Urban Space

As cities grow and more space is needed for housing, business, commercial activities, public spaces, streets, and parking needs, less space is available for mobility users. Private vehicle transport takes significantly more space than any other form of transportation, making it the least space efficient mode of transportation (Figure 7). **Cars, which are usually parked for 95% of the day, occupy space that could alternatively be used for other functions.**

Figure 14: Karl Jilg / Swedish Road Administration. Source: The Climate Change Review.

With the way highways and roads are laid out, a trip from home to work uses 90 times more space in a car than it would via metro. Bus and trams trips take up 20 times less space than cars. In many cities, a significant portion of public space is for cars. In central London, parking makes up 14% of road space (UITP, 2021). Whether you are in a quit suburb or an urban downtown, most public spaces are designed for cars instead of pedestrians.

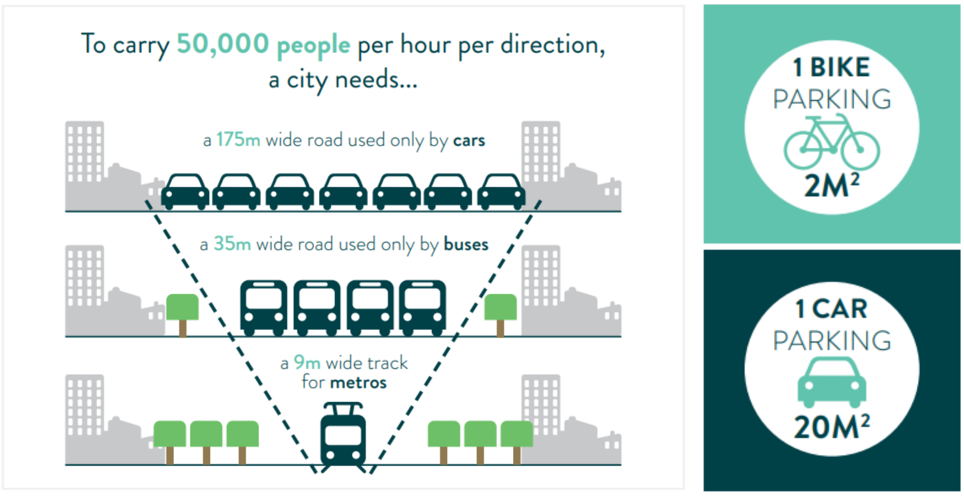

Figure 15: Wide of the road needed by different modes of transport. Source: UITP (Union Internationale des Transports Publics.

Investing in active mobility and public transportation would not only help increase health, accessibility, and environmental friendliness of urban mobility, but it would enable the more efficient use of land, making room for more housing, hospitals, parks, and other public realms.

3.6 Congestion and Noise Pollution in Cities

With an increase in road users, studies have found that **congestion has increased significantly, making urban mobility less efficient for all**. From 2013 to 2018, congestion worsened in 25 of 37 cities. In Barcelona, it now takes drivers the same amount of time to travel significantly less than was the case in 2012 (ECA, 2020). Accordingly, 60% of EU citizens consider congestion to be the greatest issue affecting roads in Europe (European Commission, 2016).

Congestion is estimated to result in an annual economic loss of €270 billion in Europe. With a 10% decrease in journey time, productivity could increase by 2.9%. In highly congested regions, that could translate to up to 30% gains in productivity (ECA, 2019). Despite the obvious benefits of reducing congestion, urban congestion continues to increase, partially because of increasing road capacity, which has been proven to only increase congestion. As of 2019, 15 out of 28 European countries had established strategies to address congestion.

One solution that has been implemented is the congestion charge. Passenger cars travelling during hours of high congestion must pay a toll, discouraging the high use of private road transport. Cities such as Stockholm, Sweden and Valletta, Malta have reported decreases in congestion since implementation of the toll and the money collected from congestion charges has been used to improve public transport. Still, much more work needs to be done to make road transport more efficient and increase economic potential of cities with high congestion (ECA, 2020).

In addition to increased levels of congestion, **many cities with motorised vehicles suffer from high levels of noise pollution.** Noise pollution can have **many negative impacts on human health, including delayed cognitive development in children, increased heart rate, poor hearing, and darker moods** (Healthline, 2023; El Pais, 2022). WHO reported that 360 million people suffer from disabled hearing due to the constant noise exposure. High noise levels can also impact sleep. In the EU, 30% of the population experiences disturbed sleep due to city noise pollution (UITP, 2021). Reducing the presence of mobilised vehicles in cities could be one way to address this issue.

3.7 Looming Threat: Urban Air Pollution Endangers Human Health

Between 2013 and 2019, emissions caused by transport have increased despite the decrease of emissions in most other sectors[4]. Of all transport emissions 23% are attributed to urban areas (ECA, 2020). Road transport emissions increased more than any other transport type and in 2020, it accounted for 77% of all EU transport emissions. For this reason, many EU states are focusing on road transport as the first area which they plan to decarbonize (EEA, 2022a).

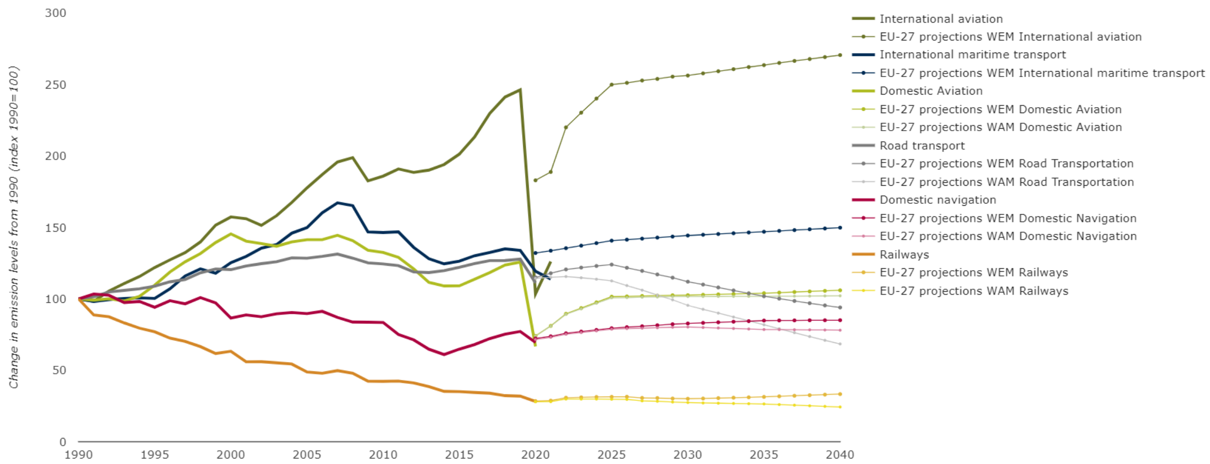

Figure 16: GHG emissions from transport in the EU, by transport mode and scenario.
Source: EEA, 2022a.

With so many emissions produced by urban mobility and pollution's subsequent concentration in cities and near roads, urban air pollution has become harmful to human health. 96% of EU citizens are exposed to levels of air pollution below the level deemed safe by WHO (ECA, 2020). In 2018 alone, four million new cases of asthma and two million pre-mature births were reported globally because of high levels of air pollution (UITP, 2021). Air pollution is now on par with smoking and poor diet in its effect on human health and poses as the single biggest environmental risk to human health in the EU (WHO, 2021; ECA, 2018). Annually, billions of euros are spent in health costs because of the effects of air pollution. Biodiversity has also been impacted by the lower air quality.

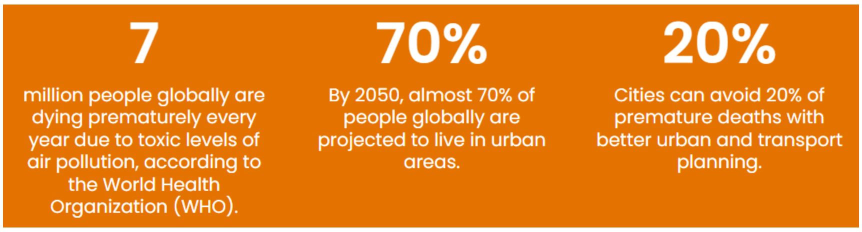

Figure 17: The connection between the health of the population and the environment. Source: ISGlobal, 2022.

Efforts to reduce NO_2 and particulate matter emissions by reducing private transportation and through a variety of other strategies have helped, however, breaches of the standards set in Ambient Air Quality Directives continue to be widespread in EU cities. Further action must be taken to ensure the safety and health of urban-dwellers (ECA, 2020).

[4] European Environment Agency, Annual European Union greenhouse gas inventory 1990- 2017 and inventory report 2019, 27 May 2019.

3.8 Encouraging Sustainable Travel Habits

There is an increasing recognition at local, national, and EU levels that promoting active mobility, particularly walking and cycling, can address many of the challenges previously discussed. In response to the Covid-19 pandemic, **major cities in Europe implemented infrastructure changes to encourage cycling and walking**. Temporary widening or creation of new cycle lanes and the implementation of lower speed limits such as 30km/h or 20km/h zones were introduced to ensure safe overtaking and physical distancing.

The pandemic has led to a decline in overall travel frequency and duration. Studies in the United Kingdom have shown a nearly 15% decrease in private car ownership since 2019, accompanied by an 18% reduction in trips made by private car occupants. Public transportation usage has also significantly decreased due to concerns about contracting the virus in public spaces. Following the lockdown, public transport lost around 80% of ridership (UITP, 2021). This decrease was paired with a slight rise in private transport users, increasing global transport emissions and contribution to climate change (Figure 11) (Eurostat, 2022a).

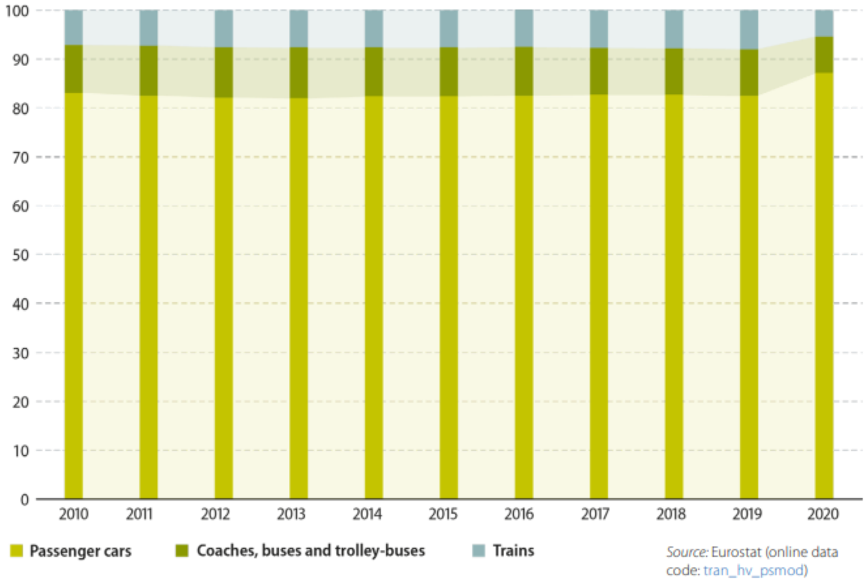

Figure 18: Development of modal split of inland passenger transport (% based on passenger-kilometres, EU, 2010–2020). Source: Eurostat, 2022a.

The pandemic has also resulted in **more flexible work habits**, with 40-70% of jobs now capable of being performed remotely. This shift offers an opportunity to encourage people to live outside of cities, reducing the need for daily commuting. However, to meet the travel needs of the population, public transport systems should extend beyond city centres. Failure to do so may lead to an increase in private transport usage, resulting in the need for more highways and parking. Such a scenario would lead to inefficient city planning, loss of valuable space, increased greenhouse gas emissions, reduced air quality, compromised public health, and higher transportation costs.

As the population recovers from the pandemic and annual trips increase, **it is crucial to encourage sustainable travel habits among returning travellers before they revert to their previous reliance on private transport.** While transportation usage has increased in most countries surveyed between 2020 and 2021, it has not yet reached pre-pandemic levels. Private passenger cars continue to dominate the modal split across all countries. Turkey had the lowest level of private transport usage, with 68.5% of all travel performed by passenger cars, while Montenegro (96.5%), Lithuania (90.4%), and Portugal (89.5%) had the highest levels (Eurostat, 2022 b). To counter these trends, there must be a greater push to increase public transport usage and promote active mobility.

Active and micro mobility options, such as walking and cycling, provide economical, sustainable, and healthy means of travel. These modes offer cost savings on fuel and parking, reduce greenhouse gas emissions, and encourage physical activity, which has been negatively impacted by excessive motorized vehicle use. Since the pandemic, there has been an increase in walking and the use of micro mobility options. Studies conducted in 2023 have shown a significant rise of 33% in the use of dockless bikes, which offer convenient and fast travel experiences. Scooters have also gained popularity, albeit to a lesser extent. While the use of mopeds is increasing in some countries, they are not as popular as other micro mobility vehicles (Mobility Innovation Marketplace, 2023). This shift toward active mobility is beneficial in addressing the global health crisis of obesity, with approximately half of adults and one-third of children affected (WHO, 2022). However, it is important to ensure that this shift does not result in a decrease in public transport usage in favour of private cars. Therefore, it is crucial to simultaneously make public transport and active mobility appealing while implementing measures to make private transportation less practical.

3.9 Strengthening Traffic Safety Measures for Safer Roads

Almost 20,000 people lost their lives in road accidents in the EU in 2021, with pedestrians, cyclists and moped riders accounting for over 32% of those fatalities (EC 2021).

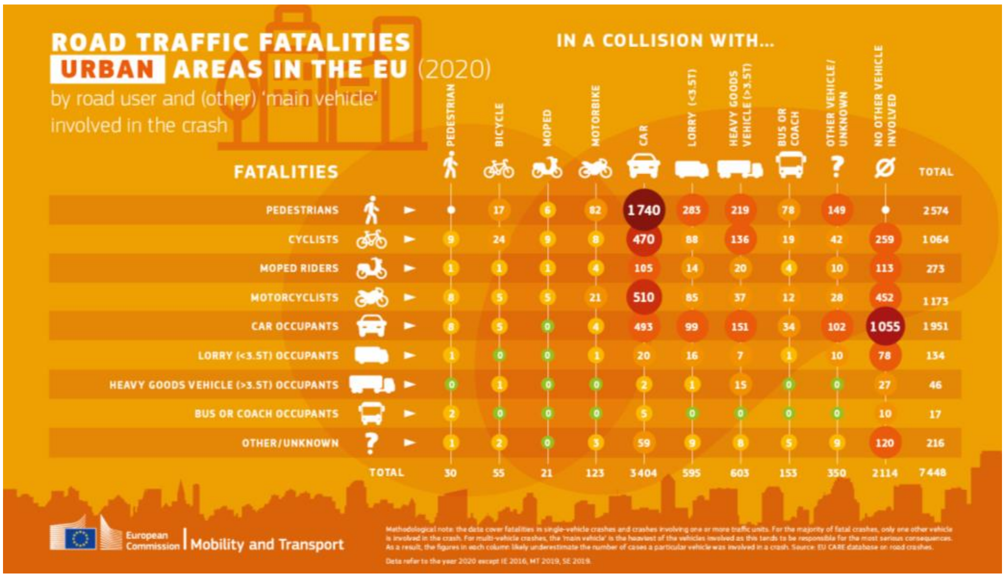

Figure 19: Road Traffic Fatalities Urban Areas in the EU. Source: EC-Mobility and Transport, 2020.

The situation is even worse in urban areas, where vulnerable users faced alarming risks. In cities, **52% of all traffic-related deaths involved pedestrians, cyclists, or moped riders, with car collisions being the primary cause** (EU figures, 2020). These numbers underscore the urgent need to enhance traffic safety measures, especially for pedestrians and cyclists who play a vital role in sustainable mobility strategies.

Creating safe environments where people can confidently walk, and cycle is crucial for encouraging the adoption of active transportation modes. This requires addressing the specific needs of mobility, public space design, and safety concerns for women, children, and people with disabilities. Additionally, clear guidelines should be provided to cities and Member States on integrating the safety and accessibility of vulnerable road users into infrastructure planning. This includes implementing digital and smart tools to enforce speed limits, regulate vehicle access, and improve the design and operation of services and public spaces, such as mobility hubs, public transport, and shared mobility options.

3.10 The Paradox of Modern Mobility: Balancing Efficiency, Quality of Life, and Meaningful Journeys

In the face of modern paradoxes, including increased traffic congestion, social distancing within massive flows, and the surveillance-fuelled freedom of movement, we witness a cultural shift where **mobility profoundly impacts quality of life**. While acknowledging the potential benefits of autonomous vehicles and optimized cities, it is the prevailing culture of speed, not just technological innovation that contributes to our collective sense of time loss. Our culture values being active and efficient, often at the expense of reflection and leisure. However, the quality and meaning of time should be prioritized over its sheer quantity.

To achieve this, seamless transport should not overshadow the significance of purposeful journeys and reducing compulsory travel. A life-centred mobility approach should focus on enhancing people's lives, promoting walking, establishing traffic calm zones, and **designing public transport systems with hospitality and conviviality in mind**. Recognizing the diverse needs of individuals, a people-centred and sensitivity-driven approach to transport policies is crucial for creating inclusive and sustainable mobility systems.

KEY IDEAS

- Europe faces interconnected challenges in demographics, public health, and the environment that impact transport and mobility.
- Climate change exacerbates urban mobility challenges through extreme weather events and infrastructure damage.
- Urbanization leads to increased road traffic and the need to expand transportation capacities.
- The aging population has specific transportation needs, with limited access to public transport hindering mobility.
- Accessibility of public transport in rural areas needs improvement to reduce reliance on private vehicles.
- Urban space scarcity requires efficient use through investment in active and public mobility.
- Congestion, air and noise pollution are significant issues in cities that impact efficiency and public health.
- Encouraging sustainable travel habits, such as walking and cycling, is crucial for addressing challenges in urban mobility.
- Strengthening traffic safety measures, particularly for pedestrians and cyclists, is essential to reduce accidents and fatalities.
- Balancing efficiency, quality of life, and meaningful journeys is important in designing inclusive and sustainable mobility systems.

12. The role of Mobility in a Circular Economy

Mobility is a key element for fostering a successful urban economy; however, many current urban mobility practices result in substantial economic losses. The reason for these losses? The linear structure of urban transport systems.

The idea of a linear economy was adopted during the industrial revolution and was based on the idea of "extract-manufacture-consume-dispose" (ICTP-CSIC, 2021). In recent years, this philosophy has been adapted, switching "dispose" with "restore" and creating what is now known as the circular economy. Despite having developed this new framework, most cities and mobility systems still follow the principles of the linear economy, leading to many urban challenges. High dependence on private cars and fossil fuels are two examples of linear practices that lead to issues like congestion and pollution. **To maximize economic growth for present and future generations, urban mobility must be adapted to fit the guidelines provided by the philosophy of the circular economy.**

Definition
The circular economy is a systems solution framework that tackles global challenges by focusing on eliminating waste and pollution, circulating products and materials (at their highest value), and regenerating nature.

Table 3: Definition of the circular economy. Source: Ellen MacArthur Foundation, 2019.

Individuals, organizations, companies, and governments all lose money from poorly designed mobility systems. An estimated 2-5% of global GDP in the form of time, fuel waste, and increased business costs is lost annually from congestion (UN Habitat, 2015). Car ownership alone accounts for 20% of the average European and United States gross household income and mobility makes up 13% of global resource consumption. Once out of use, vehicles are usually thrown out rather than recycled, constituting 8-9 million tonnes of waste in the EU[5].

Tires are one of the many car parts that are wasted in the linear economy. Every year, around 1.5 billion (or 5 billion as of 2030, experts say) tires are wasted (Elsevier Ltd, 2022). Despite the high potential recyclability of tires, due to their high concentration of steel and rubber, they are still sent to landfills year after year. By recycling tires, many resources would be saved, and emissions avoided. For each tire that is retreated twice, 70% of natural resources that would traditionally be extracted, would not be withdrawn, 21% of air pollution and 19% of water consumption would be avoided, and 30-50% of spendings would be saved. End of life tires could alternatively be used for other functions, like building insolation and artificial coral reefs. Many countries and regions are already working on reducing their tire waste. The EU, for example, recovers 52% of tire material and sends 10% of used tires to landfills or disposes of them in some other unspecified way. Of the five regions surveyed, India wastes the least tires, with only 2% going to landfills or unknown locations (ICTP-CSIC, 2021). **By closing the loop from manufacturing to end of life for tires and all other products, cities could greatly reduce their carbon footprint, while increasing economic savings.**

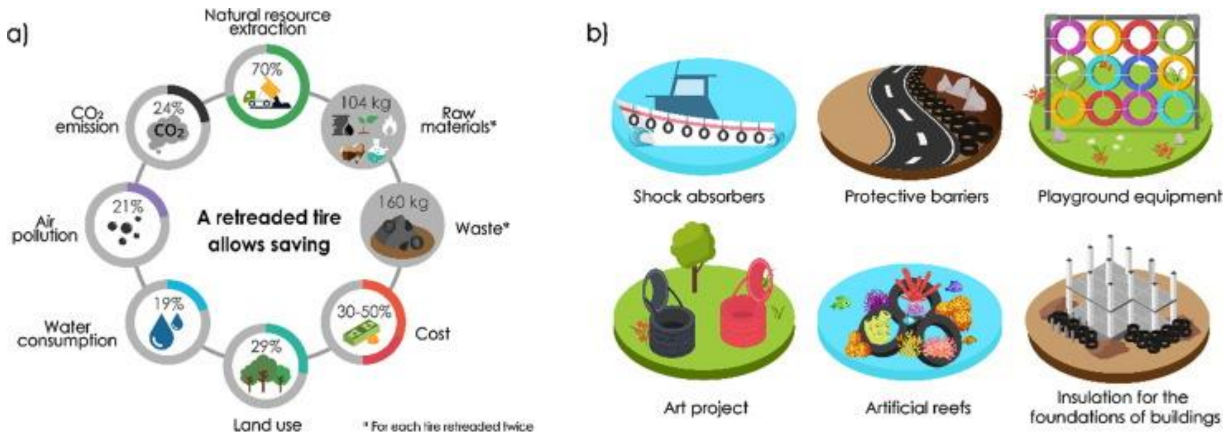

Figure 20: a) savings made by retreading end of life tires twice. b) alternative functions for tires after use. Source: ICTP-CSIC, 2021.

[5] Ellen MacArthur Foundation, SUN, and McKinsey Center for Business and Environment, Growth Within: a circular economy vision for a competitive Europe (2015), p. 18

Space and potential real estate profit is lost from the amount of land used for parking and roads. In European cities, 50% of land is used for roads and parking, even though during peak hours, only 10% of urban roads are used. European cars spend 92% of their time parked and when driven, only 1.5 of 5 seats are occupied. With so much land paved for road transport, cities become hotter, and risk of flood and other disasters increases. Each of these forms of resource, time, and monetary losses are detrimental to the urban economy (Ellen MacArthur Foundation, 2019).

Urban mobility practices not only contribute to urban heat island effects, the depletion of finite resources, and productivity losses but also result in high levels of pollution. Vehicle emissions alone cause 90% of city air pollution, with freight accounting for 60% of those emissions. The resulting low air quality, coupled with significant noise pollution, adversely affects public health. These impacts escalate healthcare costs and reduce productivity, further damaging city economies.

4.1 How can Circular Economy approach address these challenges?

The adoption of circular economy principles can mitigate these issues by promoting sustainable mobility planning that diversifies modes of transport, reuses materials, eliminates waste and pollution, and reduces operating costs. For instance, Pontevedra, Spain, implemented a city-wide car ban that resulted in a 70% reduction in greenhouse gas emissions, increased sales in local stores, and attracted 12,000 new inhabitants to the city. In Shenzhen, China, the transition to electric buses saved 70% in fuel costs and has the potential to generate further savings in maintenance expenses. Implementing permeable asphalts, concretes, and pavers can create cleaner environments, preventing up to 99% of pollutants from contaminating stormwater and groundwater systems. Investing in the circular economy can also create job opportunities, such as the example of the Central Denmark Region, where the shift to locally produced biogas for public heavy vehicles led to the creation of 100 new jobs for infrastructure development. By sourcing more products locally, freight distances can be significantly reduced, allowing for improved traffic flow and increased road space. Now, more than ever, it is crucial to invest in transitioning from linear urban mobility practices to circular ones. Such a shift would boost local economies, improve public health, and reduce environmental harm (Ellen MacArthur Foundation, 2019).

By harnessing and combining opportunities such as compact urban development, digital optimization of mobility services, innovative manufacturing and construction techniques, new business models, and advancements like remote working, cities can shape a new urban mobility system that supports overall economic, environmental, and social prosperity.

4.2 Examples of Circular Economy Opportunity

Planning

- Compact city development for effective mobility
- Urban freight strategies for effective reverse logistics and resource flows
- Infrastructure for zero-emission vehicles and energy storage
- Using big data solutions to optimise mobility systems

Designing

- Designing vehicles for adaptable and shared use
- Design for zero-emission transport vehicles and energy grids
- Designing transport infrastructure for adaptable use
- Designing regenerative and energy positive, mobility infrastructure

Making

- Sourcing infrastructure materials strategically
- Manufacturing vehicles using resource-effective techniques
- Building infrastructure with new construction techniques

Accessing

- Alternatives solutions that reduce transport needs
- Active and low-impact mobility solutions
- Multimodal transport as an integrated service
- Optimising freight capacity through shared solutions and dis tributed centres

Operating & Maintaining

- Minimising trip length, duration, and operational energy use via digital solutions
- Mobility assets operated and maintained in new business models
- Refurbishing and repairing vehicles to extend material cycles
- New techniques for infrastructure operation and maintenance

13. Future Trends

Mobility is undergoing one of the most transformational shifts of a generation, with far-reaching implications for the way we live our lives. Below are some of the most relevant trends that will shape future mobility.

5.1 Future mobility emissions

Depending on the steps taken to reduce transport emissions in the coming years, the predictions for this sector vary greatly. Global emissions must be reduced by 7.6% every year until 2031 to keep global warming to 1.5° C, as promised by the Paris Agreement (UITP, 2021). With ambitious climate policy, urban transport emissions could be reduced by 80% by 2050 compared to 2015 rates. However, if policies continue as is, emissions will only decrease by around 5% (International Transport Forum, 2021). Further efforts must be made to reduce mobility contribution to climate change, including limiting the number of private vehicles on the road.

5.2 Towards urban growth and urban sprawl

Urbanisation is not uniformed around the world: some cities are densifying while others are expanding through urban sprawl. In cities that are shrinking, it will be important to integrate sustainable innovations into their transport systems, while growing cities should focus on adopting sustainable land-use planning and transport policies (UITP, 2021). Overall, however, trends have shown an overall increase in city populations. As noted previously, half of the world population currently lives in cities and **in just twenty-five years, cities will likely contain two-thirds of the world population**. This densification will increase mobility needs and pressure on the transport network. Since many cities are expanding without proper land management, the dependence on private cars is increasing and other trends will pose as challenges for sustainable urban development. Urban passenger transport is projected to grow by 60-70% by 2050 (OECD Library, 2021; Myllyvirta, 2020), which means a growth in traffic if no effective measures are taken. Congestion is expected to double from 2015 levels by 2050 (UITP, 2021). Cost of travel will also rise. The total cost of urban journeys is related to density of travellers, the lower the density the higher the cost. In North American cities, this varies from 5% of the GDP in dense cities to 15% for low density. As cities expand, it will be ever more important to implement sustainable mobility measures into cities starting from their design phase and continuing through construction and afterwards, indefinitely.

5.3 Reduced reliance on private transport and a push for alternative modes

A study in France, Germany, and the United Kingdom done by McKinsey (2023$_a$) shows that each generation has different hopes for the future of transportation. **Some of the trends that they noticed about Gen Z include a desire to become multimodal, increase their use in public transport, invest in cheaper, more sustainable cars, and refrain from purchasing cars.** Data points to a decline in private car reliability, with Gen Zers wanting to increase use in public transport, micro mobility, and shared mobility.

Already using these forms of transport more than any other generation, Gen Zers are likely to drive the push towards intermobility within cities. Gen Zers also want more sustainable cars, with 50% of respondents planning for their next car to be fully electric. Surveys show a preference for smaller cars, with many Gen Zers guiding their purchases by price of car. This generation is also more likely to purchase cars online rather than going to the dealership, a choice that many fewer older generations would make (McKinsey & Company, 2023$_a$). To accommodate these preferences, the transport industry will have to invest more in public transport needs and sustainable mobility infrastructure.

In accordance with these trends, McKinsey predicts that use of private transport in Europe will decrease drastically by 2035 (Figure 14). Due to policies that discourage private car use, like Munich's ban of high-emission vehicles in city centres, a drop in private car use is already being observed. McKinsey also projects that shared mobility, like ride hailing, could generate close to €1 trillion by 2030, demonstrating potential economic benefits that could be reaped from the shift away from private transport. Global micro mobility is poised to reach a total market worth of €440 billion by 2030, more than double its current worth. Reductions in private transport would also lead to less noise and air pollution, increasing population health and lowering city health costs.

According to another source, however, the number of private vehicles is poised to grow by more than 30% between 2020 and 2030 and by 60-70% by 2050 (OECD Library, 2021; Myllyvirta, 2020). This increase may be a result of population growth or a shift towards private vehicle. Regardless of the cause, it is essential that further action is taken to reduce private vehicle use. Continued discouragement through financial incentives and encouragement of private transport use via development and expansion of public and micro mobility infrastructure will accelerate the shift to increased public modality in Europe (McKinsey & Company, 2023b).

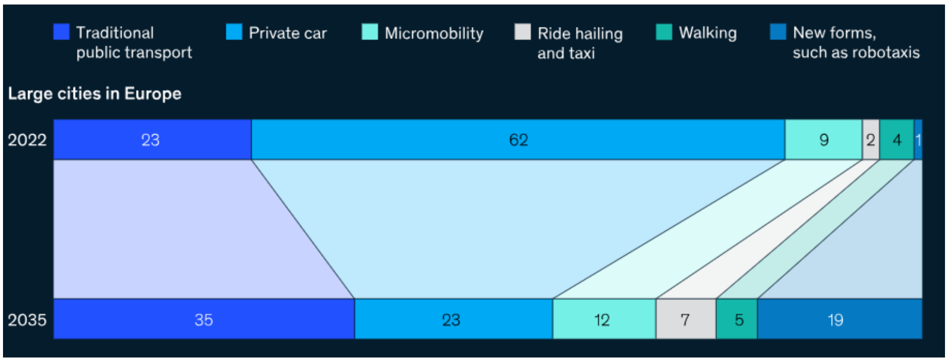

Figure 21: Mobility split by mode of transportation, % (figures may not add to 100% due to rounding). Source: McKinsey & Company, *2023b*.

5.4 Technological advancements

Every year, more and more mobility innovations are developed and soon, these products will reach the public market, changing urban mobility drastically. McKinsey estimates that autonomous vehicles will make it onto highways and in cities by 2025, becoming popular in urban areas like Beijing, New York, and London (McKinsey & Company, 2023b). Other advancements, like ultra velocity trains and flying taxi services, could make urban travel faster, increasing efficiency and attracting more urban travellers. Today, cities already have contactless ticketing for public transport, so that to board a bus or train, all that's needed is a phone or credit card. The increased use and production of electric and hybrid vehicles is also reducing air contamination and noise pollution in cities. These innovations and the many more that are yet to come will help improve urban mobility systems and create a new sector for innovation and economic potential.

	
Autonomous vehicles (AVs)	**Rise of micromobility**
Passenger vehicles in Europe and North America will have an increased amount of level-three (conditionally automated driving) and level-four (highly automated driving) automation features. Major urban areas, such as Beijing, London, and New York, could become top markets for shared autonomous vehicles, given the large pool of potential customers in these locations.	The global micromobility market is worth about 160€ billion today. McKinsey analysis shows that the value could more than double by 2030 to reach about $440 billion (McKinsey, 2023).
	

Development of intermodal applications	Transition towards shared or pooled zero-emission vehicles
Intermodal journeys involve more than one type of transportation. Platforms that integrate all possible mobility combinations for a particular route are already starting to emerge, allowing travellers to plan their journeys more easily. Jelbi, for instance, shows possible routes involving various mobility modes, as well as their time and cost.	Shared mobility (including ride hailing) is on the rise, as consumers look for transportation options that are convenient, cost-effective, and sustainable. This segment could generate up to $1 trillion in revenues by 2030 (McKinsey, 2023).

Table 4: Technological disruptions in future mobility.

KEY IDEAS

- As population grows and more people move to cities, the modal transport demands will increase greatly.
- This rise in transport use will lead to more emissions, congestion, and space produced and used by urban mobility.
- Younger generations are eager to have more sustainable and efficient transportation, specifically wanting an expansion of shared rides, public transport, and active and micro mobility.
- New technological advancements will greatly change urban mobility, likely making it more efficient, accessible, and sustainable.
- There is a move to reevaluate mobility values involving a critique of the culture of speed and the prevailing focus on efficiency and productivity. It recognizes the importance of valuing the quality and meaningfulness of time.

14. Strategies for Urban Mobility

Many governments, organizations, and individuals have made urban mobility one of their top priorities when addressing climate change. Of the 195 countries in the 2015 Paris Agreement, 40% have committed to urban passenger transport-related measures in their contributions to the agreement (United Nations Climate Change). Globally, 167 cities are determined to reduce GHG emissions in transport (International Transport Forum, 2021). This section outlines the various factors, strategies, and solutions that have been and should be considered when addressing urban mobility challenges.

6.1 Ensuring Social and Climate Justice in Urban Mobility Development

One fundamental element that must be incorporated into such problem solving is the inclusion of all individuals impacted. Certain communities are disproportionately impacted by the inaccessibility and other challenges of urban mobility. **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.** According to a UN study, 10-20% of the world's population that are minorities also suffer from lower access to transport and experience discrimination (UN, 2023). Such groups need special protection and assurance when developing sustainable urban mobility plans.

Definition

Climate justice links human rights to climate action and development with the aim of protecting the environment without sacrificing the needs of society.

Table 5: Definition of climate justice. Source: UNICEF, 2022.

Climate justice is one philosophy that can be used to help achieve equity when addressing urban mobility. It links human rights to climate action with the aim of protecting the environment without sacrificing the needs of society (UNICEF, 2022). **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 (see Figure 15).

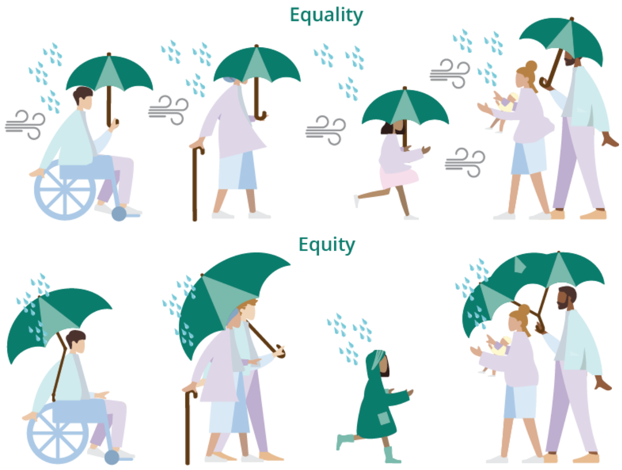

Figure 22: Juxtaposition of equality and equity. Source: EEA, 2023.

6.2 Federal Commitments to Urban Mobility Development

Many European cities have committed to adapting their transportation systems to make them more accessible, foster a healthy commuting population, lower environmental impact, and increase efficiency.

In 2021, European Commission published **The New EU Urban Mobility Framework which aims to make urban mobility more sustainable.** It requires all major cities (of which they list 424) to develop a plan to address urban mobility and provides a list of measures and initiatives that these cities can adopt. Their framework encourages the increased use of public transport and active mobility, implementation of low-energy and emission technology, urban logistics, and infrastructure, continued collaboration between cities and programs with the eventual goal of establishing 100 climate-neutral and smart-cities by 2030, heightened support for private transport companies and drivers to make their services more sustainable, the use of integrated data monitoring systems to ensure proper monitoring of progress and outcomes of these changes, and civic awareness of and engagement in problem-solving for urban mobility (EC, 2021).

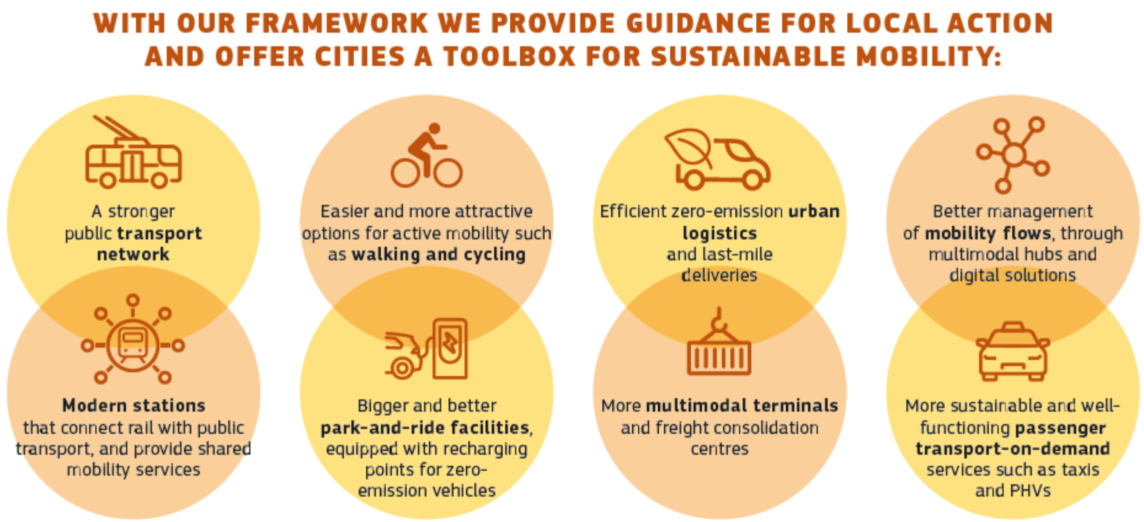

Figure 23: The New EU Urban Mobility Framework. Source: EC, 2021.

Since its publication, many cities have developed their own Sustainable Urban Mobility Plans to meet these goals (EC, 2021). Vienna is one such example. In 2015, Vienna released the Urban Mobility Plan, which sets out the ambitious goals of the City of Vienna for a viable transport system of the future and describes the steps to be taken in the next ten following years so these goals can be reached. The motto of the Urban Mobility Plan is "Together on the move" and it banks on a variety of approaches which help seize the many opportunities opening up. Another example is Stuttgart's action plan "Sustainable mobility in Stuttgart", which field of action include local public transport, motorised individual transport, walking or cycling, commercial transport, commuter traffic, and intramodality and networking.

In the context of the action plan, the city council took the decision to remove 200 public parking lots located in the city centre in order to create more space for cycling and pedestrian infrastructure as well as playgrounds and green areas. The municipality also released a new procedure to enable and regulate initiatives from civil society and other stakeholders to create and implement temporary "Parklets" in the central city districts. Also, a lot of initiatives and technical developments have already been realized to improve air quality and noise. These measures involve limited access zones, traffic calming zones, speed reduction on main roads, parking management, public transport priority schemes, traffic management, and mobility information services.

In Spain, Madrid released Plan A in 2017, which analyses the historical and current impacts of transportation and other sectors on city emissions and details potential solutions to these issues. In it, Madrid commits to upgrade public transportation vehicles to low-emission buses, financially incentivize taxi companies to invest in low-emission vehicles, and limit access to parking to deter investments in private transportation. Madrid has also implemented bike rates on buses, facilitating ease of intermobility on a few major routes in the city. Not only does this change encourage use of public transportation and cycling, but it also ensures access to active transportation for those who may be limited by ability to bike hills or encounter poor weather (ECF, 2017). Such measures are supposed to reduce annual average concentration of NO_2 by 23%. These changes were made possible by political and social consensus around the issue (EEA, 2022_b).

6.3 Urban Projects: Government Solutions

New urban models to make cities healthier

Many cities are working on increasing active mobility and public transport use by simply providing the infrastructure and making the transport modes more accessible. One example is Salvador, Brazil, which rather than promoting active mobility through health campaigns and advertising, constructed 15 elevated bridges, 3 roundabouts, 6 new avenues, 18 footbridges, a 12km bike and jogging track, as well as a 670,000m^2 green area with 6,000 new trees. They also installed 17 bike-sharing stations along metro lines to facilitate intermobility and increased accessibility with tactile floors, accessible walkways, elevators, braille signalling, and adapted restrooms (UITP, 2021). As of 2022, foot travel accounted for 38% of Salvador´s modal split and public transport, another 35.9% (TUMI, 2022). Such high rates of public and active transports mean significantly lower levels of air and noise pollution and an overall more sustainable society.

Barcelona's Superblocks became a part of global best practices. They are becoming the street transformation model for the entire city by prioritising people over cars with a focus on accessibility. The basic idea is to identify a 3 x 3 grid of 9 city blocks and restrict vehicle traffic to the streets on the perimeter.

Following this model, over 500 superblocks are planned in Barcelona, which reduce motorized traffic in some streets of a block and provide space for people, active travel, and green space. Following small-scale initiatives carried out in areas such as Poblenou, Horta and Sant Antoni, Superblocks are now taking a leap in scale and pace, with the creation of a network of green hubs and squares where pedestrians have priority.

Figure 24: Superblocks in Barcelona. Source: Barcelona City Council, 2023.

On the other side, **Paris is introducing the 15-minute city**, where work, school, entertainment and other activities are reachable within a 15-minute walk of the home. The 15-minute city will require a fairly radical re-think of our cities and a mixing of different population groups rather than the current zoning by social economic status and therefore likely to reduce inequalities. It will also reduce the need for long distance travel and thereby CO_2 emissions, and air pollution and noise levels.

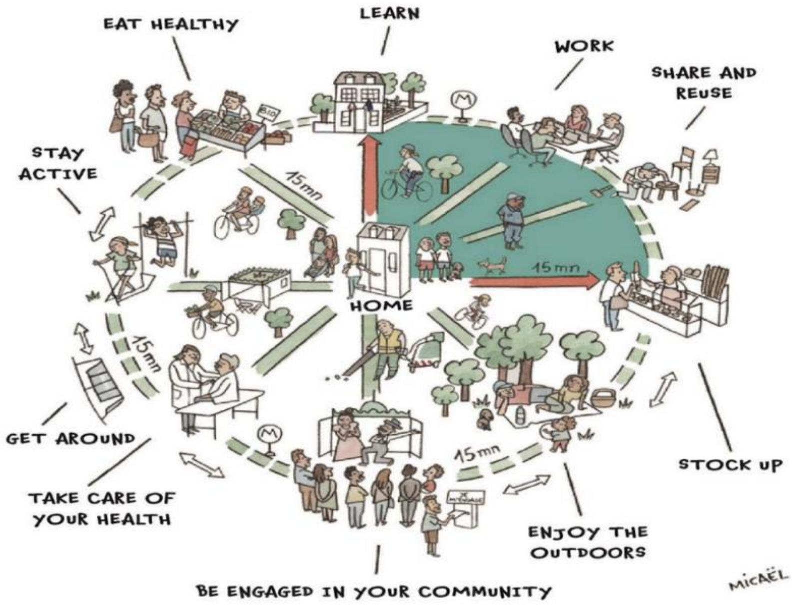

Figure 25: 15-minute city, Paris. Source: Ubique.

London, UK is also taking monumental steps to improve air quality and travel safety in the coming years. **Healthy Streets for London is constructing bicycle superhighways, providing extra space for walking and biking paths, and developing public transport stations and public realm** (Figure 19). Their final goal is to increase sustainable mode share to 80%, integrate 20 minutes of active travel into everyone´s commutes, reduce road danger to zero, and decrease private travel by 3 million private car trips by 2041. Such actions should result in overall improved health, air quality, and security.

Figure 26: London's bike superhighway. Source: Evening Standard, 2019.

Optimal transport planning pyramid

By making active mobility more attractive, cities around the world are observing a rise in modal share of active mobility. A few strategies to attain these goals include increasing access to green spaces that can be used for social, commercial, and leisure activities and are connected to transport networks, designating paths for each type of transport mode, constructing wide roads with no kerb drops (a tactic used to make streets more pedestrian than car friendly), planting trees along sidewalks to provide shade, installing bike parking, limiting access to passenger vehicle parking, taxing private car purchases, reducing speed limits in pedestrian busy areas, designating certain areas as Low Emission Zones (LEZs) and restricting access to them from high emitting vehicles, providing better lighting to increase safety and visibility especially at night, developing safe pedestrian intersections (such as raised crosswalks known as “table-top crossings”), and increasing access to public amenities (including water, restrooms, waste bins, and wayfinding signage) (UITP, 2021). Each of these tactics can help make active mobility more comfortable, safe, and efficient and would be made even more effective if matched with actions that simultaneously discourage private transport travel.

The integration of LEZs alone have been shown to reduce transport emissions significantly. In Berlin, Germany, diesel emissions dropped by 58% while nitrogen oxide fell by another 20%. Brussels, Belgium experienced similar results after implementing these zones nitrogen oxide by 9% and black carbon by 38%. Combined with urban tolls, access to certain areas becomes restricted by vehicle type and car traffic as well as emission are reduced. In Area C Milan, Italy, these tariffs have reduced incoming traffic by 30% and simultaneously increased speed of public transport. A program in Helsinki, Finland facilitates intermobility between cars and public transport by locating parking near transport stations. These facilities are called Park & Ride and are often free or discourage parking in city centres with progressive parking prices getting more expensive closer to the centre. Some parking areas are only accessible by public transport ticket, further incentivizing the populous to take advantage of the intermobility infrastructure. This program has reduced congestion in Helsinki and kept cars out of the city centre. **All these successes demonstrate the potential to reduce mobility emissions by decreasing private car use. If LEZs, urban tolls, and Park & Ride were implemented together, it is likely that the positive effects that have been noted would be even greater.**

Bern, Switzerland is taking public transportation a step further and bringing it outside of main city lines. They are developing extensive public transport networks that connect city centres to their periphery. Main transfer stations will be turned into mobility hubs, with access to regional bus lines, rental bicycles, e-scooters and other services. Such measures will facilitate access to jobs and reduce reliability on cars. Goiânia and Fortaleza, Brazil have also integrated an innovative solution to increasing public transport accessibility and efficiency. With a new app and 40 and 18 buses in each city respectively, riders can call the service and be picked up at a designated bus stop. These programs (i.e., CityBus 2.0 and TopBus+ respectively) are integrated in the city´s official bus network and managed by the same operators. Of all users, 81% had relied on their personal car for transport before using the on-demand transport service (UITP, 2021). **Each of these cities serve as models that which others cities can follow to similarly increase public and active mobility, reduce their emissions, and improve public health.**

Gender Equality initiatives in mobility

When trying to maximize accessibility of public transport, planners must take geographical coverage, affordability, physical access, and information availability into account. Women make up the majority of public transport riders in many cities. In France, they account for two-thirds of public transport users and in the US cities of Philadelphia and Chicago, over 62% (Ceccato, 2017). Public transport, though welcoming to women riders, does not have the necessary safety measures to ensure safe travel for women. In London, over 50% of women experience unwanted sexual attention while using public transport. Reporting rates of these incidents are catastrophically low at only 2% (Figure 20). Policies must be passed to increase safety of women in transport and prevent sexual harassment.

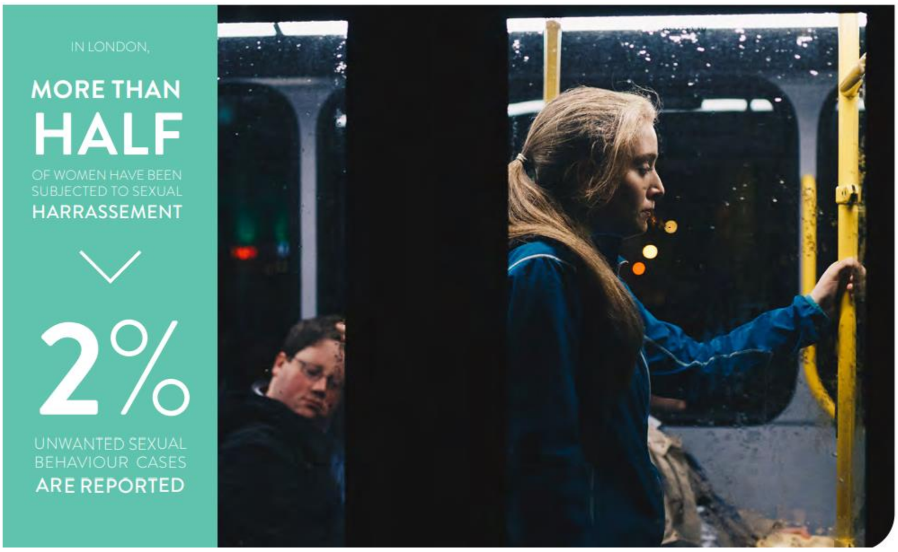

Figure 27: Women's safety in transit environments. Source: YouGov Survey Results, 2019.

In Paris, one of the public transport providers, RAPT, has focused on female safety in transport. During a crisis they may call the police, escort the victim by taxi if needed, help the victim file complaints, and provide access to professional after care. RATP also accompanies female users on public transport to reduce feelings of insecurity in and around the infrastructure. The following table demonstrates a few measures that can be taken to increase accessibility of public transport and the related performance indicators (Figure 17) (UITP, 2021).

	PRACTICAL MEASURES	OPERATIONAL ASPECTS	URBAN ENVIRONMENT	COMMUNITY INVOLVEMENT	POLICY/LEGAL ASPECTS	CAPACITY BUILDING
COMFORT	Improve waiting environment	✓	✓	✓	-	-
	Maintain shelters with AC and ventilation	✓	-	-	-	-
	Clean public toilets	✓	-	-	-	-
EASY-TO-USE	Services between stops	✓	✓	✓	✓	-
	Control camera, panic buttons	✓	-	-	✓	-
	Women-only services	✓	✓	✓	✓	-
	Process for harassment reports	-	✓	✓	✓	✓
SAFTEY & SECURITY	Better lights and pavements	-	✓	✓	-	-
	Trained and professional staff	✓	-	-	-	✓
	Enforce rules and regulations	-	✓	✓	✓	✓

Figure 28: A consideration of the different aspects for practical measures related to performance indicators. Source: UITP, 2021.

Better monitoring and planning

Many cities are not only attempting to make their transport more sustainable, but the planning processes behind them as well. In Toronto, Canada, they have created a Business Case Guidance to help measure and predict outcomes of transport plans through a business perspective. It analyses strategy, economic impacts, finances, deliverability, and operation of any initiative. When used to analyse Go Rail – a project which aims to improve travel time, make roads safer and less congested, and reduce emissions – the business case calculated that the region would gain an equivalent of around €2.18 worth in benefits from every €1 invested. By analysing transport plans in this way, the city can maximize benefits and efficiency of each plan.

In Antwerp, Belgium, their Smart Ways of Antwerp programme works with employers and mobility service providers to get the same result. Their work enables companies to develop mobility policies that take into consideration employee travel behaviours and encourage the use of more sustainable transport modes. With such close collaboration between the implicated actors, different mobility offers could be made available including public transport, bike leasing, car-sharing, and car-pooling. As a result, 26% of employers now commute to work using one of these alternative transport modes instead of driving to work (UITP, 2021). Other **planning systems that incorporate the needs of the public and consult residents in their development have the potential to be more positively received and could increase success outcomes.**

Integrating economic activities with public transport

One method used to increase efficient city land-use integrates lifestyle and business with public transport. In Japan, malls, restaurants, offices, and hotels are built in and around stations. Such land-use increases real estate revenue. By 2027, revenues may rise by 150% compared to 2017 levels. If set up by the state or transport departments, these profits could be used to fund public transport operation and development costs.

Nottingham, London took a different approach to fund the transport system: levies. Offices with over eleven employers are charged a tax on parking spaces. From 2011 to 2021, this program raised around €87 million enabling the city to expand their tram system and redevelop their central station and bus networks. In addition to benefiting the public transport system, this policy actively discourages the use of private transport, potentially taking more cars off the road and increasing air quality and reducing noise pollution. Both the Japan and Nottingham funding strategies ensure constant and reliable revenue for the transport system.

To decrease the cost of installing new mobility infrastructure, many cities have transformed abandoned or unused infrastructure into pedestrian walkways and parks. In New York City, the Manhattan High Line, an old railway, has been reutilized as a 2.33km green space, lined with real estate development projects and museums (Figure 22). Similarly, in Seoul, South Korea, a highway became the Seoul Skygarden, which is adjacent to a main public transport station and features many green pathways for active mobility travellers (UITP, 2021). **The reutilization of space is a great option for saving funds and is a solution that can be implemented anywhere.**

Figure 29: New York City Highline (left) and Barcelona's Highline in Sants Neighbourhood. Source: Go City.

15. Case Studies: What will be needed in the future?

In addition to the actions taken by governments to improve the mobility possibilities of population, **many smaller companies and start-ups have taken it into their own hands to develop technology and systems that help address Urban Mobility**. The following table details just some of the many startups that have taken the initiative to develop their own solutions to the problem.

Chainge - Designing low-emissions delivery services

Many companies have been working on designing low-emissions delivery services. **Chainge,** a company founded in Copenhagen, Denmark, uses bike-driven vans to ship foods and subscription goods without creating as much noise and air pollution. Another startup, **Homerr** (Amsterdam, Holland), invites private people and companies to serve as intermediate deliverymen and reducing the van trips needed to verify if the receiver is home (EU-Startups, 2022). Other similar startups include **Magway** (Wembley, UK), **Onomotion** (Berlin, Germany), and **Bolt** (Tallinn, Estonia).

Figure 30: Chainge Start-up. Source: Chainge.

Upway – Pushing for sustainability by recycling used or unwanted vehicles

Upway, founded in 2021 in France, refurbishes e-bikes and e-scooters, selling second hand micro mobility vehicles and reducing their ecological footprint. Their business model not only encourages micro mobility but pushes for sustainability by recycling used or unwanted vehicles (Upway, 2023). Other companies provide rentable electric micro mobility vehicles or offer trading platforms for people to sell micro mobility vehicles, such as **Bicing** (Barcelona, Spain), **Dott** (Amsterdam, Netherlands), and **Voi** (Stockholm, Sweden).

Figure 31: Upway: making electric mobility accessible to everyone. Source: Chainge.

Lilium - Developing an electric flying taxi service

A company based in Wessling, Germany, **Lilium,** is in the process of developing an electric flying taxi service. The jet takes off vertically, limiting space consumption, and produces zero-emissions after production. For long distance transport, Lilium provides a cheaper service than taxis in the USA (Lilium). Other similar startups include **Volocopter** (Bruschall, Germany) and **Joby Aviation** (Santa Cruz, USA).

Figure 32: The Lilium Jet. Source: The Lilium Jet.

BlaBlaCar – Connecting drivers with passengers for a collective mobility

BlaBlaCar, headquartered in France, is a long-distance ride-sharing platform that connects drivers with passengers traveling in the same direction. It offers an affordable and sustainable alternative for intercity travel (Seedtable, 2023). Similar startups include **Ants** (Oslo, Norway), **flinc** (Berlin, Germany), **Heetch** (Paris, France), **Ride Joy** (California, USA), and **Toogether** (Noord-Holland, Netherlands).

Figure 33: BlaBlaCar. Source: BlaBlaCar.

ParkBee - Reutilizing underused parking spaces and giving them back to the city

In Amsterdam, Netherlands, **ParkBee** is reutilizing underused parking spaces and making them available to the public. Users can book their spot online or pay by the minute. Their work takes more drivers off the road, makes parking more affordable, and makes use of underutilized areas, benefiting real estate owners and drivers (ParkBee). **Get My Parking** (Bengaluru, India), **ParqEx** (Chicago, USA), and **Just Park** (London, UK) are other startups that also provide public parking services.

Figure 34: ParkBee. How Parkbee gave space back to the city. Source: Parkbee.

Ride Vision - Enhancing motorcycle safety

Ride Vision is a company from Herzliya, Israel that produces lights and cameras that riders can attach to their motorcycles to enhance motorcycle safety. It uses artificial intelligence and computer vision technology to provide real-time warnings of potential hazards on the road. The device also records all rides, and they are developing a system to make emergency calls in times of crisis (Ride Vision). Other companies addressing rider safety include **Brake Free Technologies** (Denver, USA) and **Cosmo Connected** (Paris, France).

Figure 35: Ride Vision. Source: Ride Vision.

MUV B Corp – Playing to move, moving to play

MUV B Corp is an Italian company in 2012 that aims to promote sustainable mobility through a sport-based transport app. Players gain points whenever they move in a sustainable way and can participate in training sessions, challenges, and team tournaments. When using the app, users give permission to anonymously share their data to help policy makers improve mobility around the world. MUV also has a corporate version that allows companies to encourage their employee´s sustainable transport habits (MUV).

Figure 36: MUV App. Source: MUV.

Cling – Pushing for sustainability by recycling used batteries

Founded in 2020 and based in Stockholm, **Cling** provides a solution for the soon to be excess of used batteries from electric vehicles. The company connects manufacturers, workshops, and dismantlers to end-of-life batteries so that once used, batteries can be reused and recycled. Their program will look for the ideal partners in this trading system to optimize trade efficiency (EU Startups, 2022). Other companies developing similar recycling systems include **Circunomics** (Mainz, Germany), **Akksel** (Therwil, Switzerland), and **Reneos** (Tienen, Belgium).

Figure 37: Cling. Source: Cling.

KEY IDEAS

- Many countries have committed to reducing their carbon emissions and improving their mobility systems, though much more work needs to be done to reach these objectives.
- Climate and social justice must be taken into consideration when developing mobility solutions and innovations to ensure equitable access to transport.
- Cities across the world are developing urban mobility plans to increase public transport use and active mobility and discourage private car use.
- Municipalities are partnering with companies to develop concrete plans to improve urban mobility.
- Urban mobility projects raise funds through levies and other fees on private car owners as well as by reutilizing urban spaces.
- Many individuals have taken it into their own hands to develop projects to address urban mobility challenges, founding startups to implement their innovative solutions.

16. Barriers to Urban Mobility Initiatives

Sustainable urban mobility initiatives are often met with challenges of different types. One of the main issues that comes up is funding. Transport funds usually come from passenger fares, authorities, local taxes, levies – such as congestion charging, revision of parking policies, and land-value capture mechanisms – and commercial revenues. While public transportation used to be a growing industry, operation costs have increased significantly with the drop of riders since the pandemic. With less money flowing into the system, it can be hard to gather funds to support public transport expansion.

Municipal organization is another common issue to implementing such plans. In developing cities, institutions may not have the systems in place to facilitate easy coordination, slowing down the planning and implementation processes. Similarly, in fast growing cities, mayors may not have enough power to integrate such changes into policies with such divided priorities within the given administration (UITP, 2021).

When it comes to the legal arena, some challenges may arise when trying to initiate and impulse mobility strategies. These include:

- **Privacy and data protection laws**: The European Union has strict laws regarding data protection, such as the General Data Protection Regulation (GDPR), which can make it difficult to collect and use data in smart city projects.

- **Regulatory barriers**: Different cities and regions in the EU have different regulations and requirements for deploying new technology. This can make it difficult to roll out pilot projects on a larger scale, as each city or region may have its own unique set of rules and regulations that must be followed. For example, some cities may have specific regulations regarding the use of drones, while others may have more restrictive regulations on the use of cameras in public spaces. These regulatory barriers can make it difficult for companies and organizations to develop and deploy smart city projects that are consistent across different cities and regions.

- **Liability and safety concerns**: When deploying new technology in public spaces, there are potential liability and safety concerns that must be addressed. For example, if a self-driving car were to be involved in an accident, there may be questions about who is responsible for the accident. Additionally, there may be concerns about the safety of the technology, particularly if it is being used in a way that it has not been tested or validated. These concerns can make it difficult to secure funding and insurance for pilot projects, as investors and insurers may be hesitant to invest in or ensure a project that carries significant liability or safety risks.

- **Procurement laws**: EU countries have different procurement laws and regulations which can make it difficult for companies to bid for and win contracts for urban projects.
- **Interoperability**: lack of standardization of infrastructure and software across EU countries can make it difficult to ensure that different smart city systems can work together effectively.

These barriers can be overcome by developing clear regulations and guidelines, securing funding, and building partnerships between public and private sector organizations. To mitigate these concerns, it's important to conduct thorough testing and evaluation of the solutions before deployment, to develop clear guidelines and regulations for the use of the technology, and to establish clear liability and safety protocols. Additionally, partnerships between public and private sector organizations can help to mitigate these concerns by sharing the risk and responsibilities.

There may be specific regulations or guidelines that govern the use of certain strategies or pilots regarding mobility. For example, there are legal regulations for installing sensors in European cities. The European Union has strict laws and regulations regarding data protection, such as the General Data Protection Regulation (GDPR), which applies to the collection, processing, and storage of personal data. These regulations can have an impact on the deployment of sensors in European cities, as they can limit the types of data that can be collected, how it can be used, and how long it can be stored.

Additionally, there are regulations and laws that govern the installation of sensors in public spaces. For example, there may be regulations that prohibit the installation of cameras in certain areas, or that require certain types of notifications to be provided to the public before sensors are installed.

Furthermore, different cities and regions may have their own regulations regarding the installation of sensors in public spaces, so it's important to check the specific regulations that apply in the location where you plan to install the sensors.

To comply with these regulations, it's important to conduct a thorough data protection impact assessment (DPIA) before the deployment of sensors, to ensure that the data collected, processed, and stored complies with the GDPR and other regulations, to provide clear information to the public about the sensors, and to establish clear protocols for data management, security, and retention.

17. Suggested Sources

To learn more about urban mobility, 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 Urban Mobility Playbook
The International Association of Public Transport (UITP) published this playbook 2021 to support the transition to better urban mobility. This packet provides a thorough review of different strategies that can be used to improve urban mobility and promote sustainable city planning with case studies for each recommendation.
https://cms.uitp.org/wp/wp-content/uploads/2022/02/Report-BETTER-URBAN-MOBILITY-PLAYBOOK.pdf

Urban Mobility Next 6 Urban vehicle access regulations: from design to implementation
This 2022 report on urban mobility policy making was produced by the EIT Urban Mobility. The document provides detailed information on urban vehicle access regulations (UVARs) and their current and potential use and impact in Europe.

https://www.eiturbanmobility.eu/wp-content/uploads/2022/10/EIT-UrbanMobilityNext6_HD2.pdf

Sustainable Urban Mobility in the EU
This report, published by the European Union, provides extensive detail on the actions and commitments needed to be taken by member states to reach international climate goals, focusing on mobility.
https://op.europa.eu/webpub/eca/special-reports/urban-mobility-6-2020/en/

Future of Mobility
McKinsey produced this site to provide more information on the future of mobility, including projected advancements in the sector and predictions for a few specific regions.
https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-future-of-mobility-mobility-evolves

Circular Economies in Cities: Opportunity and Benefit Factsheet
The Ellen MacArthur Foundation released a report in 2019 that details the benefits of transitioning to circular urban mobility practices. It provides statistics on current urban mobility practices, examples of possible and realized solutions, and the subsequent results of these changes.
https://op.europa.eu/webpub/eca/special-reports/urban-mobility-6-2020/en/

Improving the convenience of public transport
Interreg Europe published this report on public transport in 2020. It outlines the benefits of using public transport, as well as possible measures that can be and concrete examples that have been taken to improve public modal accessibility and convenience.
https://www.interregeurope.eu/sites/default/files/inline/Public_Transport_TO4PB_final.pdf

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Co-funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the ERASMUS+ Key Action 2 Partnerships for Innovation Alliances for Innovation 2021. Neither the European Union nor the granting authority can be held responsible for them.